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Planning, developing, and pilot testing a mobile health promotion program to prevent type 2 diabetes after gestational diabetes mellitus

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To all women at high cardiometabolic risk

who aspire health and wellbeing for themselves and their families.

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München, 14.08.2020 Anne Lotte Potzel

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List of abbreviations

AUC glucose	Area Under the glucose Curve
BMI	Body Mass Index
BO	Behavioral Objective
CHD	Coronary Heart Disease
CKR	Commitment, Knowledge, and perceived Risk
CVD	Cardiovascular Disease
DI	Disposition Index
DPP	Diabetes Prevention Program
DZD	German Center for Diabetes Research (Ger.: Deutsches Zentrum für Diabetesforschung)
ER	Emotional Reaction
GDM	Gestational Diabetes Mellitus
HbA1c	glycated hemoglobin
HDL-C	High-Density Lipoprotein Cholesterol
HOMA-IR	Insulin Homeostatic Model Assessment of Insulin Resistance
IGT	Impaired Glucose Tolerance
IFG	Impaired Fasting Glucose
IPAQ	International Physical Activity Questionnaire
ISI	Insulin Sensitivity Index
LDL-C	Low-Density Lipoprotein Cholesterol
mHealth	mobile Health
MetS	Metabolic Syndrome
OEA	Outcome Expectations and Attitudes
oGTT	oral Glucose Tolerance Test
PAPM	Precaution Adoption Process Model
PB	Perceived Barriers
PO	Performance Objective
PRECEDE	Predisposing, Reinforcing and Enabling Constructs in Educational Diagnosis and Evaluation
PROCEED	Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development
PSS-10	Perceived Stress Scale-10 items
SSE	Skills and Self-Efficacy
SN	perceived Social Norm

RCT	Randomized Controlled Trial
RE-AIM	Reach, Effectiveness, Adoption, Implementation, and Maintenance
SIH	Self-Image and Habits
SMART(S)	Specific, Measurable, Attainable/Action-oriented, Realistic, Timely, (Self-determined).
SSL	Secure Sockets Layer
SUS	System Usability Scale
T2D	Type 2 Diabetes
TTM	Transtheoretical Model of Behavior Change
uMARS	user Mobile Application Rating Scale
V1	Visit 1
V2	Visit 2
VCO_2	Carbon dioxide production per minute
VO_2	Oxygen consumption per minute
VO_2max	Maximal oxygen uptake
VO_2peak	Peak oxygen uptake
WHO	World Health Organization
WHO-5	World Health Organization-5 Well-Being Index

Zusammenfassung

Hintergrund: Gestationsdiabetes mellitus (GDM) ist mit einem erhöhten Risiko assoziiert, später einen Typ-2-Diabetes mellitus (T2D) und damit verbundene kardiometabolische Störungen zu entwickeln. Ein gesunder Lebensstil mit ausreichend Bewegung, einer ausgewogenen Ernährung und psychosozialem Wohlbefinden senkt das Risiko für das Auftreten dieser Beschwerden in den Jahren nach der Entbindung. Aktuelle Präventionsprogramme für Frauen nach Schwangerschaftsdiabetes entsprechen nicht den Anforderungen an ein flexibles und praktisches Hilfsmittel für das tägliche Leben der betroffenen Frauen. Ziel dieses Dissertationsprojektes war die Entwicklung einer theorie- und evidenzbasierten Mobile Health (mHealth) App, die sowohl wissenschaftlichen als auch industriellen Standards gerecht wird, skalierbar ist, Verhaltensänderungen unterstützt und auf die besonderen Bedürfnisse von Frauen nach GDM eingeht.

Methodik: Der "Intervention Mapping"-Ansatz bot die Struktur für den Entwicklungsprozess. Die "Intervention Mapping" Schritte 1 bis 4 dienten als Konzept und Analyseinstrument für die Planung, die Entwicklung und den Pilottest der Smartphone-basierten *TRIANGLE* Intervention zur Vorbeugung von kardiometabolischen Störungen nach GDM. In den Schritten 1 bis 3 konzipierten wir ein theorie- und evidenzbasiertes Interventionsmodell. In Schritt 4 kooperierten wir mit industriellen Partnern. So konnte bei der Umwandlung des Modells in eine praktische Intervention ein hoher technologischer Standard der Smartphone App gewährleistet werden. Für die Nutzerstudie und die klinische Pilotstudie wählten wir ein „Mixed Methods Design“ basierend auf validierten Fragebögen zu Nutzerakzeptanz und Verhaltensweisen in verschiedenen Lebensstilbereichen, App-Nutzungsprotokollen, „Think-Alouds“ mit teilstrukturierten Interviews, Ernährungsprotokollen und klinischen Messwerten.

Ergebnisse: Das entstandene *TRIANGLE*-Programm ist eine der ersten mHealth Apps für stufenweise personalisierte Gewohnheitsänderungen in den Bereichen Bewegung, Ernährung und psychosoziales Wohlbefinden. Die interaktive App umfasst 11 Einflussfaktoren auf das Gesundheitsverhalten, bietet 39 Verhaltensänderungsmethoden zur Unterstützung individueller Lebensstiländerungen und erlaubt den Teilnehmern, selbst über die Intensität des Programmes zu entscheiden. Eine an die App gekoppelte online Coaching-Plattform erlaubt eine individuelle Beratung durch Gesundheitspersonal. Das einzigartige „Challenge“-System unterstützt Gewohnheitsänderungen und vermittelt Informationen. Sobald eine Beta-Version von App und Coaching-Plattform verfügbar war, wurden Frauen nach GDM im Rahmen einer Nutzerstudie in den iterativen Entwicklungsprozess eingebunden. Die Ergebnisse führten zu Anpassungen des *TRIANGLE*-Programms, bevor wir die restlichen Interventionsmaterialien erstellten. Eine deutsche randomisiert-kontrollierte Multicenter-Pilotstudie deutete auf erste klinische Effekte des *TRIANGLE*-Programms nach sechs Monaten Intervention hin. Frauen nach GDM zeigten eine hohe Akzeptanz des *TRIANGLE*-Programms und nahmen einen hohen Einfluss dessen auf ihr Verhalten wahr.

Fazit: Mithilfe des "Intervention Mapping"-Ansatzes entwickelten wir eine innovative mHealth-Lösung für Frauen nach GDM. Das *TRIANGLE*-Programm bietet eine leicht verfügbare technologische Unterstützung zur Verhaltensänderung um kardiometabolische Erkrankungen vorzubeugen. Das Programm muss stetig weiterentwickelt und noch in einer groß angelegten Studie getestet werden. Die "Intervention Mapping" Schritte 5 und 6 können diesen Implementierungs- und Evaluierungsprozess unterstützen.

Summary

Background: Gestational diabetes mellitus (GDM) is associated with an increased risk for type 2 diabetes (T2D) and related cardiometabolic disturbances. A healthy lifestyle with sufficient physical activity, a balanced nutrition, and psychosocial wellbeing decreases the risk of developing these conditions in the years following delivery. Current prevention programs for women after GDM insufficiently address the needs of a flexible, accessible, and practical tool for daily life in this target group. The aim of this dissertation project was to create a theory- and evidence-based scalable mobile health (mHealth) application that fulfils both academic and industrial standards, supports behavior change, and addresses the specific needs of women post-GDM.

Methods: The Intervention Mapping approach was implemented to structure the development process. In the scope of this thesis, Intervention Mapping Steps 1 to 4 were applied as blueprint and analytical tool for planning, developing, and pilot testing the smartphone-based *TRANGLE* program to prevent T2D and related cardiometabolic disturbances in women post-GDM. In the Steps 1 to 3, we designed a theory- and evidence-based intervention model. In Step 4, we cooperated with industry to secure a high technological standard when translating the model into a practical intervention based on a smartphone app. For the associated user study and the clinical pilot trial, we used a mixed methods design based on validated questionnaires on user acceptance and lifestyle behavior, user logs, think alouds with semi-structured interviews, nutrition protocols, and clinical assessments.

Results: The resulting *TRIANGLE* program is among the first mHealth apps for personalized stepwise habit change in the areas of physical activity, nutrition, and psychosocial wellbeing. The interactive app allows for self-pacing, addresses 11 behavioral determinants, and offers 39 behavior change methods to support individual lifestyle change. An associated online platform for healthcare practitioners allows for human coaching while a unique challenge system fosters habit change and education. Once a beta-version of the app and the coaching platform was available, the iterative development process comprised a user study with women post-GDM, followed by adaptations before the full program production. Lastly, a German multicenter randomized controlled pilot trial of the *TRIANGLE* program indicated first clinical effects for behavior change after six months of intervention. Women post-GDM showed a high acceptance and a high perceived impact of the program on their behavior.

Conclusions: Using the Intervention Mapping approach, we developed an innovative mHealth solution for women post-GDM. The novel *TRIANGLE* program has the potential to prevent cardiometabolic disease as an easy to deliver technological support for behavior change. The program needs to be further refined and tested at a large scale. Intervention Mapping Steps 5 and 6 may support this implementation and evaluation process.

1. Introduction

1.1 Clinical background

In 2017, the International Diabetes Federation estimated that about 18 million of live births were complicated by gestational diabetes mellitus (GDM) worldwide [1]. GDM is the most common complication during pregnancy [2] and implies an eightfold higher risk for type 2 diabetes (T2D) [3, 4] and a high risk for related cardiometabolic disturbances, such as cardiovascular disease (CVD) [5-7], and the metabolic syndrome (the MetS) [8, 9]. The relative risk to develop T2D is the highest during the three to six years following GDM [4]. Longitudinal studies of at least 5 years follow-up demonstrate that between 20% to 65% of women post-GDM develop T2D [10]. German data shows that the average 8-year risk of developing T2D post-GDM is 53% and varies from 12 to 96%, dependent on the profile of risk factors [11]. Diabetes ranks fourth as global cause of disabilities and lowers the quality of life of affected individuals [12].

T2D is a polygenetic disease and depends on many risk factors – both modifiable and unmodifiable factors. Unmodifiable risk factors include genetics, ethnicity, and aging demographics that are beyond individual control. In contrast, modifiable risk factors allow for preventive measures in psychosocial wellbeing, lifestyle behaviors, and living environment. Post-GDM, the unmodifiable genetic risk for T2D remains hidden due to lacking symptoms and lacking awareness after delivery – often despite pre-diabetic states [13]. Hence, some women post-GDM are unaware of their high risk for T2D [14-16] and the required lifestyle changes that may lower their risk [17]. Others seemed aware of risk behaviors, yet unable to change their lifestyle since they lacked the respective skills [17-19]. Therefore, few women post-GDM adhered to preventive health behaviors [17]. They need effective strategies for psychological, behavioral, and environmental change to reduce the number of modifiable risk factors for T2D and to increase a healthy life expectancy post-GDM [20].

1.1.1 Modifiable risk factors for type 2 diabetes

Modern fast-paced lifestyles and living environments tend to cause high mental and emotional strain and offer easy access and repeated cues for detrimental behaviors. The quality of the resulting thoughts, emotions, and behaviors in physical activity, nutrition, and sleep is decisive for human health. In the 2017 analysis of the Global Burden of Disease Study, diabetes ranked third as a cause of diet-related deaths and disability-adjusted life years lost [21]. Diet-related deaths and disability-adjusted life years lost were attributable to high intake of sugar-sweetened beverages, high intake of red and processed meat, low intake of fruits and whole grain, and low intake of nuts and seeds [21]. Nearly as much as dietary patterns, sedentary behaviors and low physical activity contribute to the development of T2D [22]. Further, sleep duration and poor sleep quality were related to metabolic risk markers for T2D [23]. Most risk behaviors interact or determine one another, such as unhealthy dietary behaviors, physical inactivity, insufficient sleep, pessimistic thinking, and negative emotions [24-28]. In turn, a good sleep hygiene, optimistic thinking, positive emotions, a healthy nutrition, and physical activity were also associated with one another [29-34] – possibly due to self-regulatory spillover effects [35]. These interactions show that many risk behaviors form clusters [36] and reinforce one another. Adverse lifestyle behaviors further cause or reinforce physiological risks for the progression to T2D such as obesity, dyslipidemia, or high blood pressure [37].

Randomized controlled trials (RCTs) with lifestyle interventions achieved T2D risk reductions of about 50% in women with a history of GDM, mostly later in life when they had already developed impaired glucose tolerance [38, 39]. In such interventions, lifestyle changes were superior to medication for preventing or delaying T2D post-GDM [40]. In particular weight loss in the overweight or obese prevents or delays T2D [40, 41]. However, most lifestyle programs post-GDM neglect the needs of women in the first years post-GDM [42], the opportunities of new technological healthcare solutions [43], the use of a logical theory- and evidence-based intervention model, the socio-ecological behavioral contexts [44] or the window of opportunity in the late postpartum period [45, 46].

1.1.2 Healthcare gaps for women post-gestational diabetes mellitus

Current healthcare systems fail to provide sufficient and specific support for women post-GDM to change their lifestyle in order to reduce modifiable risk factors for cardiometabolic disease. The most critical challenges to be addressed by healthcare systems are the following:

1) Translation of guidelines into practical tools for healthcare practitioners and women post-GDM
2) Specific programs for women post-GDM
3) Interdisciplinary behavior change support including psychology

First, guidelines for lifestyle-related postpartum care are impractical for both healthcare practitioners and women post-GDM [47]. On the one hand, healthcare practitioners for women post-GDM lack a practical tool for lifestyle advice. Few large-scale implementations of existing programs with a limited scope have been tested in single countries [48-50]. In Germany, the healthcare practitioners treating GDM are responsible for follow-up care [51, 52], yet have to rely on guidelines only. Gynecologists and diabetologists have good knowledge of treatment guidelines post-GDM with a focus on subgroups with two or more risk factors [53]. However, current lifestyle counselling depends on a healthcare practitioner's habits to give lifestyle advice due to the lack of an accessible program. This brings about many cases lost to follow-up for preventive measures. On the other hand, women post-GDM miss a practical tool [54] for individual [55], self-paced [56], and affordable [54] behavior change support for concrete health actions in daily life. They struggle with recommendations and lack skills to apply health behaviors in varying situations or with competing life goals [57]. Hence, the gap between healthcare contacts and daily health decisions needs to be closed [58].

Second, most of the lifestyle programs for women post-GDM are traditional one-on-one or group-based sessions bound to a specific location and to fix sequences [58-60]. However, mothers with infants are difficult to recruit and enroll into traditional programs [59, 60]. Women post-GDM perceive traveling to time-bound and time-consuming counseling sessions as barrier to participation [61]. For similar reasons, women post-GDM dismiss intensive interventions with many sessions [62]. Next to the need for a practical tool, a woman's decision to participate in a program may depend on the timing of the recruitment [62], continuity in care [63], access to the program [54, 56, 64, 65], postpartum topics [66], and compatibility with family life [67]. While some programs with remote delivery [58, 68-70] address some of the needs, most of the technologies used are already outdated once tested. Expert panels and reviewers call for innovative, flexible, and individualized interventions specific to the requirements of women post-GDM [44, 52].

Third, current programs for women post-GDM fail to support behavior change through proven methods and beyond nutrition and physical activity. Most behavioral programs post-GDM contain different behavioral goals for nutrition and/or physical activity [42], yet few add goals for psychosocial wellbeing [71], stress management [72, 73] or sleep [59]. Further, few interventions include a limited amount of behavior change methods [58, 60, 74, 75], focus on program engagement [76] or specify sub-behaviors and preparatory actions. Overall, behavioral psychology and mental health are underserved areas in current prevention programs [77-79]. Yet, two reasons call for psychological training for women post-

GDM: a high risk for postnatal depression [80] and fewer contacts with mental healthcare practitioners compared to controls [81]. Optimistic thinking and positive emotions support behavior change and can be trained as a skill [78, 82-85]. Hence, health promoters may achieve better health outcomes post-GDM when addressing the three intertwined lifestyle areas psychology, nutrition, and physical activity and when targeting behavioral determinants with proven behavior change methods.

1.1.3 Unique opportunities for intervention post-gestational diabetes mellitus

Mobile health (mHealth) and habit-based behavior change provide new opportunities to address the healthcare gaps for women post-GDM listed in the previous section to prevent T2D and related cardiometabolic disturbances post-GDM.

mHealth technology offers the following six benefits for interventions post-GDM [86-92]:

1) Low delivery costs
2) National and international dissemination
3) Easy to use in daily life
4) Coaching by diverse experts, independent from the expert's location
5) Multimedia appeal
6) Flexible systems based on behavioral psychology

Available features like tailoring and individualized health coaching improve user outcomes in knowledge, attitudes, and behavioral skills [93]. Overall, the benefits of mHealth and respective apps qualify as vehicle for interventions for women post-GDM [58]. However, mHealth apps for women post-GDM need to live up to current industrial standards of health and fitness apps [43].

Interventions at the habit-goal interface suit the postpartum period filled with changing and challenging circumstances due to a newborn at home. Women after delivery face new repeated behavioral contexts in daily family life that provide both cues for new behaviors and may disrupt existing habits. New repetitive context cues support habit change since habits are repeated actions in stable contexts [94]. Most behaviors occur in such stable contexts and are or become repeated actions, such as fruit and vegetable intake [95-98], physical activity [99-101], or negative thinking [102-104]. Lifestyle interventions depend on stable contexts in daily life and thus on habit formation for long-term success [105]. Small changes in dietary, physical activity and psychological habits impact body weight, physical fitness and psychological health on the long run. These changes depend on the awareness on how psychological, behavioral and environmental cues influence behavior on a subconscious level and how family life and being a homemaker may disrupt some cues [106]. Therefore, women post-GDM need to gain awareness and learn how they can use cues to their benefit, especially when stressed or exhausted [107-109]. Trials based on habit formation for weight loss achieved similar results to those with cognitive behavioral therapy [110]. The combination of targeting both conscious and subconscious behavior at the habit-goal interface via a multi-theories approach holds promise for effective behavior change post-GDM.

1.2 The Intervention Mapping approach for health promotion programs

Theory- and evidence-based approaches facilitate the complex process of planning, developing and evaluating health promotion programs. Health promoters need to translate multiple theories into practice considering empirical evidence, environmental factors, and the requirements of the at-risk population [111-113]. Further, they face changes and challenges in healthcare of the 21st century. In search of a proven, systematic, and iterative framework to plan a health promotion program, the

Intervention Mapping approach offered a good fit for this project. Intervention Mapping was developed in 1998, yet has become increasingly popular among health promoters during the past few years [114]. It has been applied in similar health promotion projects worldwide with more than 1,000 publications [115]. So far, no other intervention post-GDM has been guided by the Intervention Mapping approach.

The Intervention Mapping framework benefits health promoters and program participants in two ways. First, Intervention Mapping supports the understanding of the context of the health problem and models the planned intervention by including relevant stakeholders. Second, it integrates theory and empirical evidence for effective decision making in six systematic steps with specific tasks that repeat a loop of six core processes [116]. This secures a clear outcome orientation.

1.2.1 Understanding the intervention context

Intervention Mapping opens the focus of health promoters from a restrictive individual view to the bigger context [117] via the social ecological model [118, 119] and systems thinking [120]. Both models acknowledge the interaction between individual and environmental factors that determine an individual's health. Health promoters need to uncover these interactions for a particular health problem. Therefore, they need to work across the disciplines, involve stakeholders, and apply ethical principles [116].

In the social ecological model, an individual's environment includes factors and agents on four levels: interpersonal networks (e.g. family), organizations (e.g. managers of cafeterias), communities (e.g. newspaper editors), and societies (e.g. legislators) (Figure 1.1). The environment involves physical, social, and cultural components controlled by environmental agents at the different levels, such as the family or legislators. Environmental agents influence an individual's behavior, psychology, and physiology directly or through environmental factors that either reinforce or attenuate the influence of an intervention [121]. Changing an environmental factor at one level may impact factors in the same level or in other levels. Therefore, an understanding of the socio-ecological context is important even if an intervention targets change at the individual level [116].

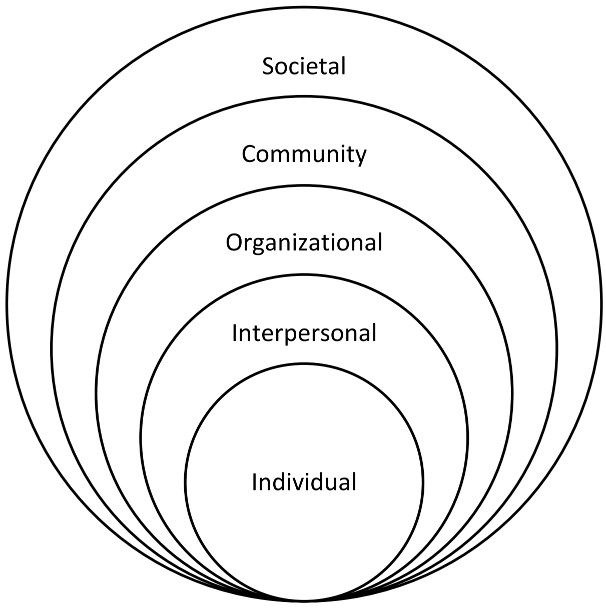

Figure 1.1: Social ecological approach
(adapted from Kok et al., 2017)

Systems thinking supports health promoters to understand and manage complex problems (Figure 1.2). Health problems usually occur in complex systems. Hence, systems thinking helps to select the most effective intervention points for changes in system activity [120] and effective methods for change. The resulting theory of the health promotion program is crucial for program effectiveness [122]. System-based frameworks helped health promoters explore factors for nutrition and physical activity behaviors for specific subgroups [123].

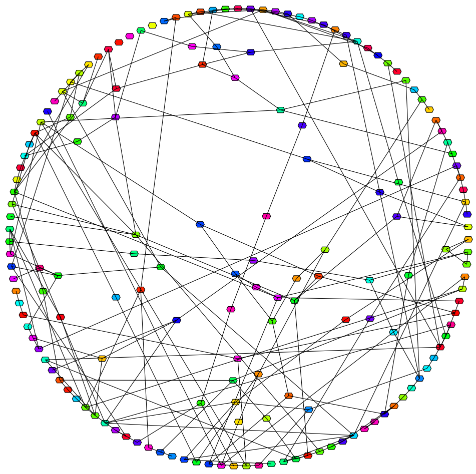

Figure 1.2: Systems thinking model

Intervention Mapping aims at involving stakeholders as much as possible in the development process to guarantee that stakeholders accept the resulting intervention. Best practice requires that all stakeholders join the project team to plan, develop, and disseminate an intervention [116]. The more stakeholders attend a core process in an Intervention Mapping step, the more diverse the related knowledge, skills, and expertise. This gets more important with conflicting stakeholder views, diverging goals, values, and life experiences [124]. However, most crucial is that health promoters communicate with the at-risk population [116].

Intervention Mapping applies ethical principles during program planning and program implementation [125]. The goal is to provide interventions to the public considering human rights, social justice, and possible burdens or undesirable consequences [116, 126]. Undesirable consequences may occur in mHealth since many individuals are unaware of data issues and must be protected. Therefore, health promoters need to discuss privacy, security, and data ownership [127-129].

1.2.2 Effective decision making in systematic steps, tasks and processes

Intervention Mapping links two methodologies. First, a systematic six-step planning process with specific tasks to develop and implement health promotion programs [130]. Second, six core processes that support decision making in the steps and tasks. This mix of steps, tasks, and processes allows health promoters to take theory- and evidence-based decisions – a precondition for effective interventions. Intervention Mapping starts by understanding the problem and delivers an implementable solution. Success is measured as outcomes related to the health problem [116].

1.2.2.1 *The six Intervention Mapping steps*

The six Intervention Mapping steps are iterative and cumulative (Figure 1.3). The tasks in each step and the products of each step build on one another. Yet, new information may require to go back to a previous step and repeat or revise a task. The tasks of each Intervention Mapping step are described in Table 1.1. Intervention Mapping Step 5 and Step 6 – the program implementation plan and the program evaluation plan – will not be part of this thesis and will be discussed briefly as outlook in Chapter 5.5. Intervention Mapping Steps 1 to 4 [116] will be described briefly in the following paragraphs.

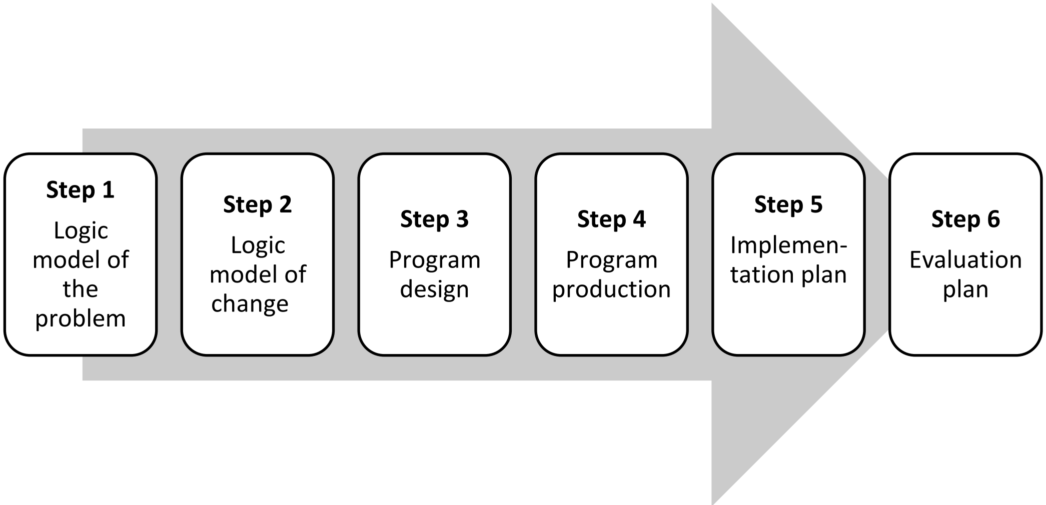

Figure 1.3: The six Intervention Mapping steps
(adapted from Eldredge et al., 2016)

Intervention Mapping Step 1 depicts the full scope of the health problem as basis for the following steps. Step 1 helps to form the project team, assesses the needs, and aims at understanding the program context and goals. The needs assessment is based on the PRECEDE/PROCEED model by Green and Kreuter [131]. The final product of Step 1 is the logic model of the problem. This model describes the health problem in detail. The starting point is the priority population, their health problem, and related quality of life issues. The model further uncovers risk factors at the individual and environmental level, the respective determinants (barriers and facilitators) of these risk factors, and differentiates between subgroups, if necessary (Figure 1.4).

Informed by the logic model of the problem, Intervention Mapping Step 2 determines what needs to change by whom to prevent the health problem. Step 2 starts with expected program outcomes, the respective performance objectives and change objectives for agents at the individual and environmental level. The resulting logic model of change reveals critical targets for intervention (Figure 1.5).

Intervention Mapping Step 3 delivers a first draft of the health promotion program. Step 3 matches theory- and evidence-based change methods with practical applications. It aims at clear deliverables, coherent program themes, and a logical program sequence. Step 3 centers around the "how" to ensure that both implementers and participants will accept the program. The outcome is a detailed, fully designed, and logic program plan with proven strategies to put all components into practice.

Intervention Mapping Step 4 develops the program's structure, organization, and material until ready-to-use. The output are pretested protocols, messages, applications, and supporting material. The more program components are included, the more complex is the program production. If producing all components from scratch, the project team must prepare plans, draft, pretest, and refine all materials. The end of Step 4 allows health promoters to run pilot studies to assess if program production was successful or not, and if the program fits the targeted agents and the intervention context.

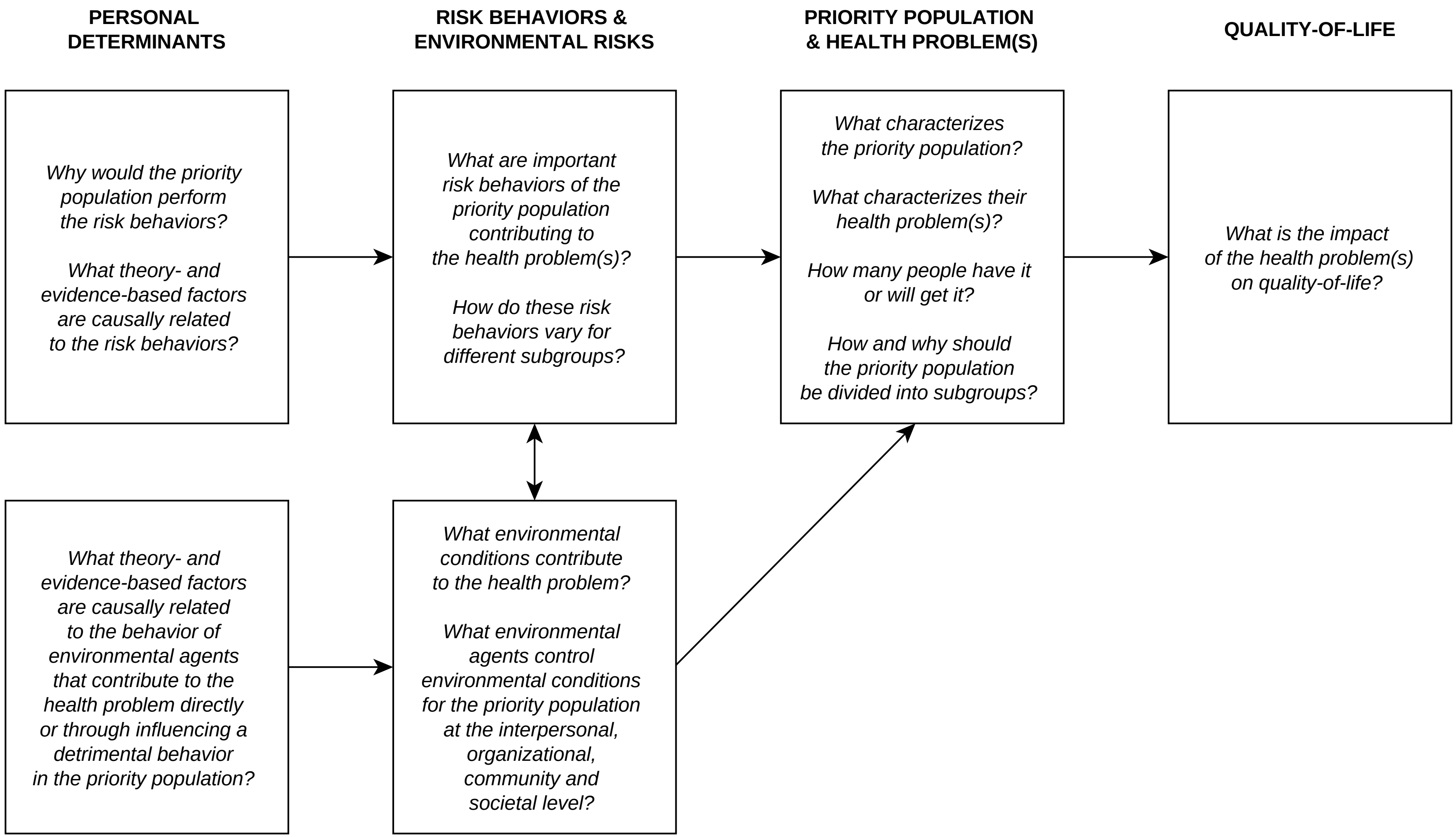

Figure 1.4: Intervention Mapping Step 1
Questions for the logic model of the problem (adapted from Eldredge et al., 2016)

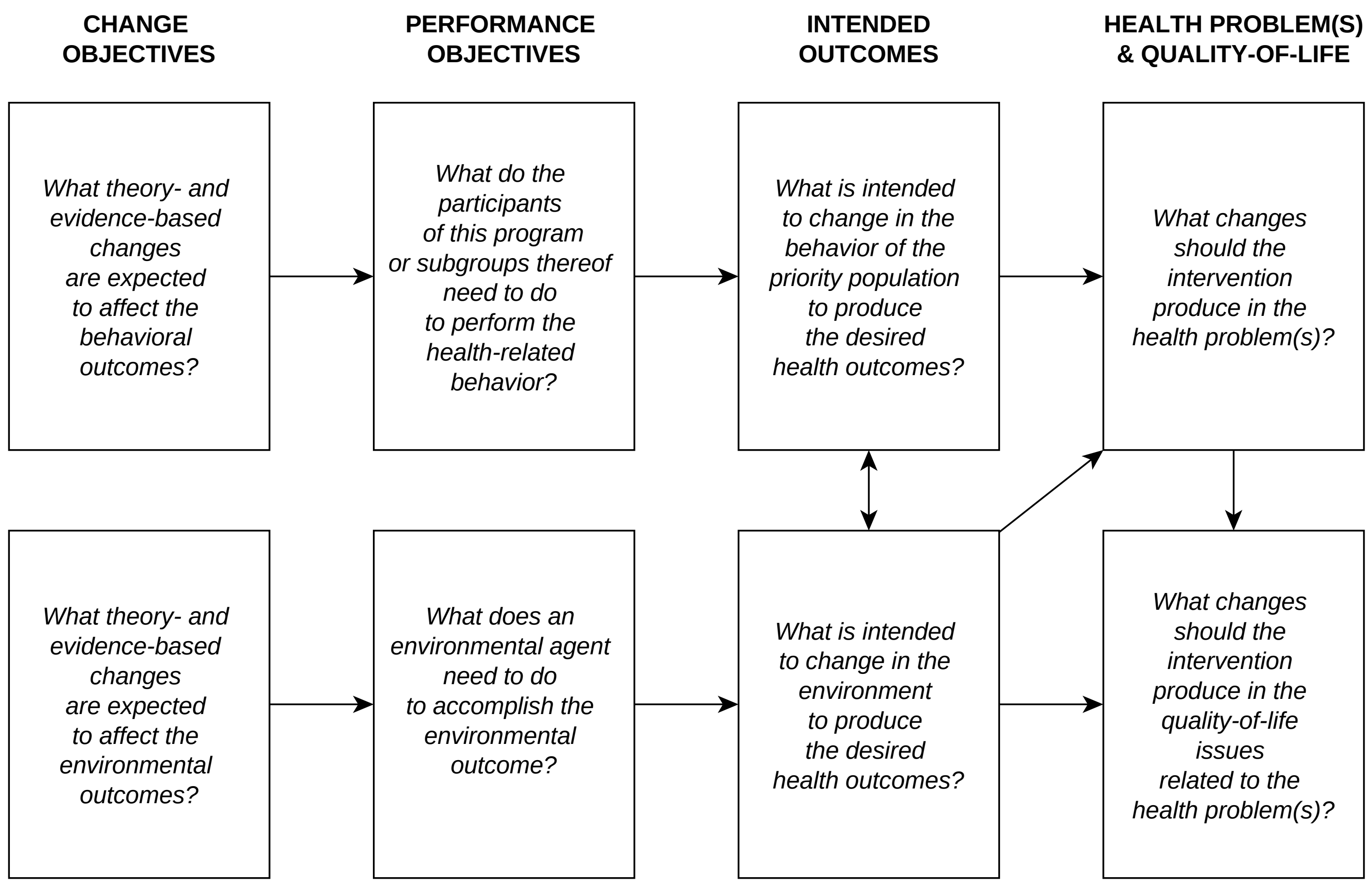

Figure 1.5: Intervention Mapping Step 2
Questions for the logic model of change (adapted from Eldredge et al., 2016)

1.2.2.2 *The six Intervention Mapping core processes*

The tasks in each of the six Intervention Mapping steps demand effective decision making. Six core processes support health promoters to make effective decisions (Figure 1.6) [116]. The core processes can be applied to all Intervention Mapping steps, especially the Steps 1, 2, 3, and 5 [116]. A topical approach allows to integrate different data sources, such as theory, empirical evidence, and expert knowledge [132]. The respective reporting grants transparency [133]. Further, the core processes are iterative and thus flexible, which is required during the development of mHealth solutions. The six Intervention Mapping core processes [116] will be described briefly in the following paragraphs.

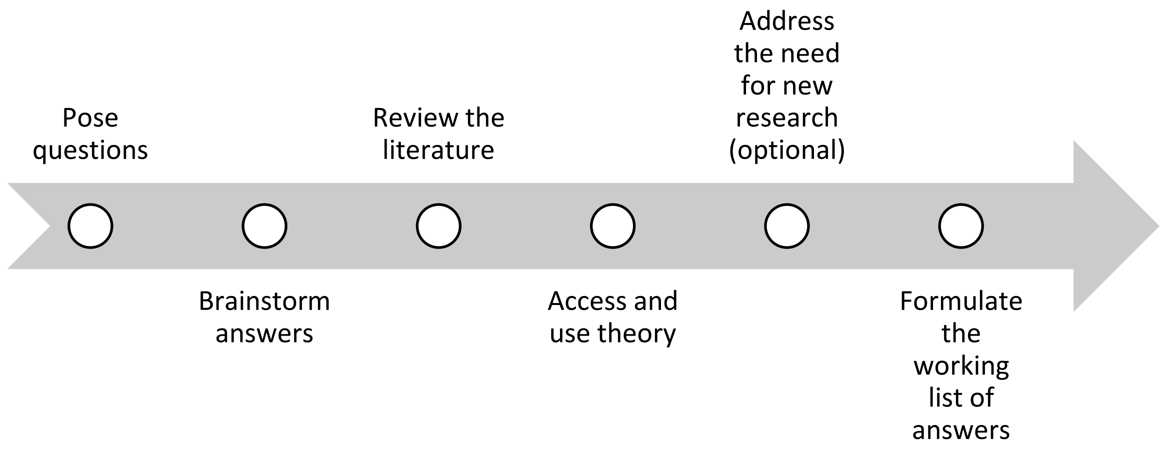

Figure 1.6: The six Intervention Mapping core processes
(adapted from Eldredge et al., 2016)

During the first three core processes, health promoters answer a problem-driven question with expertise and empirical evidence, for example *"Why would the priority population perform the risk behaviors?"* (see above, Figure 1.4). With a clear question in mind, health promoters "brainstorm" or "freely associate" for first answers in the second core process. They orient on practice wisdom, local knowledge, and personal beliefs. This is a creative process that prevents the project team from narrowing their focus or favoring explanations too early. The brainstorming supports health promoters to find as many explanations as possible. The resulting provisional list of answers guides the third core process – a review of the empirical literature. The literature review does not equal a formal systematic study, but links to a specific question with pre-defined parameters for the required evidence. If the evidence is insufficient, the health promoter may open up the search for comparable populations with shared demographic and cultural characteristics, and for comparable behaviors. The results of the empirical literature review either approve or contradict brainstormed answers.

During the core processes four to six, health promoters add theoretical approaches and, if necessary, new research to solve the question at hand, before formulating the working list of answers. Theories are accessed and used by topic, general theory, or theoretical construct. This approach supports multi-theory use to detect the less obvious parts of a health problem [134]. The review of the empirical literature often guides health promoters towards theories by topical search. Those theories can now be screened and followed up as a whole to further investigate specific theoretical constructs, such as behavioral intention. All theories and theoretical constructs might contribute to the best solution of a problem. The challenge is to find the best mix of theories or theoretical constructs. The fifth core process is optional, depending on the need for new data. The need for new data often arises from new information or questions during the previous core processes. For example, theoretical constructs may have to be tested in the priority population. If additional research is needed, health promoters are advised to use both qualitative and quantitative research methods. The sixth core process results into a working list of answers. Health promoters include answers with sufficient evidence for causation and plausibility. They further assess answers for relevance and changeability. Only causal determinants that are important and changeable will be part of the final list. Similarly, only those methods proven effective in comparable situations will be kept. Once finished with the entire core processes, the project team can proceed with the next question.

1.3 Relevant behavioral theories

Planning, developing, and evaluating a health promotion program demands an understanding of human behavior. Behavioral theories explain why most people behave in a certain way. They uncover which internal and external factors influence behavior by addressing the questions *"Who?", "What?", "When?", "Where?", "Why?",* and *"How?"*. Internal factors such as skills and external factors such as social pressure form theoretical constructs. Many theories share several of these constructs. Constructs and their relationship to one another were tested in empirical studies. Hence, health promoters can link theory and evidence to understand behavioral contexts and influences in their priority population and to select proven methods for behavior change [135].

Health promotion projects lead to more success when health promoters use several theories and theoretical constructs compared to a single or no theory [136, 137]. No theory or theoretical construct is superior to another [138]. Instead, theories and theoretical constructs complement one another [139]. Evidence on the relative importance of theoretical constructs is pending [135]. Therefore, health promoters are on the safe side using several theories to link aspects of a health problem to suitable theoretical constructs. A multi-theory approach further helps to account for differences between early and late stages of behavior change.

Six types of behavioral theories informed the current project:

1) Theories of automatic behavior and habits
2) Goal-setting theories
3) Learning theories
4) Theories of information processing and persuasive communication
5) Process models of (health) behavior change
6) Social cognitive models

This project primarily focused on habitual behavior and the habit-goal interface since most health or risk behaviors are automated in recurring contexts [140-142]. Still, habit formation requires self-control until automaticity reaches a plateau [105]. Thereby, a previously goal-driven and conscious behavior gets more and more activated by subconscious behavioral or environmental cues [143]. This is why this project integrated the two types of behavioral control – subconscious and conscious control. Theories of habitual and goal-driven behaviors can be seen as detailing higher-order behavioral theories such as social cognitive models or process models of behavior change. Habit and goal theories, in turn, require further detailing of some aspects by theories of learning and information processing. Relevant theories are visualized and discussed in terms of core constructs, implications for health behavior change, and relevant behavior change methods for this project.

1.3.1 Theories of automatic behavior and habits

The science of automatic behavior and habits studies subconsciously repeated behaviors in stable contexts [144-146]. About 47% of daily behaviors are automated to preserve energy and cognitive capacity for other important decisions and tasks [144]. This enables survival and efficiency in everyday life [147, 148] and links to an individual's identity [149].

1.3.1.1 *Characteristics of automatic behavior and habits*

Automatic behavior is characterized by the lack of awareness or conscious intent, the lack of control, and mental efficiency [141, 150]. Habits are automatic responses/response sequences to specific cues with short-term rewards and long-term consequences – one form of automatic behavior [141]. Most health behaviors are habitual [140]. Most people sleep, think, feel, drink, eat, and move the same way, every day, in the same contexts and form strong habits [141, 150, 151]. These habits lead to long-term health outcomes [151]. However, the habit system is insensitive to health consequences and cannot differentiate between "good" or "bad" habits for health. Therefore, unhealthy, nervous or even "pathological" habits may persist despite negative consequences when never questioned or challenged [152, 153] – for example, in the scope of a health promotion program.

1.3.1.2 *The rules of habit formation and habit change*

Habit formation and habit change follow five rules:

1) A stable and rigid context with specific cues [142, 154, 155]
2) Consistency in the response sequence that forms a routine [105, 141]
3) Sufficient repetition of the routine, especially for more complex tasks [105, 156, 157]
4) Rewarding outcomes or reinforcement following the routine [141]
5) Mental accessibility of past behavior due to changed neural networks in prior experiences [158, 159]

On average, individuals need approximately 66 days to reach behavioral automaticity, with great interpersonal variation between 18 and 254 days [105].

1.3.1.3 *Facilitators of habit formation*

All variables in the model of habit formation may act as facilitators (Figure 1.7). Research established some specific relationships for the following four facilitators: stimulus/cue, response frequency, response complexity, and implementation intentions. First, new stable contexts in an individual's life such as a new job, apartment, or friend provide repeated stimuli and support habit formation [155, 160]. Yet, the changes in context and stimuli can be more subtle, such as a new performance location, preceding routine, companion [142], or motivation [161]. Second, habit formation slows down when one lapse equals a missed week [162], but is not harmed by a single lapse for a daily behavior [105]. Third, most people are more consistent for simple behaviors such as drinking a glass of water when compared to more complex behaviors such as sports [105]. Fourth, implementation intentions eliminate residual effects of past or current habits on future behavior [146, 155, 163]. Yet, implementation intentions are insufficient for strong habits [97, 158, 164].

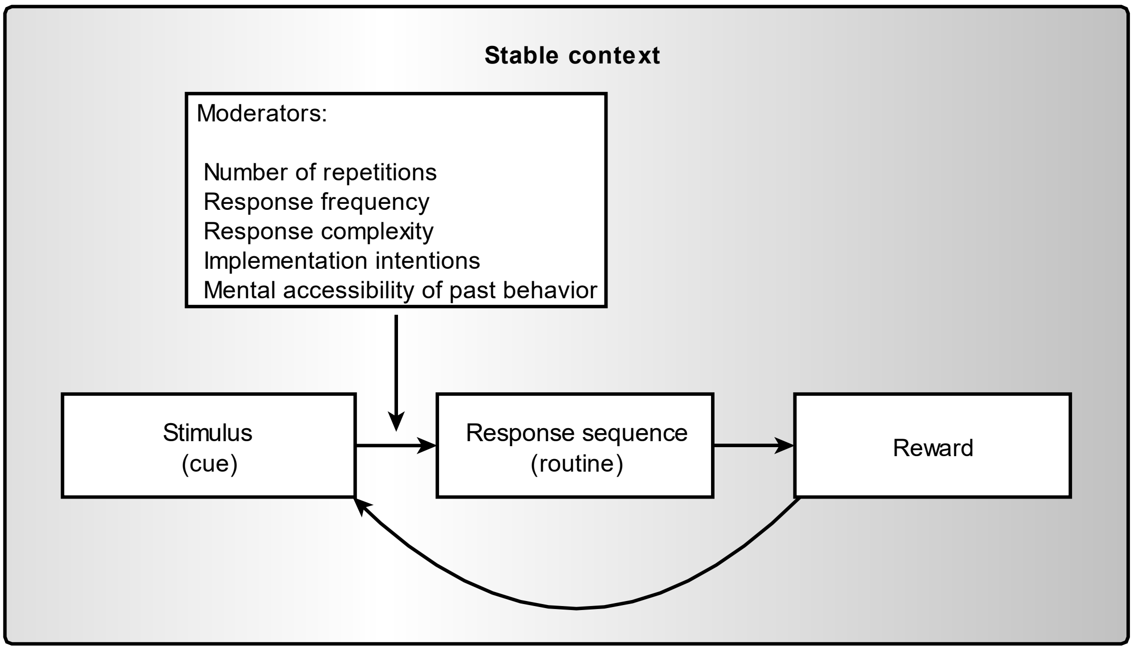

Figure 1.7: Model of habit formation

Undesirable habits change better with competing response practice when compared to trying to stop them [153] or to using negating implementation intentions [165]. Lastly, so-called “keystone habits” such as physical exercise facilitate other self-regulatory behaviors and habits [166]. New research suggests to establish time-independent health habits in the morning [167]. Effective behavior change methods for habits relevant to this project include cue altering, coping planning, self-monitoring, stimulus control, public commitment, early commitment, counterconditioning, and implementation intentions.

1.3.1.4 *The habit-goal-interface*

Habits and goals interact in three main ways at the habit-goal interface: goals direct habits by promoting repetition or exposure to cues, habits inform goals, and habits and goals work together to maintain learned habit associations [142]. Depending on the situation, the very same action can be controlled by either the goal (conscious) or the habit (subconscious) system [168]. Habits rely on stable contexts while goal-driven behavior also applies to unstable contexts. However, individuals differ between the habitual or goal-directed action control in different situations [169]. The balance between habitual and goal-directed behavior control decides over health outcomes [152], underlies impulsivity regulations [169], and is disrupted in obesity-related behaviors [170]. Further, complex behaviors such as physical exercise require the habit-goal interface: they take longer to become automatic [105] and become less automatic compared to simple behaviors [171]. Changes in dopamine trigger the shift from goal-directed to habitual actions [172]. The “goal-oriented automaticity” remains flexible with a clear goal orientation when compared to a traditional habit [142].

1.3.2 Goal-setting theory

Goal-setting theory describes which mechanisms and moderators affect the relationship between goal-related criteria, performance, and achievement [173] (Figure 1.8). Goal-directed behavior relies on action-outcome representations [141, 143, 174]. Value-expectancies drive goal-directed behavior, which is innate for survival [175] and links to internal concepts such as self-control, self-efficacy, and self-regulation [176]. In contrast, goal-setting theory also accounts for interactions between individuals and their environment via assigned, self-set, and shared decision goals. These interactions call for a close and consistent cooperation between an individual and all involved parties [177]. Goal achievement is mediated by choice, effort, persistence, and strategies [175].

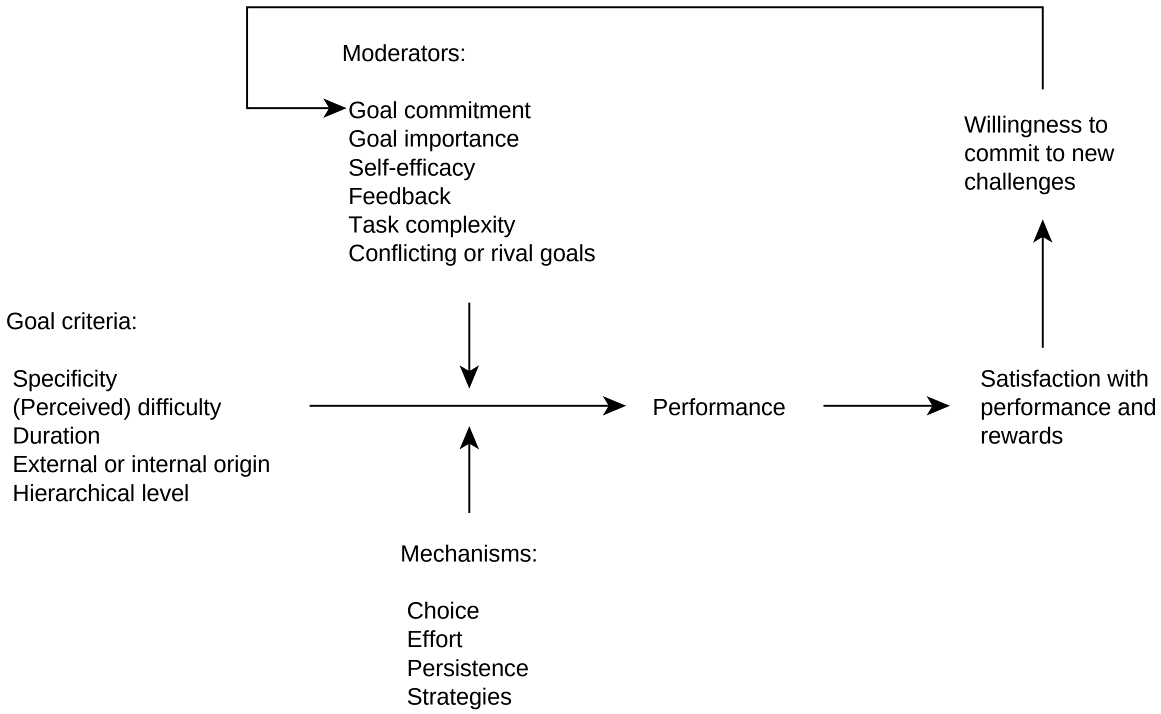

Figure 1.8: Goal-setting theory
(adapted from Locke and Latham, 2002)

1.3.2.1 *The goal hierarchy*

Newer models from the last decade build on a goal hierarchy with one to two high-level life goals, a few mid-level goals (outcome-oriented), and many low-level goals (action-oriented) [178] (Figure 1.9). Low-level goals occur on a daily or weekly basis while mid-level or high-level goals operate on a monthly, annual or lifetime basis. The different levels are important for successful behavior change [177]. If a lower-level rival goal interferes with a higher-level goal, an individual needs self-control to act in line with the higher-level goal [178]. Low-level goals often conflict with higher-level goals in dieters [179]. To achieve a high-level goal, an individual further needs to generate alternative low-level goals in case of setbacks and suppress rival goals at higher levels [178].

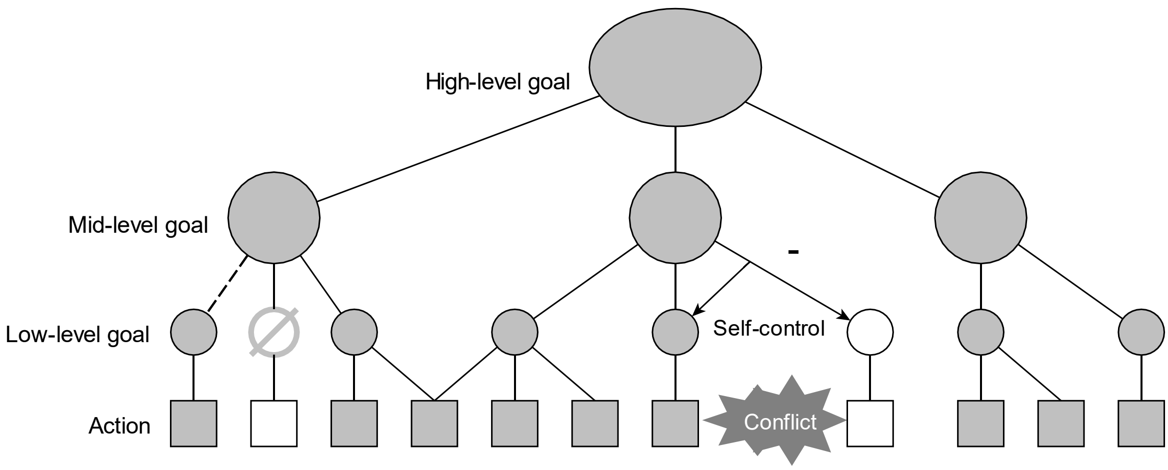

Figure 1.9: Goal hierarchy
(adapted from Duckworth and Gross, 2014)

1.3.2.2 *Facilitators for goal achievement*

All 18 variables in the adapted goal-setting theory (see p.13, Figure 1.8) may act as facilitators. Optimal goal criteria are the foundation for performance and goal achievement. The relationship between goal difficulty and performance is positive and linear as long as the individual is committed, physically and mentally able to attain the goal, and not challenged by conflicting goals at higher levels in the goal hierarchy [180]. Optimal short-term goal criteria translate into the acronym SMART(S): specific, measurable, attainable/action-oriented, realistic, timely, (and self-determined). Related behavior change methods for this project – besides goal setting – comprise feedback, cue altering, coping planning, self-monitoring, public commitment, early commitment, and implementation intentions. The overlap of most of the methods with those for habit change is caused by the habit-goal-interface.

1.3.3 Learning theories

Humans learn most behavior as response to (repeated) social and environmental stimuli. Hence, learning theories form the basis for most other behavior theories and offer effective methods for behavior change. The three most common types of behavioral learning are classical conditioning [181], operant or instrumental conditioning [182], and observational or vicarious learning [183]. All three types of behavioral learning contributed to the understanding of health behavior in this project.

First, classical conditioning allows to uncouple detrimental associations between (impulsive) risk behavior and their stimuli [184]. Second, in operant or instrumental conditioning a response is increased via positive or negative reinforcement or decreased via positive or negative punishment. The reinforcement process can be leveraged by four measures: continuous reinforcement, positive feelings, a short time interval between the behavior and the reinforcement, and individual reinforcers in terms of size, value, and quality [116]. Third, observational learning explains imitated responses through the observation of others' behaviors [183, 185]. The subtype of vicarious learning adds a (role) model that is reinforced for a specific behavior [182]. Relevant behavior change methods for this project originating in learning theories include feedback, reinforcement, early commitment, direct experience, and contingent rewards.

1.3.4 Theories of information processing and persuasive communication

Theories of information processing and persuasive communication investigate how people respond to information and how health promoters can design messages that transform attitudes and perceptions. Responses to information depend on how people perceive, comprehend, encode, and retrieve information in both the working memory and the long-term memory [116]. The two theories selected for this project are the Elaboration Likelihood Model and the Protection Motivation Theory.

1.3.4.1 *The Elaboration Likelihood Model*

The Elaboration Likelihood Model distinguishes between central and peripheral information processing and shows that elaboration is a skill that can be learned (Figure 1.10). Hence, it assumes some people are more skilled in elaborating than others. Central processing leads to elaboration and long-term attitude change, protects of counter persuasion, and aligns attitude with behavior – preconditions for long-term health behavior change [116]. Central processing is associated with learning by integrating new information with prior or contrasting knowledge and beliefs. In contrast, peripheral processing is superficial, skips logical analysis and leads to no attitude change or temporary attitude change only. Peripheral processing switches to central processing via motivation to process [186]. Other facilitators include [187-189]:

- Positive emotion
- Credible information source
- Message coherence
- Few high-quality arguments in a logical order
- Repeated exposure
- Otherness or novelty
- Personal relevance and importance
- Self-paced processing
- Simple messages with old information before new
- Skill training for information processing

Hence, health promoters need to consider these factors when they present health information. Methods to increase knowledge, change attitudes or behavior in this project comprise chunking, advance organizers, imagery, discussion, strong arguments, persuasive communication, and elaboration.

1.3.4.2 *The Protection Motivation Theory*

Health promoters use Roger's Protection Motivation Theory to shape educational health messages. The Protection Motivation Theory shows that evoking fear in risk communication only leads to protective behaviors if an individual beliefs in an effective coping response [190, 191] (Figure 1.11). It acknowledges different sources of information at the environmental (verbal persuasion, observational learning) and intrapersonal (personality variables, prior experience) level. An incoming message triggers cognitive mediating processes that contribute either to response inhibiting factors (threat appraisal) or to response facilitating factors (coping appraisal). Maladaptive coping behaviors occur if the threat appraisal outweighs the coping appraisal [192]. They comprise anger, avoidance, denial, hopelessness, and wishful thinking. In contrast, health behavior for protection motivation occurs if the coping appraisal outweighs the threat appraisal [190, 193, 194]. Therefore, coping information outperforms threat information in health messages [195]. Behavior change methods based on the Protection

Motivation Theory that are relevant to this project comprise tailoring, message framing, and verbal persuasion.

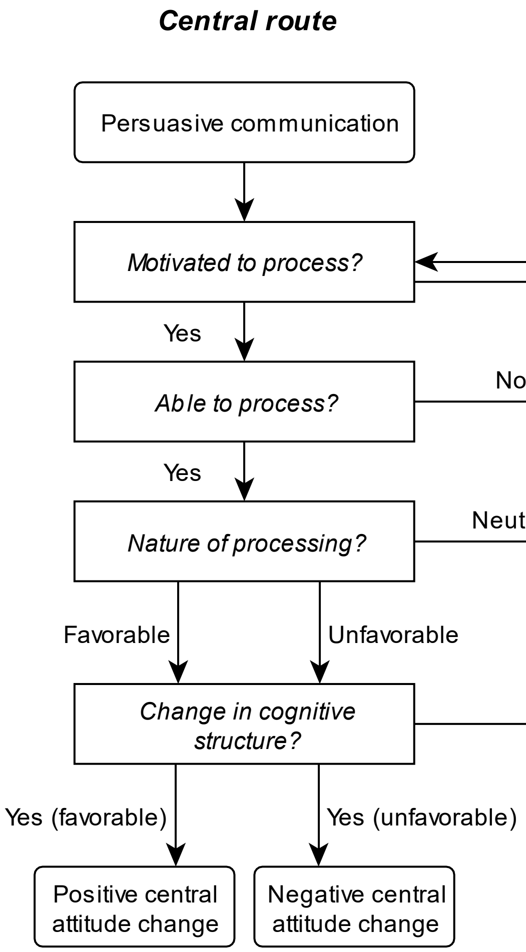

Figure 1.10: The Elaboration Likelihood Model
(adapted from Petty et al., 1987)

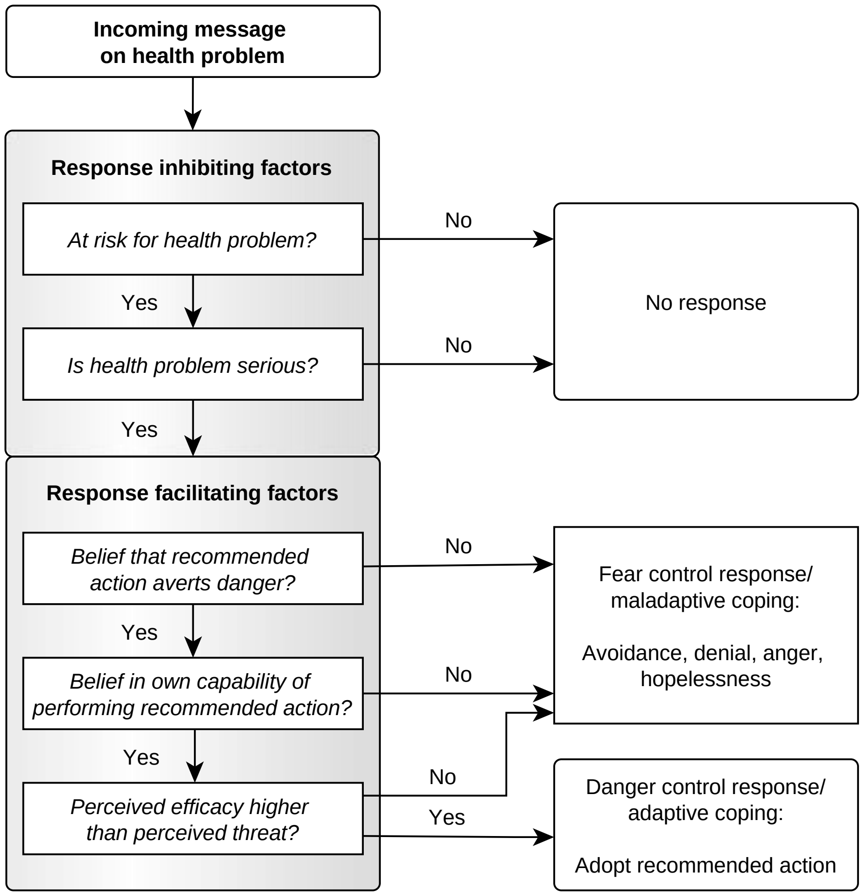

Figure 1.11: Simplified Protection Motivation Theory
(adapted from Cismaru et al., 2011)

1.3.5 Process models of health behavior change

Process models of behavior change support health promoters to understand behavioral changes over time, as an individual moves from inaction to consistent action. They uncover and weigh the importance of different factors at different points in time throughout the behavioral transformation. In the following, the three behavioral process models applied in this project will be explained briefly.

1.3.5.1 *Precaution Adoption Process Model and Transtheoretical Model of Behavior Change*

Behavioral stage-adjusted health program materials increase the likelihood that an individual accepts and identifies with the material. Hence, interventions based on stage models outperform those without such models [196]. Stage theories delineate the process of behavior adoption into a sequence of distinct stages. Specific tasks need to be performed to move from one stage to the next. Therefore, each stage has a specific set of determinants [197]. The process of moving through the stages is not linear, but rather cyclical or spiral, with relapses to previous stages [198] (Figure 1.12). Stage models are best suited for deliberate behaviors or weak habits such as exercise due to the limited focus on behavioral context [138]. Still, automatism can be reached for such deliberate behaviors.

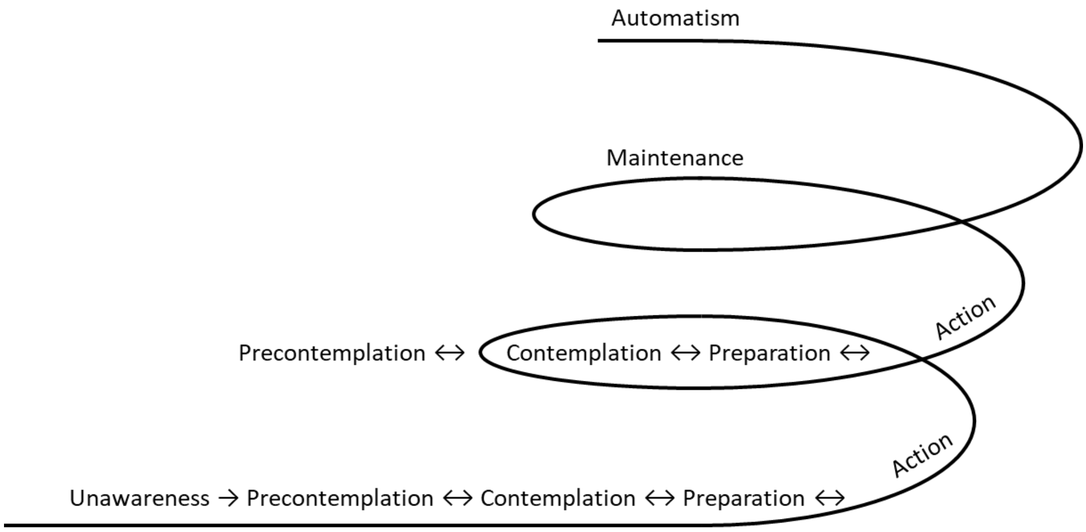

Figure 1.12: Cyclical process in stage theories
(adapted from Prochaska et al., 1994)

The most prominent stage theory is the Transtheoretical Model of Behavior Change (TTM) by Prochaska [198], followed by the Precaution Adoption Process Model (PAPM) by Weinstein [197]. Both are relevant for this project. The main difference is that the PAPM adds the stage “unaware of the issue” previous to the five shared stages [198, 199]:

1) ”Precontemplation”(TTM) or “unengaged by the issue” (PAPM)
2) ”Contemplation” (TTM) or “deciding about acting or non-acting” (PAPM)
3) “Preparation” (TTM, added later) or “decided to act” (PAPM)
4) “Action” (TTM and PAPM)
5) “Maintenance” (TTM and PAPM)

Automatism was added as the stage following a longer behavioral maintenance to describe the link to habitual behavior in this project. Each stage links to several behavior change methods to move to the next stage. The following behavior change methods were relevant for this project: individualization, tailoring, consciousness raising, environmental reevaluation, mobilizing social support, resistance to social pressure, self-reevaluation, stimulus control, reinforcement, and counterconditioning.

1.3.5.2 *Self-Determination Theory*

The Self-Determination Theory by Ryan and Deci explains motivation, self-regulation, and behavior on a continuum between nonself-determined (externally controlled) and self-determined (autonomous) [200, 201] (Figure 1.13). Behaviors on this continuum differ in the following factors [200, 202-204]:

1) How related information is being processed
2) How actions are motivated
3) How actions are regulated
4) Where the perceived cause is located
5) To what degree the three needs of autonomy, competence, and relatedness are satisfied

Type and quality of motivation and health actions matter more compared to the total number of actions. Most behavioral learning occurs autonomously motivated [205]. Several studies showed that the more autonomous the motivation, the better the outcomes in terms of persistence, performance, engagement, problem solving, positive emotions, quality of the behavior, and physical and psychological wellbeing [206-208]. These better outcomes are reflected in automatic behavior [209]. The opposite was shown for controlled motivation [210].

People can internalize external motivations up to a point where they identify with them so that their motivation becomes autonomous. Health promoters can support this process with the following eight actions [211-213]:

1) Explain from the perspective of an affected individual
2) Share decision-making and strengthen self-initiative in finding new solutions and strategies with optimal challenge
3) Provide structure
4) Give positive feedback and empathy
5) Promote mindfulness and congruence of conscious and non-conscious motives and values
6) Acknowledge emotions
7) Minimize external pressure
8) Give a meaningful rationale

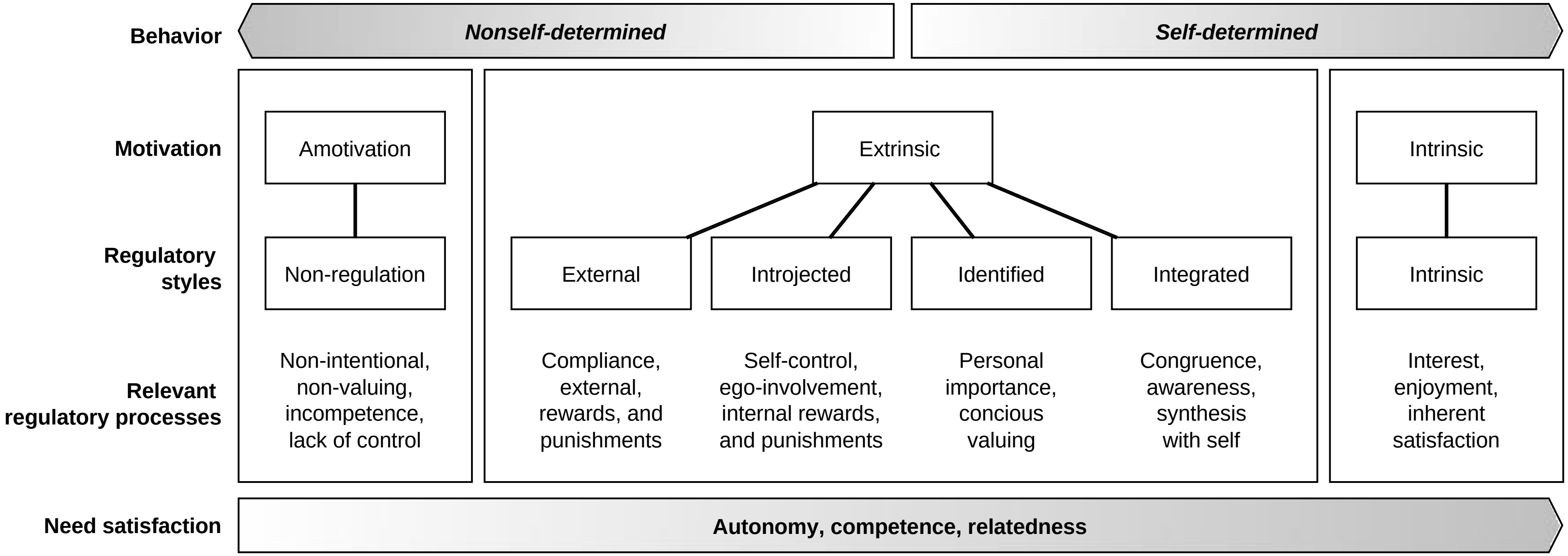

Figure 1.13: Self-determination continuum
(adapted from Ryan & Deci, 2000)

1.3.6 Social cognitive models

Social cognitive models consider environmental, psychological and behavioral factors that contribute to behavior. They assume that humans are thoughtful learners and that a great proportion of behavior is regulated by cognitive activity such as goals and expectancies. Cognitive behavior accounts for about 25% to 35% of behavior [214, 215]. Most social cognitive models include the two core constructs "self-efficacy" and "outcome expectancy" (Figure 1.14). Self-efficacy describes an individual's belief to be capable of performing an action. Outcome expectancy stands for an individual's belief to reach a specific outcome after having engaged in a specific behavior.

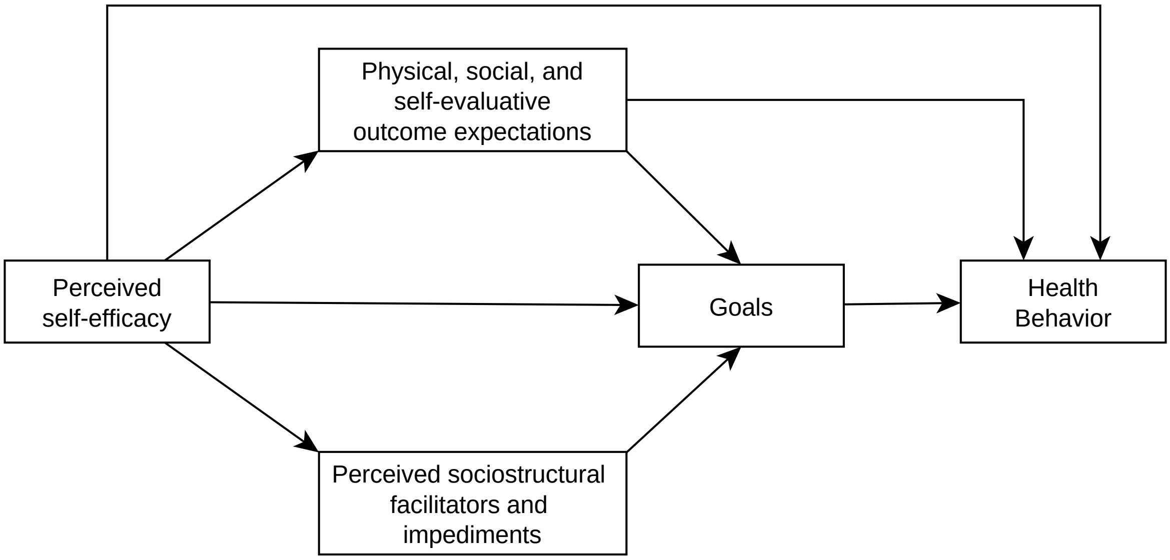

Figure 1.14: Health promotion by socio cognitive means
Structural pathways of influence (adapted from Bandura, 2004)

1.3.6.1 *Social Cognitive Theory*

Bandura's Social Cognitive Theory of human behavior explains how an individual motivates and regulates behavior in light of internal and external factors [216, 217]. Self-regulation may occur on three levels – covert (self), behavior, and environment [218] – leading to a triadic model of reciprocal determinism (Figure 1.15). The dynamic between these three levels is different over time. With regard to health behavior, the Social Cognitive Theory adds goals and sociostructural factors in the health system as facilitators or impediments to the original model (see above, Figure 1.14) [219]. The current project implements the following behavior change methods derived from the Social Cognitive Theory: feedback, graded tasks, guided practice, reinforcement, verbal persuasion, enactive mastery experiences, and improving physical and emotional states.

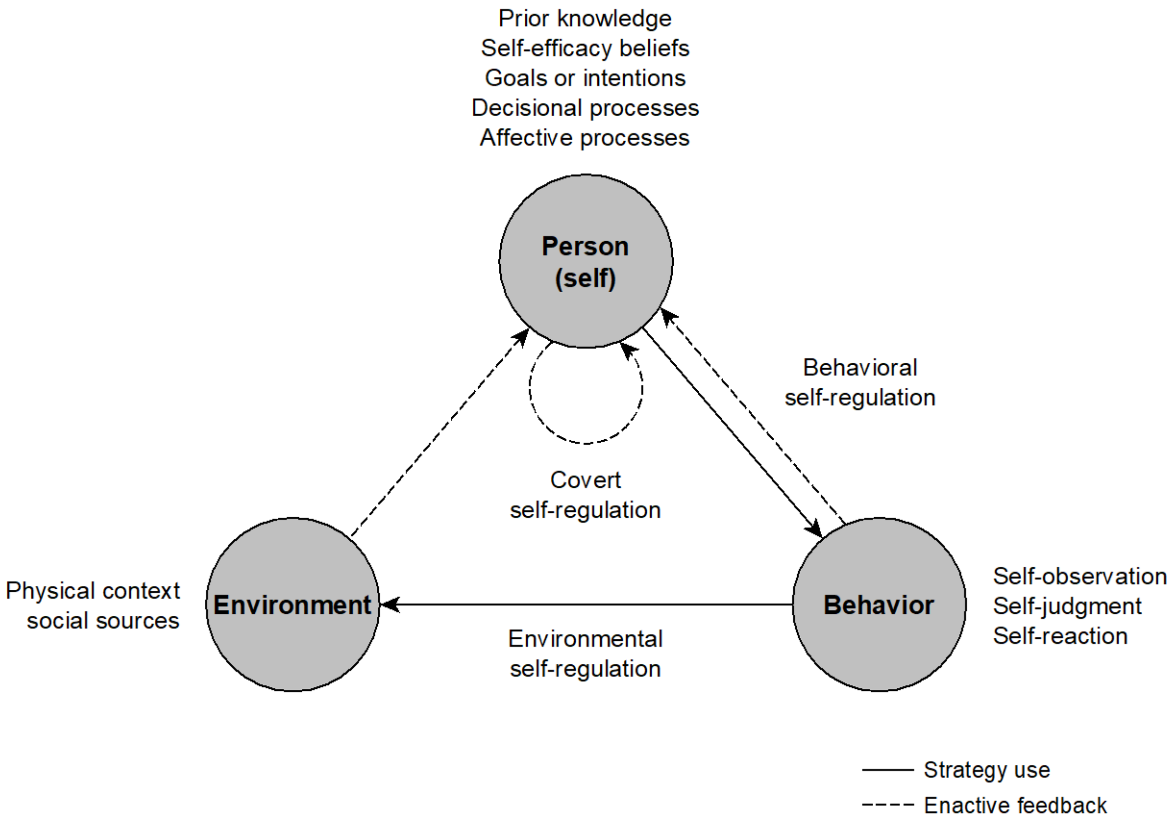

Figure 1.15: Social cognitive view of the triadic determinants of self-regulated learning
(adapted from Clark and Zimmermann, 2014)

1.3.6.2 *Theories of Reasoned Action*

The Theories of Reasoned Action originate in the Theory of Reasoned Action by Fishbein & Ajzen, were extended to the widely used Theory of Planned Behavior, followed by the Integrated Behavioral Model, and the Reasoned Action Approach [220-222]. The three common constructs include attitudes, subjective norms and perceived behavioral control (Figure 1.16). These three factors influence behavior via behavioral intention and are determined by behavioral beliefs and evaluation of behavioral outcomes, normative beliefs and motivation to comply, and control beliefs and perceived power, respectively [221]. More constructs were added and some of them further specified over time, such as personal agency split into perceived behavioral control and self-efficacy [222]. Background factors acknowledge individual differences such as past behavior, demographics, and culture. More recent models dampen the influence of intention on behavior by adding knowledge and skills to perform the behavior, environmental factors, salience of behavior, and habits [222]. Hence, current Theories of Reasoned Actions seem to bridge the gap between conscious and subconscious influences on health behavior. Relevant behavior change methods for this project include belief selection, resistance to social pressure, and information about others' approval.

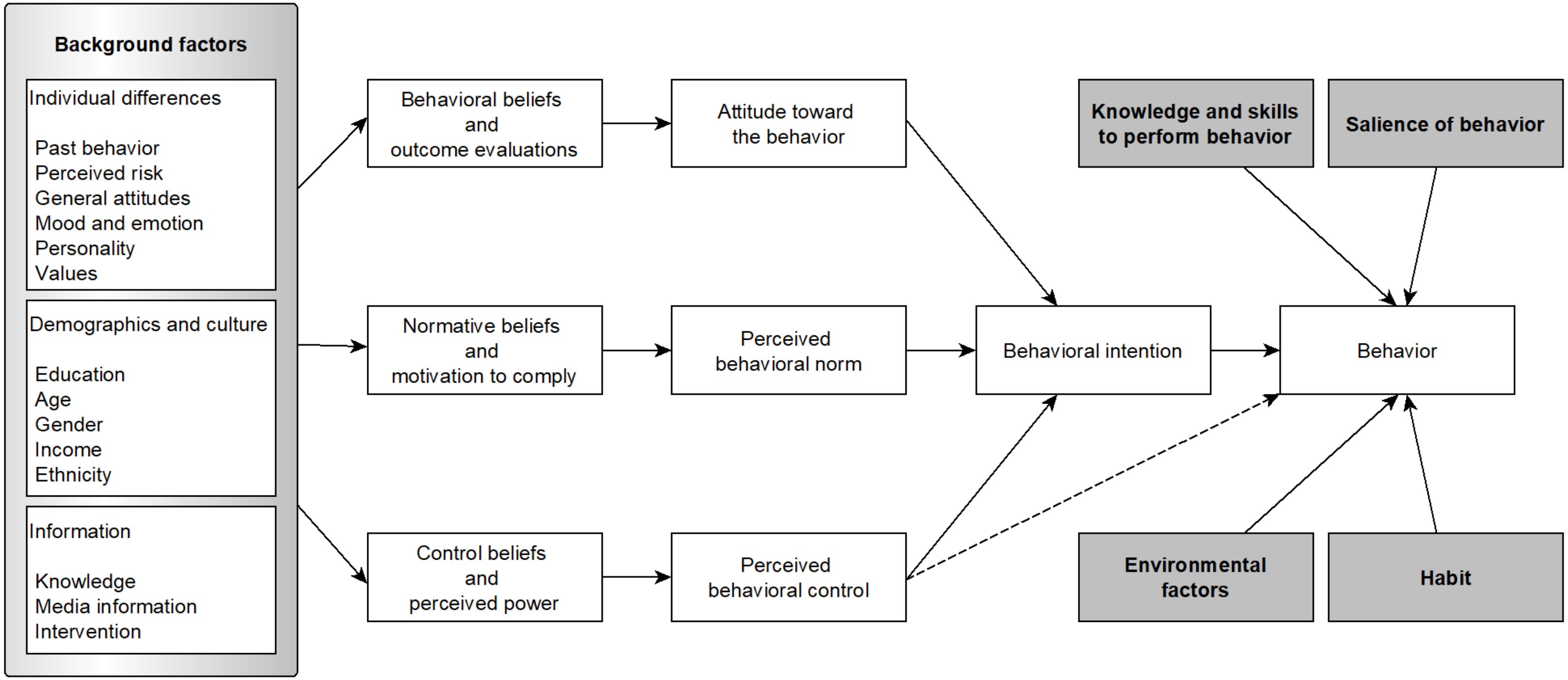

Figure 1.16: Theories of Reasoned Action
(adapted from Head and Noar, 2014)

1.4 Aims and outline of the thesis

This thesis project aimed at planning, developing, and pilot testing one of the first mHealth programs for women post-GDM. The intervention focuses on the prevention of T2D and related cardiometabolic disturbances via long-term health behavior change.

First, the systematic and iterative intervention planning followed the Intervention Mapping protocol as much as feasible with given time, staff, and budget. The planning was based on behavioral theories, empirical evidence, and interdisciplinary expertise to grant an understanding of the health problem, intervention context, and intended changes. The resulting intervention model includes the three lifestyle areas physical activity, nutrition, and psychosocial wellbeing/sleep. Further, several behavior change methods target the determinants of health behaviors in these lifestyle areas.

Second, initial program plans were translated into practical tools: a smartphone app for women post-GDM with an associated online coaching platform for healthcare practitioners. The software programming occurred in close cooperation with a software company. App features and app content deliver theory- and evidence-based behavior change methods. As soon as a beta-version of the smartphone app and drafts of additional program materials were available, a small user study pretested the program material. The user study allowed for user-approved adaptations before full program production.

Third, the adapted mHealth intervention was pilot-tested in a randomized, controlled clinical multicenter pilot trial. The pilot trial provided first insights on intervention acceptance and efficacy after six months. Primary outcomes included behavior change goals while secondary outcomes explored clinical parameters, app usage, and the perceived impact of the app on behavior. These outcomes allowed for further refinements of the program and will guide the choice of endpoints, duration, measurement instruments, and sample size for a larger trial.

Overall, this project prepared the next steps of program implementation and further evaluation. Table 1.1 outlines the structure of this thesis in relation to the six Intervention Mapping steps (Chapter 1.2.2) and the respective tasks.

Table 1.1: Intervention Mapping steps and tasks in the respective thesis chapters

Thesis chapter	Intervention Mapping step	Intervention Mapping task (thesis subchapter)
Chapter 2 **Planning a mobile health promotion program to prevent type 2 diabetes after gestational diabetes mellitus**	**Step 1** **Needs assessment - logic model of the problem**	Establish and work with a planning group (2.1.1) Conduct a needs assessment to create a logic model of the problem (2.1.2) Describe the context for the intervention including the population, setting, and community (2.1.3) State program goals (2.1.4)
	Step 2 **Program outcomes and objectives - logic model of change**	State expected outcomes for behavior and environment (2.2.1) Specify performance objectives for behavioral and environmental outcomes (2.2.2) Select determinants for behavioral and environmental outcomes (2.2.3) Construct matrices of change objectives (2.2.4) Create a logic model of change (2.2.5)
Chapter 3 **Developing the mobile health promotion program**	**Step 3** **Program design**	Generate program themes, components, scope, and sequence (3.1.1) Choose theory- and evidence-based change methods (3.1.2) Select or design practical applications to deliver change methods (3.1.2)
	Step 4 **Program production**	Refine program structure and organization (3.2.1) Prepare plans for program materials (3.2.2) Draft messages, materials, and protocols (3.2.3) Pretest, refine, and produce materials (3.2.4)
Chapter 4 **Clinical pilot trial with the mHealth program**		Addition: Pilot-testing in a randomized, controlled clinical trial (4.1.1 to 4.5)
Chapter 5 **Discussion**	**Step 5** **Program implementation plan**	Identify potential program users (adopters, implementers, and maintainers) State outcomes and performance objectives for program use Construct matrices of change objectives for program use Design implementation interventions (5.5.1)
	Step 6 **Evaluation plan**	Write effect and process evaluation questions Develop indicators and measures for assessment Specify the evaluation design Complete the evaluation plan (5.5.2)

In grey: Intervention Mapping Step 5 and Step 6 are not part of this thesis but discussed as outlook.

2. Planning a mobile health promotion program post-gestational diabetes mellitus (Intervention Mapping Steps 1 and 2)

2.1 Intervention Mapping Step 1 – Needs assessment and logic model of the problem

During Intervention Mapping Step 1, the project team formed and conducted a needs assessment to uncover T2D-related cardiometabolic risk behaviors and why women post-GDM engage in these behaviors. The final product of the needs assessment was a logic model of the health problem. The logic model of the health problem delineated the epidemiologic, behavioral, and psychosocial context for the intended program – a precondition to state program goals (Figure 2.1).

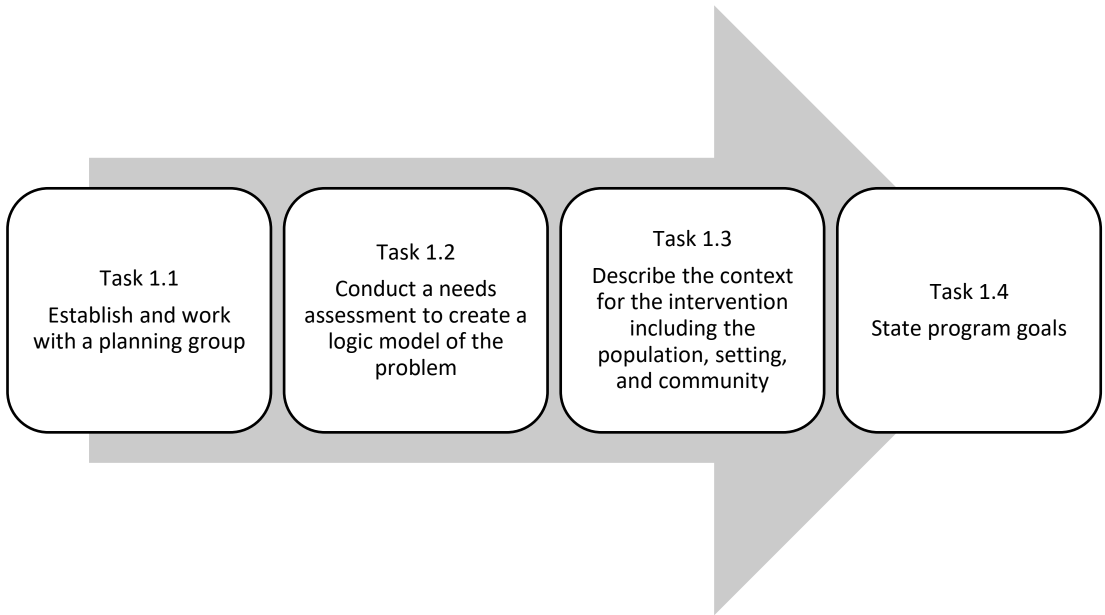

Figure 2.1: Tasks of Intervention Mapping Step 1
(adapted from Eldredge et al., 2016)

2.1.1 Establish and work with a planning group (Task 1.1)

The two-headed core team of this project is part of the Diabetes Research Group, a clinical cooperation group of the Helmholtz Center located in the Medical Center of the University of Munich. The core team comprises the head of the research group (doctoral supervisor) and the author (doctoral student), further referred to as "we". During the first year of planning, the core team also included an epidemiologist.

Since 2012, the Diabetes Research Group (n=11) runs the 10-year follow-up study PPSDiab (Prediction, Prevention, and Subclassification of T2D) with 304 participants, in a 2:1 ratio of women post-GDM and controls after a normoglycemic pregnancy. During the PPSDiab study, the team gained numerous insights on the priority population's lifestyle based on cardiometabolic exercise testing and validated lifestyle questionnaires such as the Pittsburgh Sleep Quality Index [223-226]. Further, the team received information on daily life challenges and noticed certain behaviors of women post-GDM during their annual three-hour clinic visits. Internal expertise for the current project spans the fields of epidemiology, health sciences including nutrition, and diabetology.

We consulted external experts in sports science, personal training, psychology, user experience design, software engineering, graphic design, and filming. External experts contributed to the project in varying degrees, depending on the respective Intervention Mapping step. Three sports scientists and sports cardiologists from the Medical Center for Preventive and Rehabilitative Sports Medicine of the Technical University of Munich consulted us for physical activity and exercise. The personal trainer Katrin Böning runs the Studio Bodyconcept in Munich and provided practical expertise and facilities for the videos on physical activity. For psychological content, we contracted the psychological therapists Dr. Sabine Waadt-Heim, Dr. Gabriele Duran-Atzinger, and Amelie Müller from different psychological centers. Our industry partners in software engineering included Linova Software GmbH and QuickBird Studios GmbH, with the technical project manager Dr. Lukas Alperowitz from the Chair of Applied Software Engineering, Technical University of Munich. Elisabeth Wagner created the logo as graphic designer. The cameraman Kersten Hüttner filmed all videos for physical activity and provided the respective equipment. We further interviewed a large diabetology practice team to gather healthcare practitioner’s opinions outside the clinical setting.

For most parts of the project, smaller work groups of about three persons tackled specific tasks by expertise. This granted a parallel workflow for lifestyle content and software engineering during the planning and development phases. The three psychological therapists formed the psychological work group. Two nutritional scientists (including the author) with phasic input by a dietician from the own team formed the nutritional work group. Three sports scientists started the physical activity work group to be continued by the core team and the personal trainer. The software engineering work group comprised a project manager, three software engineers, and one user interface designer. We scheduled regular meetings with every work group to ensure coherence. Iterative project management helped us maintain group processes such as brainstorming for idea generation and consensus-based decision making. Further, joint meeting agendas, short debriefings at the beginning of each meeting, and timelines for project sub-goals supported our workflow.

2.1.2 Conduct a needs assessment to create a logic model of the problem (Task 1.2)

The systematic needs assessment discloses determinants of risk behavior, risk behaviors associated with the health problem, characteristics of the priority population and relevant subgroups, and the health problem with related quality of life implications [116]. The resulting logic model of the problem describes the discrepancy between what is and what should be in the priority population in as much detail as possible in the scope of this project (Figure 2.2).

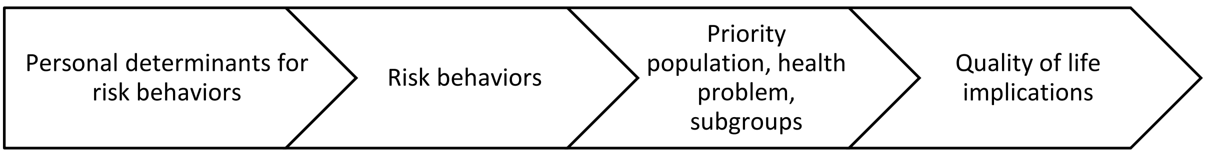

Figure 2.2 Components of the logic model of the problem in this project
(adapted from Eldredge et al., 2016)

2.1.2.1 *Describe the priority population, their health problem, and relevant subgroups*

The needs assessment started with the population at risk for a specific health problem. Hence, the first cycle of the six Intervention Mapping core processes tackled the question *“What demographic* *(non-behavioral) factors characterize women post-GDM (priority population) at risk for T2D (health problem), and what are relevant subgroups (such as different body weight categories)?".*

2.1.2.1.1 Characteristics of the priority population

We applied the Intervention Mapping core processes to define the priority population with the following six criteria:

- Female gender in reproductive age
- Predominant age range between 18 and 45 years
- At least one child in the household
- At least one recent pregnancy complicated by GDM
- Extended postpartum period (until maximum five years after delivery)
- At high risk for or with present cardiometabolic disturbances following GDM

Despite this rather narrow definition of women post-GDM as priority population, we raised our awareness for the overrepresentation of women with a higher risk for developing GDM in the first place [227-241]:

1) Pre-pregnancy metabolism with characteristics of the MetS, including (abdominal) overweight/obesity [231]
2) Advanced maternal age [227]
3) Low socioeconomic status [227]
4) High-risk ethnicity [236] such as Asian [235], Hispanic [234], or Turkish [229]
5) Family history of diabetes [227]
6) GDM in a previous pregnancy [238]
7) Excess weight gain during pregnancy [233]
8) The polycystic ovary syndrome [242], fertility problems [230] or in-vitro fertilization [232]
9) Multiparity [236]
10) Pre-existent depression [228]

Moreover, women post-GDM share demographic characteristics with the wider population of young mothers – such as being married, living with a partner and infant(s), or being a working mother. We considered the overrepresented traits in our wider characterization of the priority population, yet not in the main definition (Supplementary Table 1, Part 1).

2.1.2.1.2 Characteristics of the health problem

The related second set of questions addressed the health problem: *"What characterizes T2D (health problem) following GDM, including cardiometabolic precursor stages, complications, and co-morbidities?" and "How many people have this health problem or will get it?"*

Following the Intervention Mapping core processes helped us to define the health problem (Supplementary Table 1, Part 2). Our main focus remained T2D, yet we saw the need to add related cardiometabolic disturbances to the definition. Cardiometabolic disturbances contribute to the development of a pre-diabetic state, the MetS, CVD, T2D, and T2D-related complications or comorbidities. Hence, we re-defined the health problem as T2D and related cardiometabolic disturbances post-GDM. In the scope of this project, cardiometabolic disturbances include the following four clusters of risk factors:

- (Abdominal/visceral) overweight/obesity:
    - Increased body mass index (BMI) [243, 244]
    - Increased waist circumference [245, 246]

    - Increased percent body fat/(visceral) fat mass [245]
- High blood pressure/hypertension:
    - Increased systolic blood pressure [247]
    - Increased diastolic blood pressure [248]
- Dysglycemia:
    - Increased fasting glucose [249]
    - Increased two-hour glucose in oGTT [250]
    - Increased glycated hemoglobin (HbA1c) [251]
    - Increased Insulin Homeostatic Model Assessment of Insulin Resistance (HOMA-IR) [252]
- Dyslipidemia:
    - Increased low-density lipoprotein cholesterol (LDL-C) [253, 254]
    - Decreased high-density lipoprotein cholesterol (HDL-C) [243]
    - Increased triglycerides [255, 256]
- Combinations of the above [257-261]

We excluded further cardiometabolic risk factors comprising pro-inflammatory factors (cytokines and adipokines, such as tumor necrosis factor-α or interleukin-6) and pro-thrombotic factors (such as fibrinogen or C-reactive protein) for the following three reasons: Pro-inflammatory factors are not part of the routine care assessments, non-specific for cardiometabolic disturbances only, and we had to limit our model for the following steps.

The global prevalence of hyperglycemia in pregnancy (GDM and manifest T2D in pregnancy) has been estimated around 15% to 18% [262-264]. GDM was diagnosed in seven percent of pregnancies after the introduction of a two-step screening process in Germany [265]. Women post-GDM show a higher risk for cardiometabolic disturbances compared to controls with a normoglycemic pregnancy. The cumulative incidence for T2D ranges from three to 70% in a period between six weeks to 28 years postpartum [3]. The cumulative incidence increases in the first five years post-GDM (between 20 and 65% develop T2D) and plateaus at about 10 years post-GDM [10]. The relative risk is the highest between three to six years post-GDM compared to the risk of women with a normoglycemic pregnancy [4]. German data indicates that the average eight-year-risk of developing T2D following GDM is 53% and varies from 12% to 96%, dependent on the combination of risk factors [11]. In addition, the cardiovascular risk post-GDM is increased [6, 7, 266-270], with an odds ratio of 1.85 [7]. Metabolic disturbances measured five years post-GDM include hyperglycemia and insulin resistance, despite normal glucose tolerance [271]. Further, a meta-analysis found an approximately fourfold higher risk of the MetS post-GDM when compared to controls [8]. In a more recent Finnish study, the seven-year prevalence for the MetS in a post-GDM group with a GDM diagnosis early in pregnancy was 50% [9]. Predictors for the development of the MetS can already be found during the oGTT of the index pregnancy [272].

In addition, we considered diabetic complications and comorbidities as part of the health problem post-GDM for three reasons:

1) With overt T2D pre or around mid-life, several acute and chronic complications and comorbidities are likely to develop due to longer disease duration [273-275].
2) Some of the complications are more prevalent in women compared to men – such as the increased risk for stroke [276], depression [277], and vascular dementia [278].
3) Pre-diabetic patients show prevalences in comorbidities that are comparable to diabetics [279].

The prevalence of acute and chronic T2D complications varies, even on a national basis [280]. The most common chronic complications are a wide range of micro- and marcovascular diseases that affect major organs such as the heart, kidneys, and eyes and cause damage to the nerves [281]. Microvascular damages such as diabetic nephropathy [275, 282], diabetic retinopathy [283, 284], and diabetic neuropathy [285, 286] are the leading causes for end-stage kidney disease/failure [287], visual impairment [288], and lower-limb amputations [289], respectively. Macrovascular damages such as coronary artery disease [5, 273, 290], peripheral artery disease [274], and the diabetic foot [291, 292] cause angina or sudden cardiac death [293], stroke [294], and lower-limb amputations [295], respectively. The main cause of death in T2D are of renal or cardiovascular nature [296], yet most complications contribute to a higher mortality [297]. Acute events associated with T2D include hypoglycaemia, acute prancreatitis [298], diabetic ketoacidosis, hyperglycaemic diabetic coma or hyperosmolar state, and specific types of infections [299]. Many of the complications and comorbidities have a reinforcing effect on one another, such as severe hypoglycaemia on CVD [300], or depression on neuropathy [301].

2.1.2.1.3 Characteristics of relevant subgroups

The intertwined third set of questions addresses subgroups of the priority population: *"Does the prevalence or severity for T2D and related cardiometabolic disturbances (health problem) vary between demographic subgroups of women post-GDM (priority population)?" "What segments of women post-GDM have an excess burden from T2D-related cardiometabolic disturbances?", and "Are there other relevant subgroups in the priority population for program participation?"*

The Intervention Mapping core processes guided us in characterizing relevant subgroups among women post-GDM (Supplementary Table 1, Part 3). The most pronounced high-risk subgroup post-GDM are overweight or obese women [11, 272, 302]. The mean BMI in most studies with women post-GDM was above 25 kg/m^2 to be classified as "overweight" or above 30 kg/m^2 to be classified as "obese" [303, 304]. A US and two Australian studies showed that between half to almost two thirds of women post-GDM were overweight or obese [55, 305, 306]. A higher BMI post-GDM was associated with deteriorated cardiometabolic risk factors including percent body fat, blood pressure, blood lipids, and insulin sensitivity [307].

In a comparison between different weight and GDM/no GDM subgroups, the cumulative incidence of diabetes, hypertension, and CVD was highest among women with GDM and overweight (36%, 27%, and 3%, respectively) while women with no GDM and no overweight had the lowest incidence (1%, 6% and 1%, respectively) [6]. Similarly, a meta-analysis identified overweight/obesity as the most consistent risk factor for vascular dysfunction post-GDM [308]. Hence, we distinguished the following two subgroups with a lower versus a higher risk and burden of T2D and related cardiometabolic disturbances post-GDM:

- BMI of < 23 kg/m^2
- BMI of ≥ 23 kg/m^2

The International Diabetes Federation recommends weight maintenance for those within a healthy weight range and 5- 10% of weight reduction for adults with a BMI > 25 kg/m^2 in Caucasians, and > 23 kg/m^2 in Asians [309]. This includes those with metabolically healthy obesity [310]. We chose a BMI of ≥ 23 kg/m^2 instead of the traditional cutoff at a BMI of 25 kg/m^2 to define overweight due to the relatively young age of the priority population.

Despite our main focus on the overweight/obese for program tailoring, we considered additional subgroups for individualization purposes. Next to the BMI, three other clusters of risk factors show an increased risk or burden of T2D and related cardiometabolic disturbances.

First, some risk factors for developing GDM in the first place also form subgroups at higher risk for cardiometabolic disturbances post-GDM:

1) Ethnicity or ethnic identity
2) Low socioeconomic status
3) Family history of diabetes
4) Metabolic status with characteristics of the MetS
5) Pregnancy-related factors such as excess weight gain during pregnancy
6) Depressive symptoms
7) The polycystic ovary syndrome

Second, GDM-related factors form vulnerable subgroups with a higher prevalence of cardiometabolic disturbances post-GDM [13, 51, 311-314]:

1) Insulin treatment during pregnancy
2) Early GDM diagnosis before the 20th week of gestation
3) Antenatal glucose value in the oGTT of > 200 mg/dl

Third, the following vulnerable postpartum subgroups need to be considered [315-321] among women post-GDM:

1) No or short breastfeeding
2) Weight retention for a longer period after pregnancy
3) Postpartum fatigue or sleeping problems
4) Physical disturbances such as urinary incontinence
5) Psychological disturbances such as postpartum depression, postpartum posttraumatic stress disorder, obsessive-compulsive disorders, anxiety disorders, or negative postpartum body image

In line with these findings, data from the PPSDiab study describes a subgroup of women post-GDM with subclinical mild to moderate depressive symptoms with an unfavorable metabolic profile in terms of higher BMI, systolic blood pressure, and abdominal visceral fat [224]. Especially women post-GDM with a low socioeconomic status and immigrant women may be affected by postpartum depression [51, 322], or experience negative emotion [323]. Overall, the subgroups mentioned above have a higher cardiometabolic risk compared to the general population of women post-GDM and are thus considered for further individualization.

2.1.2.1.4 Describe quality of life implications

The quality of life questions addressed in this project included*: "What are a) short-term quality of life implications in the postpartum period and in the years following GDM (priority population), and b) long-term quality of life implications of T2D and related cardiometabolic disturbances (health problem) in individuals living with these conditions?", and "To what extent are dimensions such as activities of daily living in family life, work or leisure time affected?"*.

Following the Intervention Mapping core processes and a theoretical framework on quality of life, we identified the most important quality of life implications (Supplementary Table 1, Part 4). We differentiated between short-term and long-term effects of the health problem on quality of life. The short-term effects relate to the post-GDM phase with no or little cardiometabolic disturbances – including the postpartum phase in general. In contrast, we attributed the long-term effects on quality of life to T2D, related cardiometabolic disturbances, complications, and comorbidities. In this project, we focused on short-term quality of life improvements, with the long-term quality of life impacts and goals in mind.

Women post-GDM rate their quality of life postpartum similar to controls with a normoglycemic pregnancy [324]. The two groups share an impaired quality of life postpartum [325]. Both groups rated their health-related quality of life weakest for “discomfort”, “sleeping”, and “discomfort and symptoms” [324]. Compared to the third trimester, women post-GDM tended to rate their quality of life better [326]. This can be explained by their normalization of blood sugar values. However, five subgroups of women post-GDM perceive a lower quality of life:

1) Depression postpartum [327]
2) Single mothers [324]
3) Lower socioeconomic status [328]
4) Obese [329]
5) Perceived fair or poor health, with more days of sick leave and more use of medication [330]

We compared these subgroups with the subgroups of the previous section (Chapter 2.1.2.1.3) and added the second (single mothers) and the fifth (perceived fair or poor health) retrospectively to the subgroups of women post-GDM (Supplementary Table 1, Part 3).

Regarding the long-term effects, the starting point for a reduced quality of life is moving from low to high risk – including a pre-diabetic state [331]. Metabolic disturbances and diseases impact all quality of life domains and most of their facets in varying degrees [332-335]. Overall, different quality of life measurement instruments with different domains and facets and dissimilar publications complicate meta-analytic conclusions across studies [336]. Disease-related quality of life factors interact with demographic [337, 338], psychosocial [335], and lifestyle factors [339, 340] that are often not controlled for [335].

We structured the empirical studies of long-term impacts of T2D and related cardiometabolic disturbances on quality of life with the four domain and 24 facet model by the World Health Organization (WHO) [341]. We highlighted the four domains by underlining and excluded those facets without evidence for T2D and related cardiometabolic disturbances (Supplementary Table 1, Part 4):

1. <u>Physical functioning</u> [342-344]
    - Pain and discomfort [332, 345-348]
    - Energy and fatigue [332, 342, 347, 349]
    - Sleep and rest [332, 350-354]
    - Mobility [334, 348, 355]
    - Activities of daily living [334, 347, 348, 356, 357]
    - Dependence on medication [334, 346, 358]
    - Working capacity [334, 340, 346, 359]
2. <u>Psychological functioning</u> [347]
    - Negative feelings/emotions [332, 334, 344, 346-348, 356, 360]
    - Cognitions (thinking, learning, memory, and concentration) [332, 347]

- Self-esteem [334]
- Body image [334]
- Spirituality/religion [361]
- Personal beliefs [334]

3. <u>Social functioning</u> [332, 334, 362]
    - Personal relations [363]
    - Practical social support [364-366]
    - Sex [334, 367]
4. <u>Environmental wellbeing</u> [368]
    - Home environment [334]
    - Financial resources [334, 359, 369]
    - Recreation and leisure, with the most severe effect on the facet "Freedom to eat as I wish" [334]

Several studies point to diabetic subgroups with lower quality of life perceptions:

- Demographic
    - Female gender, especially for physical and psychosocial functioning [344]
    - Obese [343, 370, 371]
    - Immigrant status [372]
- Disease-specific
    - Higher disease severity [346, 373]
    - Longer disease duration [374, 375]
    - Higher number and severity of disease-related complications [336, 370, 371, 376] – especially the presence of two or more complications [335] or comorbidities [340]; lowest ratings if both micro- and macrovascular complications [370]
    - Low glycemic control [348, 377]

The demographic diabetic subgroups stress the high vulnerability of women – the present priority population. Further, the obese subgroup shows a recurring pattern for a lower perceived quality of life and confirms our primary choice of BMI categories as subgroups in the logic model of the health problem.

2.1.2.2 *Describe cardiometabolic risk behaviors*

The term "risk behavior" in this project describes all behavior influencing cardiometabolic risk, including risk lowering behavior. The questions guiding our search on risk behaviors comprised: *"What are important risk behaviors linked to the development of T2D and related cardiometabolic disturbances (health problem) in terms of increased risk, incidence, prevalence, or burden?", "How do cardiometabolic risk behaviors vary for different subgroups (post-GDM)?", and "What are relevant behaviors for intervention?"*

The Intervention Mapping core processes helped us to select the most relevant risk behaviors (Supplementary Table 1, Part 5). We specified the following four criteria for our literature search:

1) A first search with women post-GDM (limited number of studies), followed by an extended search of studies with other adult populations that link risk behaviors to T2D and related cardiometabolic disturbances/diseases – including the MetS, CVD, coronary heart disease (CHD), stroke, and related mortalities

2) Screening of both observational studies and RCTs since relevant risk behaviors not only influence cardiometabolic disease risk directly, but also the four clusters of cardiometabolic risk factors specified above (Chapter 2.1.2.1.2):
    - (Abdominal/visceral) overweight or obesity (increased BMI, increased waist circumference, increased percent body fat/(visceral) fat mass)
    - Increased blood pressure (systolic or diastolic)
    - Dysglycemia (increased fasting glucose, increased two-hour glucose in oGTT, increased HbA1c, increased HOMA-IR)
    - Dyslipidemia (increased LDL-C, decreased HDL-C, increased triglycerides)
3) Focus on systematic reviews or meta-analyses since we aimed at a high level of evidence to account for possible biases of single studies, such as those in favor of industry sponsorship [378, 379]
4) Search risk behaviors in the following five behavioral domains: nutrition, physical activity, psychology, sleep, and other risk behavior

2.1.2.2.1 Nutritional risk behaviors

We found the highest number of cardiometabolic risk behaviors in the area of nutrition. Diet is composed of many single nutritional behaviors often influencing one another. The most important questions for nutrition behaviors in this chapter are: *"What?"*, *"How much?"*, and *"How often?"*. We clustered our answers into:

1) Healthy vs. unhealthy nutrition patterns
2) Macronutrient compositions and quality
3) Predominant choice of food groups
4) Positive vs. negative energy balance

2.1.2.2.1.1 Dietary patterns

An individual's diet can be categorized as "predominantly healthy" or "predominantly unhealthy" dependent on recurrent dietary patterns.

Unhealthy dietary patterns are based on "Western dietary choices", including high intakes of animal-derived and energy-dense highly processed food and low intakes of plant-derived non- to minimally processed food. "Western dietary choices" are based on convenience food, refined grains, canned fruits, red and processed meat, sugar sweetened beverages, high-fat dairy, spreads and sauces, alcoholic drinks, sweets, confectionary, and fried food [380-382]. Predominant unhealthy dietary choices were related to a higher risk for central obesity [383], the MetS [380], CVD/CHD/stroke [381, 384], and T2D [382, 385-387]. Unhealthy dietary patterns are further linked to a high sodium intake above the recommended 5 g per day due to large quantities of sodium in processed food. A high sodium intake was positively associated with obesity [388], hypertension [389], CVD [390], CVD deaths [391, 392]. Women post-GDM showed a lower nutrition quality compared to controls after a normoglycemic pregnancy [393].

In contrast, healthy or prudent dietary patterns are characterized by high intakes of nutrient-dense non-to minimally processed plant-based food. Healthy dietary patterns are based on fresh fruits and vegetables, whole grains, legumes, nuts, and seeds – and may be extended to limited amounts of oily fish, poultry, and low-fat dairy [380-382, 386]. Healthy dietary patterns were associated with a reduced risk for central obesity [383], the MetS [380], CVD/CHD/stroke [381, 384], and T2D [382, 385-387] and improved related biomarkers such as systolic or diastolic blood pressure [394].

Several predefined healthy dietary patterns have been studied in diverse at-risk populations. Public health authorities recommend these dietary patterns to reduce cardiometabolic risk globally. The patterns vary by geographical region or prevention purpose, but most share a focus on non-to minimally processed plant food. The variable factors include limited amounts of some animal-derived food groups such as low-fat dairy and limitations such as in total cholesterol, saturated fat, red and processed meat, added sugar, sweets, sugar-sweetened beverages, and salt. Most prominent are the following four predefined healthy dietary patterns:

1) Mediterranean diet [395]
2) "The Dietary Approaches to Stop Hypertension" [396]
3) The Healthy Eating Index or the Alternate Healthy Eating Index [386, 396]
4) Vegetarian or vegan diets [397, 398]

First, the Mediterranean diet was associated with a decreased risk for the MetS [399, 400], CVD/CHD [401, 402], T2D [386, 403-406], and improved related biomarkers such as HbA1c [404], HDL-C [404], triglycerides [398], and systolic and diastolic blood pressure [407]. These improvements make the Mediterranean diet the most effective dietary approach for reducing diabetic dyslipidemia [398] and fasting glucose [408]. Second, the Dietary Approaches to Stop Hypertension was associated with a reduced risk for CVD [396, 409], stroke [410], T2D [386, 396], and improved related biomarkers such as systolic and diastolic blood pressure [411], LDL-C [412], BMI [413], and waist circumference [413]. According to recent meta-analyses, the Dietary Approaches to Stop Hypertension was the most effective dietary approach for the reduction of blood pressure in pre-hypertensive and hypertensive individuals [414, 415]. Third, the Healthy Eating Index and the Alternate Healthy Eating Index were associated with a decreased risk for CVD [396], CVD mortality [416], and T2D [386]. Fourth, vegetarian or vegan diets were associated with a reduced risk for prediabetes [417], T2D [397, 418], CVD [419], and improved related biomarkers such as triglycerides [420], HbA1c [421], HOMA-IR [417], LDL-C [422], and HDL-C [422]. Vegan diets achieved greater weight loss in comparison to lacto-ovo-vegetarian diets [423], and lower BMI, waist circumference, LDL-C, triglycerides, fasting glucose, and systolic and diastolic blood pressure compared to omnivores [424]. The effects on blood pressure by normo-caloric vegan diets were comparable to those of energy-restricted diets and to diets recommended by medical societies [425].

Women post-GDM adhering to the alternate Mediterranean diet, the Dietary Approaches to Stop Hypertension, and the Alternate Healthy Eating Index showed a decreased risk for T2D [304] and less long-term weight gain [426].

2.1.2.2.1.2 Macronutrient composition and macronutrient quality

Healthy dietary patterns vary in their macronutrient composition. This reflects the contradicting conclusions of meta-analyses on recommended dietary proportions of fat, carbohydrates and proteins related to cardiometabolic risk. The discussion of superior cardiometabolic health benefits of specific macronutrient compositions for everybody remains controversial, including low carbohydrate diets [427-429], low fat diets [430-432], and high protein diets [404, 433-437]. Next to the diverse study designs, individual metabolic responsiveness to different nutritional measures might be responsible for inconclusive study outcomes. Nevertheless, the low-fat approach is most established in recommendations by public health authorities such as the American Diabetes Association [438] – albeit recently questioned [430]. The American Diabetes Association recommends a reduced total dietary fat intake of 30% of total energy intake or less, while keeping protein intake at approximately 15 to 20% and carbohydrate intake at approximately 50 to 60% of total daily energy intake for weight management [438]. Still, total energy intake (Chapter 2.1.2.3.1.4) and macronutrient quality are, in sum, more important for cardiometabolic health than quantities of the three macronutrients [439-442]. The importance of macronutrient quality is mirrored in the recommendations by public health authorities, as described in the following paragraphs.

First, complex carbohydrate intake high in dietary fiber lowered the risk for the MetS [443], CVD [444-446], and T2D [428, 447-451], and improved systolic blood pressure [440]. Thereby, cereal fiber appeared superior to fruit fiber [450] and to vegetable fiber [449, 452]. The greatest risk reductions occurred between 25 g and 29 g of daily fiber intake while dose-response curves suggested greater benefits for CVD and T2D for higher doses of dietary fiber [440]. Women post-GDM showed a higher daily fiber intake about three years after pregnancy compared to pre-pregnancy, yet below the recommended level [67].

Second, plant protein was favorable for human metabolism in comparison to animal protein, with protective effects for T2D [453-456] and improved cardiovascular biomarkers such as LDL-C [457]. Further, the HbA1c improved when replacing animal protein with plant protein in diabetic patients [458]. In contrast, high animal protein intake was associated with an increased risk for T2D [453-456].

Third, the quality of dietary fat depends on the proportion of the following five components (highlighted by underlining). Plant fat high in mono- and polyunsaturated fatty acids showed beneficial cardiometabolic effects overall [459, 460]. An increased polyunsaturated fatty acid intake was related to a decreased risk for T2D [442], CVD/CVD deaths [461, 462], stroke [462], and improved related biomarkers such as waist circumference [463], HbA1c [460], HOMA-IR [460, 464], and triglycerides [462]. The American Diabetes Association recommends a polyunsaturated fatty acid intake of approximately 10% of total daily energy intake [438]. An increased monounsaturated fatty acid intake was associated with improved cardiometabolic biomarkers such as HbA1c [460, 465], HOMA-IR [460], systolic and diastolic blood pressure [466], fasting glucose [467], triglycerides [467], and HDL-C [467]. Diets high in monounsaturated fatty acids were superior to diets high in polyunsaturated fatty acids in reducing fasting glucose [467] while diets high in polyunsaturated fatty acids were superior in improving insulin secretion capacity [460].

Further, most animal fat and related processed food contain high levels of saturated fatty acids, trans fatty acids, and cholesterol that harm cardiometabolic health. An increase in saturated fatty acid intake was associated with weight gain [468], CVD [469], and deteriorated related biomarkers such as LDL-C. Whether the negative cardiometabolic effects include plant sources of saturated fatty acids such as palm oil is still under debate [470-472]. The American Diabetes Association recommends to reduce daily intake of saturated fatty acids to less than 10% of total energy intake [438]. However, a recent review concluded that the effects of lowering dietary saturated fatty acids largely depend on the replacement [473]. Replacing saturated fatty acids with simple carbohydrates did not decrease CHD events or CVD mortality while replacing them with mono- or polyunsaturated fatty acids or complex carbohydrates lowered CVD events [473]. Further, convincing evidence demonstrated a positive association between trans fatty acid intake and an increased CVD risk [432, 473] and weight gain [468]. Especially industrial trans fatty acids were related to increased CHD and CHD mortality [474]. This is reflected in the guidelines of the American Diabetes Association to minimize trans fatty acid intake to less than 1% of daily total energy intake [438]. Lastly, a higher dietary cholesterol intake was associated with an increased T2D risk [475]. Women post-GDM with early postpartum prediabetes and diabetes consumed more animal fat when compared to the normal glucose tolerance group [476].

2.1.2.2.1.3 Predominant choice of food groups

Nutrition patterns and macronutrient compositions depend on the intake frequency and amount of the following eleven food groups (highlighted as underlined words) that will be discussed in more detail. For practical reasons, we screened the evidence on each food group related to cardiometabolic risk starting with plant-based food, followed by animal-based food, processed food, and beverages:

1) Whole grains vs. refined grains
2) Fruits and vegetables
3) Legumes
4) Nuts and seeds
5) Fish and seafood
6) Dairy
7) Eggs
8) Meat
9) (Ultra-) processed food
10) Beverages
11) Alcohol

A high whole grain intake was associated with a lower risk for weight gain [477], CVD [440, 478, 479], and T2D [440, 452, 480-482], and improved related biomarkers such as fasting glucose [477], and LDL-C [483]. Similarly, regular breakfast cereal consumption was associated with a decreased risk of overweight/obesity, CVD, T2D, and related biomarkers such as BMI [484]. Further, a meta-regression model showed a significant linear inverse association between each 10 g of whole grain ingredient consumed daily and an absolute reduction of 0.3% in T2D occurrence [485]. In contrast, refined grains were associated with an increased risk for overweight/obesity [486] and T2D [481, 487], and deteriorated related biomarkers such as LDL-C [483]. According to a systematic analysis on health effects of dietary risks for the Global Burden of Disease Study in 2017, low whole grain intake ranks second in both attributable global deaths and the number of attributable disability-adjusted life years, mainly due to CVD and T2D [21]. An Australian study showed insufficient intakes of whole grain products by women post-GDM [488].

A high fruit, vegetable, or combined fruit and vegetable intake was associated with a lower risk for adiposity and weight gain [486, 489-491], the MetS [492], CVD [493], T2D [494-496], and improved related biomarkers such as triglycerides [497]. Two servings of fruit per day and two to three servings of vegetable per day lowered T2D risk the most compared to other levels of fruit and vegetable intake [494]. Further, green leafy vegetables were associated with lower risks for CVD [493] and T2D [498]. Women post-GDM showed suboptimal fruit and vegetable intakes, with proportions between five to 33% reaching the recommendations [56, 330, 499-501]. In an Australian study with women post-GDM, 38% consumed less than one serving of vegetables per day [56]. In addition, a US study found lower intakes of green leafy vegetables in women post-GDM compared to those without a history of GDM [393].

A high legume intake was associated with protective effects for overweight/obesity [486], CVD/related mortality [502-504], and improved related biomarkers such as LDL-C [505, 506], HDL-C [505], triglycerides [505], blood pressure [507], fasting glucose [508], and HbA1c [508]. A recent network meta-analysis investigating the association between food groups and intermediate cardiometabolic disease markers identified legumes as second best food group for reducing triglycerides [483]. Regarding women post-GDM, a US study showed insufficient intakes of beans in women post-GDM when compared to those without a history of GDM [393].

A high nuts and/or seeds intake was associated with a lower risk for overweight/obesity [509], abdominal obesity [486], hypertension [510], the MetS [509, 511], CVD [479, 504, 512-514], T2D [504], related mortalities [515-517], and improved associated biomarkers such as BMI [509], waist circumference [509], blood pressure [392], LDL-C [518], triglycerides [518], fasting glucose [519], HbA1c [520], HOMA-IR [521], and fasting insulin [521]. In a recent network meta-analysis investigating the association between food groups and intermediate cardiometabolic disease markers, nuts were identified as best food group for reducing LDL-C and second best for reducing triglycerides [483].

A higher total fish and/or seafood intake was associated with a decreased risk for abdominal obesity [486], CHD [479], and stroke [479] and improved related biomarkers such as waist circumference [463]. In a recent network meta-analysis investigating the association between food groups and intermediate disease markers, fish was identified as best food group for reducing triglycerides [483]. Further, a higher intake of oily fish and seafood omega-3 fatty acids was associated with a decreased risk for T2D [522, 523], CVD [517], and improved related biomarkers such as triglycerides [524] and HDL-C [524].

Meta-analyses on dairy intake and cardiometabolic risk remain controversial, including the subgroups of low-fat dairy products and high-fat dairy products. In some meta-analyses, a higher dairy intake was associated with a lower cardiometabolic risk [454, 525-527], in others with a higher cardiometabolic risk [528, 529], and yet in others with no cardiometabolic effects [479, 486, 530]. Some meta-analyses showed the subgroup of low-fat dairy products was inversely associated with T2D risk [525-527], and improved related biomarkers such as blood pressure [531]. The evidence was considered sufficient to include low-fat dairy e.g. in the Dietary Approaches to Stop Hypertension in CVD prevention [409].

Meta-analyses on egg intake and cardiometabolic risk remain controversial: A recent umbrella review of meta-analyses found no association between a higher egg intake and cardiometabolic disorders [532]. Yet, other recent meta-analyses not included in this review associated increased egg consumption with an increased risk for heart failure [479] and deteriorated biomarkers such as LDL-C [533] while egg substitutes were associated with lower LDL-C [534].

A higher total meat intake was associated with a higher risk for hypertension [535] and T2D [536, 537]. However, the associated risks varied per type of meat and processing, with the highest risks for processed and red meat [535, 537]. An increased red meat intake was associated with weight gain [486], abdominal obesity [486], hypertension [528], CHD/stroke/heart failure [479], CVD mortality [538], T2D [536, 537, 539], and deteriorated related biomarkers such as BMI [401], and fasting glucose [540]. In line with these findings, heme iron intake was associated with T2D [541].

Regarding (ultra-) processed food intake, the three subgroups of processed meat, fried food and food with added sugar are most decisive for cardiometabolic health. First, a higher processed meat intake was associated with a higher risk for obesity [542], hypertension [528, 535], CHD/stroke/heart failure [479], CVD mortality [538], T2D [385, 452, 454, 536, 537, 543], and deteriorated related biomarkers such as fasting glucose [540]. Second, a higher fried food intake was associated with a higher risk for T2D [382, 544] and coronary artery disease [544]. Regarding women post-GDM, an Australian study found that about one quarter of the women consumed fried food at least twice per week [56]. Further, a higher fried food intake was related to an increased risk for substantial postpartum weight retention in women post-GDM [545]. Third, a higher added sugar intake was associated with a higher risk for obesity [546], the MetS [547], CVD mortality [548], T2D [549], and deteriorated related biomarkers such as ectopic fat [550], blood pressure [551], triglycerides [551], and LDL-C [551]. Public health authorities such as the World Health Organization and the American Heart Association recommend a daily limit of added sugar of less than 10% – preferably less than 5% – of total energy intake [552, 553].

A study among women with GDM found that 77% consumed processed food and 97% ultra-processed food on a daily basis in the second and third trimester of their pregnancy [554]. Ultra-processed food was associated with excess energy intake leading to weight gain [555], and processed food addiction [556] in adult populations. The more severe the processed food addiction, the higher the BMI [557] and depression, anxiety, and stress [556] in people with T2D. In addition, processed food addiction was related to eating disorders such as binge eating disorder, also associated with an increased risk for T2D [558].

Regarding beverage intake, the seven categories of sugar sweetened beverages, artificially sweetened beverages, fruit juice, coffee, tea, water, and alcohol are most decisive for cardiometabolic health. First, a higher intake of sugar sweetened beverages was associated with a higher risk for overweight/obesity [486, 559-561], hypertension [528, 562, 563], the MetS [564], CVD/CHD/stroke [479, 483, 565], T2D [385, 392, 452, 566, 567], and deteriorated related biomarkers such as fasting glucose [568], and HbA1c [569]. Similarly, nutritively sweetened beverages were associated with weight gain [570]. Regarding women post-GDM, a higher soda intake was associated with substantial postpartum weight retention [545]. Second, a higher intake of artificially sweetened beverages was associated with an increased risk for obesity [560], hypertension [562], the MetS [564], CVD [565], and possibly also T2D [566]. Third, a higher intake of fruit juice was associated with a higher risk for weight gain [561] and T2D [495, 566, 571]. The data on 100% fruit juice and T2D risk was less conclusive than the data on fruit juice with added sugar [572]. Fourth, a higher intake of coffee was associated with a lower risk for weight gain [561, 573], obesity [574], hypertension [575, 576], the MetS [574, 577], and T2D [574, 578, 579]. The association with CVD risk was a U-shaped curve [580]. Fifth, tea intake was inversely related to hypertension [581], the MetS [577], CVD [582], T2D [583], and improved related biomarkers such as LDL-C [584-587]. Most meta-analyses on tea and cardiometabolic risk investigated green tea only. Sixth, a higher water intake was associated with a lower risk for weight gain [561, 588], and possibly for T2D [589].

Further, meta-analyses on alcohol intake and cardiometabolic risk remain controversial. Some meta-analyses show a risk lowering effect of light to moderate alcohol intake for T2D in comparison to no or very low intakes [452, 590-592]. Thereby, the best associated risk reduction for T2D occurred for 10-14 g per day [591]. The protective effects were higher for females compared to males, including CVD risk [593]. Evidence related to blood pressure remained inconclusive due to different short- and long-term effects of alcohol on blood pressure [594]. Regarding women post-GDM, an Australian study indicated a high alcohol consumption [488]. Alcohol intake ranked seventh among leading risk factors for both disability-adjusted life years and deaths in a systematic review of the Global Burden of Disease Study in 2016 [595]. The authors concluded that consuming zero alcohol minimized overall health loss [595]. This is in line with the findings that alcohol consumption triggers other risk behaviors such as an increased energy intake [596]. Hence, no to minimum alcohol consumption seems the best strategy to promote health, including the health of women post-GDM.

Overall, the high number of possible confounders complicates studying the effects of a single food group on cardiometabolic risk. This led to a predominant very low to low quality of studies and to reviews or meta-analyses with contradicting results. A recent umbrella review and meta-analysis on dietary factors and incident T2D classified the risk lowering evidence as convincing for an increased intake of whole grains, cereal fiber and a moderate intake of alcohol – while the risk enhancing evidence was graded as convincing for a higher intake of red meat, processed meat, bacon, and sugar sweetened beverages [452]. Further, a recent network meta-analysis pointed to an increased nut, legume, and whole grain intake as most effective for improving intermediate cardiometabolic disease markers compared to other food groups [483]. The bottom line is that smaller effects by single food groups add up to dietary patterns that change individual cardiometabolic risk, with some food groups having a higher impact than others. This is in line with an umbrella review on risk factors for T2D stressing that a change in multiple food groups was essential [385]. The strongest evidence on cardiometabolic risk seems in favor of non- to minimally processed plant food and calls for a reduction of animal-derived and processed food products or beverages.

2.1.2.2.1.4 Caloric energy imbalances

Energy imbalances result from either a higher caloric intake compared to caloric expenditure (positive energy balance) or a lower caloric intake compared to caloric expenditure (negative energy balance). Energy imbalances for longer periods result into either weight gain or weight loss. If alternated frequently, the resulting unstable body weight may contribute to a higher risk for T2D [597].

A positive energy balance was associated with weight gain and a higher risk for obesity [598, 599], CVD [310], and T2D [597, 598]. Weight gain was classified as the strongest predictor for T2D [243]. A higher energy intake was partly attributed to a greater intake of energy-dense food and a higher food cue reactivity [600]. Both were, in turn, associated with obesity [600-602]. Two studies found that women post-GDM increased their caloric intake, weight, and BMI [67, 476], which contributed to a higher pre-diabetes and diabetes risk [476]. Each 5 kg increment in body weight post-GDM was associated with a 27% higher risk of T2D [603]. The T2D risk related to weight gain further increased for women with a baseline BMI of more than 30 kg/m^2 [603]. BMI change post-GDM was found to be an independent predictor for the development of T2D [307].

In contrast, longer periods of energy restriction were associated with weight loss [604] and improvements in biomarkers such as fasting glucose [605], triglycerides [605], and blood pressure [605, 606]. The sub-form of intermittent energy restriction was associated with weight loss [607-612], a lower risk for CVD [613], T2D [613], and improved related biomarkers such as BMI [608], body fat mass [608, 609], waist circumference [608, 609], HOMA-IR [608], LDL-C [611], and triglycerides [611]. The cardiometabolic effects of intermittent energy restriction regimens were comparable to continuous energy restriction [607-612, 614]. Further, weight loss was associated with a decreased risk for T2D [605, 615] and CVD [605]. The larger the weight loss, the larger the improvements in relevant biomarkers [605, 606]. Women post-GDM with a modest weight loss of about 2 kg between six weeks and 12 months postpartum showed improved biomarkers such as fasting glucose, and both glucose and insulin at two hours in oGTT [616]. Further, weight loss post-GDM was associated with a decreased risk for T2D [40].

2.1.2.2.2 Physical activity risk behaviors

The three most relevant physical activity behaviors related to cardiometabolic risk are sedentary/physical inactivity, physical activity, and exercise. For this project, we investigated the exercise forms endurance training, resistance training, and high intensity interval training.

2.1.2.2.2.1 Sedentary behaviors and physical inactivity

Sedentary behavior and physical inactivity were associated with hypertension [617], the MetS [618], CVD [619-621] and related mortality [622-624], T2D [243, 621-624], and deteriorated related biomarkers such as waist circumference [625, 626], blood pressure [627], triglycerides [618, 626], fasting glucose [626], and HDL-C [626] – mostly with a dose-response relationship. Sedentary behaviors further reduced energy expenditure in comparison to standing behaviors [628]. As a subcategory of sedentary behavior, a higher television viewing time was associated with a higher risk for the MetS [618], T2D [629], CVD [630], CVD mortality [623], and deteriorated related biomarkers such as HDL-C [618] and fasting glucose in women [618]. In line with these findings, a recent umbrella review on the risk factors for T2D classified the evidence as convincing for the associations of a high sedentary time, duration of television watching, and decreased physical activity with an increased T2D risk [385]. Breaks in longer sedentary times may improve overweight/obesity and cardiometabolic health [631]. Regarding women post-GDM, more than one quarter was classified as sedentary in an Australian study [55] and about one third did not engage in any leisure time physical activity in a US study [305]. These long sedentary times in women post-GDM increased their risk for T2D [629, 632].

2.1.2.2.2.2 Physical activity

A higher physical activity was associated with a lower risk for genetically predisposed obesity [633], the MetS [634, 635], CVD [636-638], CVD mortality [639], T2D [640], and improved related biomarkers such as BMI, percent body fat, blood pressure, and fasting glucose [641] – with established dose-response relationships [639, 640, 642]. An increased step count was inversely associated with blood pressure [643]. A high physical activity reduced diabetes risk by 28% when compared to insufficient physical activity, with most health gains at medium activity levels of about 3,000 - 4,000 metabolic equivalent minutes per week [642].

Next to the frequency and duration, the intensity of physical activity matters: Replacing sedentary time with light intensity physical activity was associated with improved biomarkers such as waist circumference, fasting insulin, and HDL-C, while its replacement with moderate to vigorous intensity physical activity increased the magnitude in those changes and added beneficial effects on BMI and fasting glucose [644]. Similarly, replacing one sedentary hour with moderate to vigorous physical activity led to greater cumulative energy expenditure than three to five hours of low intensity physical activity [645].

Regarding women post-GDM, about one third met the international physical activity recommendations of at least 150 minutes of moderate or at least 60 minutes of vigorous physical activity per week [55, 501, 646]. Approximately the same proportion engaged in any health-enhancing physical activity [330, 647]. An Australian study in a rural setting found an almost double proportion engaging in recommended physical activity levels [306]. This might reflect the differences in lifestyle between rural and urban areas. Physical activity was decreased on average 1.4 years post-GDM compared to pre-pregnancy [67]. Compared to women without a history of GDM, less women post-GDM engaged in moderate to high intensity physical activity [500]. A US study found a dose-response relationship with every 100 minutes per week of moderate-intensity physical activity post-GDM linked to a 9% lower risk of T2D [629]. Two other studies supported an inverse association between physical activity and the risk for T2D post-GDM [40, 646] – albeit the second only for women without abdominal obesity [646].

2.1.2.2.2.3 Exercise

Exercise was inversely related to the risk for (visceral) adiposity [648, 649], the MetS [650], and improved related biomarkers such as body fat mass [651], waist circumference [652], systolic blood pressure [652], LDL-C [651], HDL-C [653], triglycerides [652, 653], HbA1c [652-654], and HOMA-IR [653]. Improvements in most biomarkers were similar between continuous and accumulated exercise – except for greater reductions in LDL-C and percent body fat when accumulated [651]. In their joint position statement, the American College of Sports Medicine and the American Diabetes Association stress the importance of sufficient exercise of at least 150 minutes per week of moderate to vigorous intensity in the prevention, delay, and treatment of T2D [655]. Women post-GDM tended to exercise at lower intensities compared to women without a history of GDM [330].

All three explored exercise forms (endurance, resistance, high intensity interval training) improve cardiometabolic health. Endurance training was inversely associated with the risk for visceral adiposity [648], the MetS [656] and improved related biomarkers such as waist circumference [656], blood pressure [656-658], HbA1c [659, 660], and HDL-C [656], especially in higher exercise intensities [659] and in volume-intensity progressions [660]. Similarly, cardiorespiratory fitness was inversely associated with the risk for T2D [661]. Further, resistance training was inversely related to the risk for diabetes complications [662] and improved related biomarkers such as body fat mass [663], blood pressure [657, 658, 663], HbA1c [654, 663], LDL-C [664], and triglycerides [664]. Similarly, muscular strength was inversely associated with the risk for T2D [661]. Lastly, high intensity interval training was inversely related to the risk for hypertension [665] and improved biomarkers such as waist circumference [666, 667], percent body fat [649, 666-668], abdominal and visceral fat mass [669], blood pressure [665, 666], fasting glucose [670], HbA1c [670], and HOMA-IR [671], with most effects in overweight and obese subjects at-risk for T2D [666, 667, 670-672]. Thereby, running showed greater effectiveness in body fat mass reductions compared to cycling [669]. Regarding differences between high intensity interval training and moderate intensity continuous training, both training modalities showed similar cardiometabolic effects [649, 665, 667, 673]. However, high intensity interval training achieved higher improvements in HbA1c [670], HOMA-IR [674], night-time diastolic blood pressure [675], and absolute fat mass reductions [668] compared to moderate-intensity continuous training.

2.1.2.2.3 Psychology, psychosocial behaviors and sleep

We summarized the psychology and psychosocial behaviors related to cardiometabolic health as stress management behaviors – next to the category of sleep hygiene.

2.1.2.2.3.1 Stress management

Pessimistic thinking, low emotional processing, and negative emotions nurture perceived stress and increase cardiometabolic risk. A pessimistic thinking style was related to a deteriorated HOMA-IR [676]. Further, low emotional processing was associated with obesity [677]. Negative emotions and negative/depressive affect were positively associated with a higher risk for CVD [678, 679], and deteriorated mean glucose, percent hyperglycemia, and percent out-of-range glucose measured by continuous glucose monitoring [680]. In addition, high perceived (psychosocial) stress was positively associated with the risk for visceral obesity [681], hypertension [682], the MetS [683], CHD [684], stroke [685], T2D [686], and related biomarkers such as BMI, waist circumference, triglycerides, HDL-C, and diastolic blood pressure [681]. Thereby, perceived occupational stress increased the risk for the MetS more than perceived general stress [683]. Job strain was further associated with an increased risk for the MetS [687], recurrent CHD events [688], and T2D [689].

In contrast, optimistic thinking, enhanced problem solving, and positive emotions reduce perceived stress and decrease cardiometabolic risk. An optimistic thinking style was related to a lower risk for cardiovascular events [690-692], CVD mortality [693, 694], T2D-complications/mortality [78], and improved biomarkers such as BMI [695], HbA1c [78], HDL-C [696], and triglycerides [696]. This might partly be explained by healthier cardiometabolic behavior due to optimism [695, 697, 698]. Further, enhanced problem solving was associated with improved HbA1c [699]. Next, positive emotions were inversely associated with the risk for hypertension [700], CVD [701-703] CVD mortality [704], T2D [705], T2D mortality [706], and improved related biomarkers such as blood pressure [707], and stabilized blood glucose with less hypoglycemia measured by continuous glucose monitoring [680]. Positive emotions were further related to enhanced health behaviors in CVD [698, 708-710] and T2D [711], and to less rehospitalizations after implantation of coronary-artery stents [712].

Moreover, several behaviors for stress management were associated with a lower cardiometabolic risk. Mindfulness-based stress reduction, meditation, and progressive muscle relaxation were associated with lower blood pressure [713-715], triglycerides [714], and may improve HbA1c [716]. Similarly, regular enjoyable leisure activities were associated with improved biomarkers such as BMI, waist circumference, and blood pressure [717], while resilience resources were inversely associated with HbA1c [718]. Further, mind-body exercises like yoga practice were associated with improved cardiometabolic biomarkers such as BMI [719, 720], blood pressure [715, 719-722], fasting glucose [719, 722, 723], HbA1c [719, 723], triglycerides [720, 721, 723], HDL-C [720, 721, 723], and LDL-C [720-723]. Yoga was as effective as exercise for cardiometabolic improvements [720].

2.1.2.2.3.2 Sleep hygiene

A poor sleep quality was associated with a higher risk for hypertension [724], CHD [725], T2D [726], and deteriorated related biomarkers such as blood pressure [724], and HbA1c [23]. Health behaviors associated with an improved sleep quality included mindfulness meditation [727], exercise [728-730], stress management [729], relaxation practice [729], sleep hygiene [729], stimulus control [729], and aromatherapy [731].

Similarly, sleep duration was inversely associated with obesity [732-734], hypertension [732, 735], the MetS [736], CVD [732], CVD mortality [737], T2D [726, 732, 738, 739], and related biomarkers such as waist circumference [740], and HbA1c [23], and insulin sensitivity [741]. Most associations were U-shaped with optimal sleep durations between seven to eight hours [734, 736, 737].

2.1.2.2.4 Other risk behaviors excluded from this project

We considered a number of other relevant risk behaviors during the brainstorming and in the literature review. The most important ones were the following three: breastfeeding, smoking, and shift work. Breastfeeding and its duration were inversely linked to the risk for overweight/obesity [742], T2D [316, 742], and may improve related biomarkers such as HOMA-IR post-GDM [743]. Further, smoking was positively associated with the risk for the MetS [744], and T2D [243, 745, 746] in a dose-response relationship with heavier smokers being at greater risk [744]. Lastly, irregular bedtime patterns such as in rotational shift work were associated with an increased risk for hypertension [747], the MetS [687], CVD [748], CHD mortality [748], and T2D [749, 750], and deteriorated related biomarkers such as HbA1c [751] – with a dose-response relationship depending on frequency [749] and duration [748, 750].

2.1.2.2.5 Behavioral subgroups post-GDM

A literature review in 2013 found that few women post-GDM adhered to preventive health behaviors, with differences between lifestyle behaviors [17] and subgroups. While some women post-GDM made an effort to eat healthily, exercise, and participate in diabetes screening, others reported to binge eat, be physically inactive, and avoid contact with diabetes-related healthcare practitioners [752]. A healthy lifestyle post-GDM was mainly driven by planning another pregnancy or by desiring weight loss [753]. A Swedish study demonstrated origin-related differences in self-care practice post-GDM with less health activities in women born in the Middle East compared to Swedish-born women [16].

2.1.2.3 *Describe personal determinants for cardiometabolic risk behaviors*

The questions guiding the Intervention Mapping core processes on personal determinants of risk behaviors include: *"Why would women post-GDM (priority population) perform cardiometabolic risk behaviors?", "What theory- and evidence-based factors are (causally) related to cardiometabolic risk behaviors?", and "Why would different subgroups of women post-GDM behave differently?"*

The Intervention Mapping core processes guided the identification of personal determinants for cardiometabolic risk behaviors post-GDM (Supplementary Table 1, Part 6). We limited our empirical literature search to women post-GDM to grant high specificity for the determinants for risk behavior. For practical reasons, we structured these determinants primarily according to the key theoretical constructs of personal determinants of behavior [116]. Most of the theoretical constructs carry different labels in different theories or in the empirical literature while describing the same or a similar concept (the respective term used in the following chapters of this thesis is underlined) [138]:

1) <u>Habits</u>, automatic behavior, conditioned behavior, subconscious behavior, impulsive behavior, past behavior based on context cues
2) <u>Commitment</u>, strong positive intention, motivation, willingness, goal-orientation
3) <u>Behavioral knowledge</u>, behavioral awareness, health literacy, behavioral consciousness, elaboration
4) <u>Perceived risk</u>, susceptibility, vulnerability, severity
5) <u>Perceived barriers</u>, environmental constraints, exposures, temptations
6) <u>(Perceived) skills</u>, abilities, capabilities
7) <u>Perceived self-efficacy</u>, response efficacy, behavioral or stimulus control, behavioral confidence, behavioral competence
8) Weighted (advantages minus disadvantages) <u>outcome expectations and attitudes</u>, value expectancies, behavioral beliefs
9) <u>Perceived social norms</u>, peer pressure, normative beliefs, relatedness (including social support and cultural norms)
10) <u>Self-image</u>, personal or subjective norms, personal standards, identity
11) <u>Emotional reaction to behavior</u>, emotions, moods, emotional control

In line with habit theory, a behavior itself may act as determinant or cue for other behaviors – particularly in the nutrition-physical activity-psychology triangle. Mindfulness training was associated with less binge eating or impulsive eating and with more physical activity [754]. Similarly, regular exercising was associated with increased self-regulation for nutrition [166], better sleep [34], and positive psychological patterns [32, 755-757]. In contrast, other behaviors determined an increased energy intake, such as alcohol consumption [596], high food cue reactivity [600, 758], big servings [759], emotional eating [760, 761], distracted eating [762], and partial sleep deprivation [25, 763]. Therefore, health promoters must know and target individual habits – not only as behavioral outcome, but also as behavioral determinant. Further, most of the personal determinants for behavior are habitual, including perceptions, thinking style, self-image, and emotions. Thus, we considered habit formation the most important determinant for this project to change both personal determinants for cardiometabolic risk behaviors and the risk behaviors themselves.

Determinants for health behavior post-GDM were similar across different lifestyle areas, with some studies providing insights specific to one lifestyle area or behavior [764], as described in the following subsections on each determinant.

2.1.2.3.1 Habits

The first determinant is <u>habits</u>, automatic, conditioned, subconscious, impulsive, or past behavior based on context cues. Most women post-GDM struggled with making physical activity [765] or a healthy nutrition [151, 765] habitual in the daily routine. At the same time, physical activity was more likely when it used to be or became a habit [57, 766]. Related habits such as life-scheduling [752] or meal planning [767] were associated with better compliance to health behaviors. Women post-GDM were not only affected by their own daily habits, but also their family's – especially for eating habits [56]. Most women post-GDM who felt a conflict between dietary advice and family eating habits did not adhere to a healthy diet [752].

2.1.2.3.2 Commitment to behavior

The second determinant for behavior is commitment, strong positive intention, motivation or willingness to perform the behavior with clear goals in mind. Most women post-GDM were in the preparation stages for both physical activity and weight loss – especially women with a high BMI, with two children or more, and without a paid job [306]. A subgroup of women saw their children as key motivator for behavior change – both to serve as a role model and to stay healthy as a caring parent [768]. Intention determined planning and was associated with enhanced physical activity in women post-GDM [769]. In contrast, low motivation or a lack of commitment interfered with health behavior in women post-GDM [768], including weight management [65], healthy nutrition [19], and physical activity [57]. However, a high motivation was not always associated with higher health actions in women post-GDM [770].

2.1.2.3.3 Behavioral knowledge

The third determinant is behavioral knowledge and awareness, health literacy, behavioral consciousness, and elaboration regarding behavioral risks. Knowledge on how health behaviors impact T2D risk highly varied between women post-GDM [752, 764]. Many women post-GDM did not know how and to what extent they were in control in preventing or delaying cardiometabolic disturbances [771]. Formal education helped to increase awareness [772]. Most women post-GDM were aware of the need to take steps to prevent T2D including diet, exercise, and weight control behaviors [19].

The following knowledge or awareness factors may hinder health behavior in women post-GDM:

1) Reliance on information from relatives' diabetes experience, the cultural environment [752, 764], and postpartum myths or traditions [773, 774], especially if medical advice contradicts family advice [752]
2) Misleading information, including information by healthcare practitioners [16, 753, 775]
3) Inconsistent advice on follow-up testing, diet, and weight loss [776]
4) A lack of high-quality information from trusted and evidence-based sources with actionable steps after delivery in the immediate and long-term postpartum period [753, 764, 765, 777, 778]
5) Diminished awareness for healthy eating, portion size, and exercise post-GDM compared to during GDM [753], requiring repeated information [778]

Simply recalling advice on nutrition or physical activity was not associated with health behavior [501]. However, the right timing and availability of free information affected behavior [753].

Regarding nutrition, women post-GDM lacked behavioral knowledge of:

1) Social healthy eating [19]
2) The optimal mother-child diet [753]
3) Simple actionable nutrition rules for daily life [57, 765], with cultural adaptations [765]

Further, women post-GDM lacked behavioral knowledge for the relation between physical activity and T2D prevention [779].

2.1.2.3.4 Perceived risk

The fourth determinant for behavior is perceived risk, susceptibility, vulnerability, or severity. Different perceptions of cardiometabolic risk or risk behaviors led to different up to contrary behaviors post-GDM [17]. A high perceived risk for T2D promoted health behaviors in some women post-GDM while others reacted with avoidance behaviors [752].

The following factors associated to perceived risk may **decrease** health behavior in women post-GDM:

1) Risk attribution to the far future [764]
2) Optimistic bias [303], especially in ethnic minorities [16, 780]
3) Less perceived risk for T2D over time after delivery [764, 768, 781]

The following factors associated to perceived risk may **increase** health behavior in women post-GDM:

1) Perceived moderate to high personal risk [15]; those with a BMI higher than 25, a family history with diabetes, and insulin during pregnancy were more likely to perceive their risk as high [782]
2) Perceived strong link between GDM and T2D as cue to action [768] for long-term personal and familial health changes [783]
3) T2D and GDM perceived as severe conditions to be avoided in the future [19, 768]

For some women post-GDM, however, a higher perceived risk determined an increased willingness, but not an increased ability for necessary actions [764].

2.1.2.3.5 Perceived barriers to behavior

The fifth determinant for behavior is perceived barriers, environmental constraints, perceived exposures, or temptations that may interfere with behavior. Perceived barriers were associated with a lower adherence to a healthy lifestyle post-GDM [784]. In comparison to controls, more women post-GDM perceived barriers to health behaviors [17]. The most frequently perceived barriers to health behavior by women post-GDM were the following six:

1) Physical constraints or low ratings of own or children's health [330, 499, 785], repeated sick leave and medication use [330], increased GDM-related maternal morbidity or neonatal child morbidity [786]
2) Perceived lack of resources to manage family life, household chores and paid work [752, 764, 784], especially when work added opportunities for unhealthy behavior and competed with family life and health behavior [57]
3) Biased perceptions that a healthy lifestyle was more expensive than an unhealthy one [764] – especially when resources were limited such as for immigrant women and women living in developing countries [753, 773]
4) Psychological postpartum constraints and emotional barriers such as feelings of selfishness and guilt for having had GDM [765], or adverse migrant experiences [64]
5) Lack of childcare support [766], lack of trust in non-familial caregivers for children, or concern for overburdening relatives [768]
6) Low accessibility, affordability, and practicality of lifestyle interventions [54]

In sum, these barriers were not perceived for the unhealthy options, making them the easy and more convenient repeated choice in daily life.

Some other barriers were specific to one lifestyle area. Regarding healthy nutrition behaviors post-GDM, perceived barriers included:

1) Breastfeeding that interfered with appetite regulation [752, 753] via increased hunger and food cravings [764]
2) Challenging situations during social eating [771]
3) Unhealthy personal or child food preferences [19, 57]
4) Availability of unhealthy foods and low-cost convenience food [19, 57]
5) Being accompanied by children during grocery shopping [57]

Perceived barriers for physical activity were more pronounced than for nutrition for the following reasons:

1) Requires additional time apart from the prioritized family life and parenting demands [764, 779, 787]
2) Physical problems related to pregnancy, delivery or the postpartum period tended to have a strong effect on physical activity behaviors [752]
3) Perceived tiredness or laziness [765]
4) Concerns about safety [774]
5) Insufficient options for group physical activity sessions with other women post-GDM [57]

2.1.2.3.6 (Perceived) behavioral skills

The sixth determinant for behavior is perceived and actual behavioral <u>skills</u>, abilities, or capabilities. A deficit in either behavioral lifestyle skills or in skills to overcome behavioral barriers interferes with health behavior. Most skills to overcome barriers are psychological skills necessary for long-term health behavior change. These skills include prioritization, changing perspective, optimistic thinking, controlling emotions, self-regulation of behaviors, goal-setting, solving problems, self-efficacy, daily/weekly planning, and new habit formation. Women post-GDM who prioritized and planned how to overcome barriers were more likely to attend a diabetes prevention program [788]. However, most women post-GDM considered their capacities for making plans, preparing for them, and ultimately executing them as limited in daily life [764, 789].

Some women lacked specific skills related to nutrition such as planning and cooking healthy meals [56, 771] or certainty about what to eat [19]. Similarly, immigrant women struggled with recommended unfamiliar food types and their preparation [787].

2.1.2.3.7 Perceived behavioral self-efficacy

The seventh determinant is <u>perceived self-efficacy</u>, response efficacy, behavioral or stimulus control, confidence, and competence. Self-efficacy is the capability to perform the behavior under a number of different circumstances [116]. Self-efficacy was associated with health behaviors in women post-GDM [17], including physical activity [55, 647, 790], a healthy diet, and appetite regulation [647, 790]. Action self-efficacy predicted the intention for physical activity [769]. However, women post-GDM reported low self-efficacy for health behaviors in CVD prevention [771]. Knowledge about risk behaviors did not translate to a higher self-efficacy to avoid them [15, 770]. This reflects the knowledge-behavior gap in women post-GDM [303, 306]. Insufficient self-efficacy to deal with barriers to action contribute to this gap [19].

Regarding nutrition, behavioral control in women post-GDM was low in social settings, especially when involving cultural components [771]. In contrast, vegetable consumption was positively associated with self-efficacy [56].

2.1.2.3.8 Behavioral outcome expectations and attitudes

The eighth determinant for behavior is positive outcome expectations (the advantages of performing the behavior outweigh the disadvantages) and attitudes, including value expectancies, and behavioral beliefs. Women post-GDM adhering to health behaviors had a higher outcome expectancy [788]. In contrast, women with the following negative behavioral outcome expectations, beliefs or attitudes were less likely to perform recommended health behaviors:

1) Beliefs about predominant heredity regarding both CVD and T2D following GDM [771, 774, 779] or comparative optimism to experience adverse effects or T2D less likely than others [17]
2) Negative outcome expectancies for family life [764]
3) Belief that a health behavior is inferior to the respective unhealthy behavior regarding time [55, 57, 779, 791], energy and finances [57, 792], and that lead to the choice of using the car instead of active transportation or convenience food instead of healthy cooking [764]
4) Discouraged attitude to health behavior because of omnipresence of diabetes in a family or cultural setting [752]
5) Different attitudes or outcome expectations than healthcare practitioners [781]

Regarding nutrition behaviors, traditional and religious beliefs such as avoidance or restriction of certain food groups postpartum overruled science-based knowledge for behavior [773]. Regarding physical activity behaviors, some women post-GDM considered it ‘inappropriate’ to think about exercising while caring for a small child [764]. In contrast, the number of perceived exercise advantages was positively associated with women’s exercise behavior post-GDM and weight control ranked highest among the perceived advantages [791]. Comparing outcome expectations of nutrition and physical activity, many women post-GDM perceived nutrition as more important for health outcomes than physical activity [774, 779].

2.1.2.3.9 Perceived social norms for behavior

The ninth determinant is perceived social norms, normative or peer pressure, normative beliefs, or relatedness, including social support and cultural norms to perform the behavior. The following of these factors hindered health behavior in women post-GDM:

1) Less social support [17, 784], with individual variations in the need for social and professional support [19]
2) Negative relationships with healthcare practitioners or a lack of follow-up support [752]; follow-up support was seen as weak, uncoordinated, and fragmented post-GDM [753], and associated with feelings of abandonment after the intensive antenatal GDM management [19]
3) Unsupportive husbands/partners, family members, friends or colleagues [17, 752], pressure towards unhealthy behaviors [752, 764] – especially when anchored in culture [753]; low participation of immigrant women’s partners in GDM-related health education so that partners were unaware and unsupportive of health behaviors post-GDM [753]
4) Authority figures promoting feelings of uncertainty and failure [793]
5) Cultural or religious beliefs and postpartum traditions in the immediate social circle such as considering a mother’s health secondary after child birth [773], strong role perceptions and perceived cultural expectations [64], cultural hospitality [64] – with the effects depending on the cultural importance of family, social ties, and cultural values [794]

6) Cardiometabolic disturbances perceived as social norm [752]

In contrast, social support by family and friends was associated with a better diet [790], enhanced physical activity [647], and weight management behaviors [65].

Regarding nutrition, the following psychosocial factors hindered health behavior in women post-GDM:

1) Perceived conflict between dietary advice and eating norms [752]
2) Family objecting against healthy nutrition changes, particularly when conflicting with their food preferences [57, 764]
3) Perceived endangered family identity if detaching from the traditional diet [764]
4) Strong presence of family members in immigrant families providing energy dense food [753]
5) Central role of food in get-togethers and celebrations [64, 771]

Regarding physical activity, the following social factors hindered health behavior in women post-GDM:

1) Lack of social support, especially by partners [791] or peers [55]
2) Insufficient community-based physical activity programs for mothers [774, 779]
3) Concerns of social acceptability [774]
4) Less family support in childcare [779]
5) Interfering cultural norms [753] or a lack of culturally-sensitive exercise facilities [65]

2.1.2.3.10 Self-image

The tenth determinant for health behavior is self-image, based on personal or subjective norms, personal standards, and identity. Hence, performing the behavior needs to be more consistent than inconsistent with the self-image [116]. Women post-GDM predominantly identified as a mother, partner, and homemaker and their perceived responsibilities guided almost all their behavior [764]. They prioritized baby and family over self-care and health, especially if cultural norms became personal norms [64, 752, 764, 773, 779, 787]. Mothers post-GDM consistently placed the needs, preferences or finances of their families before their own, while acknowledging their T2D risk [764, 779]. Some considered self-care unnecessary once health behavior did not directly impact the baby in the womb anymore [764]. Others felt responsible to be a role model for their children or to care for themselves to be able to take care for their children [764]. Further, the strength of ethnic identity was associated with health behaviors such as fiber intake, fruit and vegetable intake, and physical activity [795].

Some subjective norms were linked to nutrition only. A subgroup of women post-GDM perceived unhealthy food as comfort, pleasure, or reward [753, 764]. Others thought that they were not the person for a healthy nutrition and that it was their right to eat what they wanted [764].

2.1.2.3.11 Emotional reaction to behavior

The eleventh determinant is the emotional reaction to performing the behavior. Emotional reactions to behavior are often linked to emotions, moods, and emotional control. Many women post-GDM show negative emotions towards health behaviors:

1) Feelings of guilt or selfishness when taking time for their health instead of childcare or family life [752, 764], especially when using childcare support during physical activity [764] and when work limited available time [764]
2) Mental distress and negative emotions due to sleep deprivation with a newborn at home, fatigue, or having a baby for the first time [753]

3) Struggle for the right balance between family-related responsibilities and a healthy lifestyle [64]
4) Negative feelings against health behaviors from restrictions during GDM continued post-GDM such as confusion, guilt, frustration, and anxiety [752] – for some immigrant women also social stigma, isolation, loneliness, and depression [753, 764, 796]

Regarding nutrition, the following social factors hindered health behavior in women post-GDM:

1) Homesickness in immigrant women promoted a higher consumption of unhealthy traditional food of the home country [753]
2) Boredom with a healthy diet due to perceived limited food choices [765]
3) Discomfort of neglecting food preferences [771] or of resisting food temptations and cravings [64], especially during social eating or when eating out [765]

Regarding physical activity, some women post-GDM felt bored with exercise [778], others struggled with the discomfort of exercising during bad weather [764]. In contrast, some women post-GDM enjoyed feeling healthier with the right eating habits and physical activity so that they formed new habits [764].

2.1.2.4 *Logic model of the problem*

We linked the main factors from each previous step in the logic model of the problem (Table 2.1) – except for the defined priority population: the priority population is of female gender in the reproductive age, with a predominant age range between 18 and 45 years, at least one child in the household, at least one recent pregnancy complicated by GDM, in the extended postpartum period (until maximum five years after delivery), and at high risk for or with cardiometabolic disturbances.

2.1.3 Describe the context for the intervention (Task 1.3)

The following questions guided the asset assessment: *"What is the character of the priority population, their strengths, their knowledge of T2D and related cardiometabolic disturbances (health problem), and their potential solutions to reduce the cardiometabolic risk?"*

Our brainstorming and review of the empirical literature led to the following assets of the priority population, including their capacities, abilities, and environment.

First, the main intervention context is daily family life with opportunities for financial or social support weighed against family responsibilities as a mother, partner, and homemaker. The primary identification as a mother can be used to motivate behavior change via strengthened role model perceptions [768]. This makes the home a favorable setting for intervention. However, varying work hours, longer travel periods abroad, irregular days, or financial restrictions during parental leave demand high program flexibility, a widespread program access, and low program costs for participants.

Second, most women post-GDM are knowledgeable and some experienced in health behaviors. Those who changed behaviors during GDM know how to change. Those not able to change during pregnancy uncovered gaps in health education such as actionable examples for meal planning, proper portion sizes [57, 764], or guided practice for exercise [764]. Hence, prior knowledge or experiences may inform further behavior change and identified gaps in behavioral health education post-GDM may be closed.

Table 2.1: Logic model of the problem for type 2 diabetes and related cardiometabolic disturbances post-GDM (short: cardiometabolic risk behavior model post-GDM)

<table>
<tr>
<th></th>
<th>“Why would women post-GDM perform cardiometabolic risk behaviors?”</th>
<th>→</th>
<th>“What are cardiometabolic risk behaviors (post-GDM)?”</th>
<th>→</th>
<th>“What characterizes type 2 diabetes (post-GDM), including related cardiometabolic disturbances?”</th>
</tr>
<tr>
<td rowspan="3">PERSONAL DETERMINANTS</td>
<td rowspan="3">• Insufficient health-promoting (family) habits
• Lack of commitment
• Misperceptions of behavioral barriers
• Insufficient self-management skills or lacking skills for specific health behaviors
• Insufficient positive outcome expectations
• Biased perceptions of social norms or family identity with no or little perceived social support for health behavior
• Insufficient role model perceptions despite primary identification as mother and homemaker, interfering cultural identity, and unhealthy lifestyle-loving identity
• Negative emotions towards health behaviors
• Low self-efficacy
• Insufficient or biased behavioral knowledge
• Low perceived risk or denial of risk</td>
<td rowspan="3">RISK BEHAVIORS</td>
<td rowspan="3"><u>Nutrition habits</u>
• Excess intake of energy-dense meals or snacks
• Excess intake of animal-derived products, especially those high in total fat/saturated fat
• Excess intake of (ultra-) processed food
• Excess total energy intake
• Excess intake of caloric drinks
• Insufficient intake of non- to minimally processed food
• Insufficient intake of (fresh) plant products
• Insufficient intake of water, plain tea or coffee
• Non-adherence to recommended healthy dietary patterns and macronutrient quality
• Insufficient control of eating behavior

<u>Physical activity habits</u>
• Insufficient daily physical activity
• Insufficient exercise or exercise intensity

<u>Psychological and sleep habits</u>
• Pessimistic thinking style
• Insufficient control of negative emotions
• Poor stress management or problem solving
• Insufficient meditation, positive emotion, optimistic thinking, or mind-body exercises
• Insufficient enjoyable leisure time activities
• Insufficient sleep-enhancing behaviors

Other behaviors
• No or limited breastfeeding
• Smoking</td>
<td>HEALTH PROBLEM</td>
<td><u>Cardiometabolic disturbances characterized by combinations of:</u>
• (Abdominal/visceral) overweight or obesity
• High blood pressure
• Dysglycemia
• Dyslipidemia

<u>Most relevant subgroups for intervention:</u>
• BMI ≥ 23 kg/m^2
• BMI < 23 kg/m^2</td>
</tr>
<tr>
<td rowspan="2">QUALITY OF LIFE</td>
<td>↓
“How is a woman’s quality of life affected by a history of GDM and by type 2 diabetes?”</td>
</tr>
<tr>
<td><u>Short-term effects:</u> Little or no overall impact, yet some <u>subgroups</u> with impaired quality of life:
• Postpartum depression
• Single mothers
• Lower socioeconomic status
• Obese
• Perceived fair or poor health

<u>Long-term effects:</u> Impairments in all four quality of life domains:
• Physical functioning
• Psychological functioning
• Social functioning
• Environmental wellbeing</td>
</tr>
</table>

BMI=body mass index, GDM=gestational diabetes mellitus

Third, the momentum of the GDM diagnosis can be harnessed to encourage or maintain behavior change [768]. This requires an active partnership between an affected woman, her healthcare practitioners, and her family in the postpartum period and beyond [768]. Thereby, favorable relationships with healthcare practitioners are an asset for accountability and continued support [764]. In Germany, the responsible healthcare practitioners for follow-up care post-GDM could be included in the program [51, 52].

Fourth, women post-GDM are a geographically scattered niche population – a community with little attention in healthcare and without a local or virtual network except for some discussion forums. The social needs [752, 764], the needs for personal support [64], and the valued social support from those with shared experiences [797] can be leveraged in a health promotion program.

Fifth, family health behavior is deeply embedded in cultural contexts. Many cultural aspects hinder health behavior since women post-GDM perceive them as barriers. However, close family ties, social resources, and a strong cultural identity can be used for health behavior change if specific to the individual culture [64, 795].

Sixth, women post-GDM choose different informants and communication channels [753]. Yet, the smartphone is one of the main information sources in this group, combining interpersonal communication, diverse social networks, practical apps supporting daily life, and access to online information. These different smartphone uses by the priority population may benefit a health promotion program.

Seventh, the physical environment in Germany allows for a high physical activity in daily life – with safe neighborhoods, bike lanes throughout the cities, free outdoor sports groups, parks, and nearby lakes or mountains in most areas.

2.1.4 State program goals (Task 1.4)

Our long-term goal for this health promotion program is to maintain or improve quality of life by decreasing the incidence of T2D and related cardiometabolic disturbances in women post-GDM. We stated our long-term intervention goal on a national level: Six years post-intervention, the T2D incidence following GDM in Germany will decrease by 30%.

In addition, we specified lifestyle goals as proxy outcomes since the evaluation time frame in a clinical study will not be long enough to assess the intervention's effect on T2D and quality of life outcomes. The resulting lower-level behavioral goal states as follows:

50% of the women post-GDM who participate in the planned mHealth program for at least six months will report having achieved at least three out of five behavioral endpoints for diabetes prevention over time. We adapted the behavioral endpoints of the large diabetes prevention trials as follows:

1) Physical activity of moderate to high intensity for ≥ 150 minutes per week
2) Dietary fiber intake of ≥ 15 g per 1,000 kcal
3) Percent fat intake of < 30% of total energy intake
4) Percent saturated fatty acid intake of < 10% of total energy intake
5) Body weight reduction of ≥ 5% if BMI is ≥ 23 kg/m^2, body weight maintenance if BMI is < 23 kg/m^2

The choice of subgroups and outcomes reflects meta-analyses that indicate the superiority of combined nutritional and physical activity interventions for weight loss and weight maintenance [798], especially after childbirth [799].

2.2 Intervention Mapping Step 2 – Logic model of change

In Intervention Mapping Step 2, we translated the description of the health problem into the description of desired changes during the mHealth program. This step uncovered how to prevent T2D and related cardiometabolic disturbances post-GDM. The final products were the logic model of change with pathways of program effects and matrices of change. We selected behavioral outcomes, translated them into subgroup-specific performance objectives, selected determinants for behavioral outcomes, and translated them into change objectives (Figure 2.3).

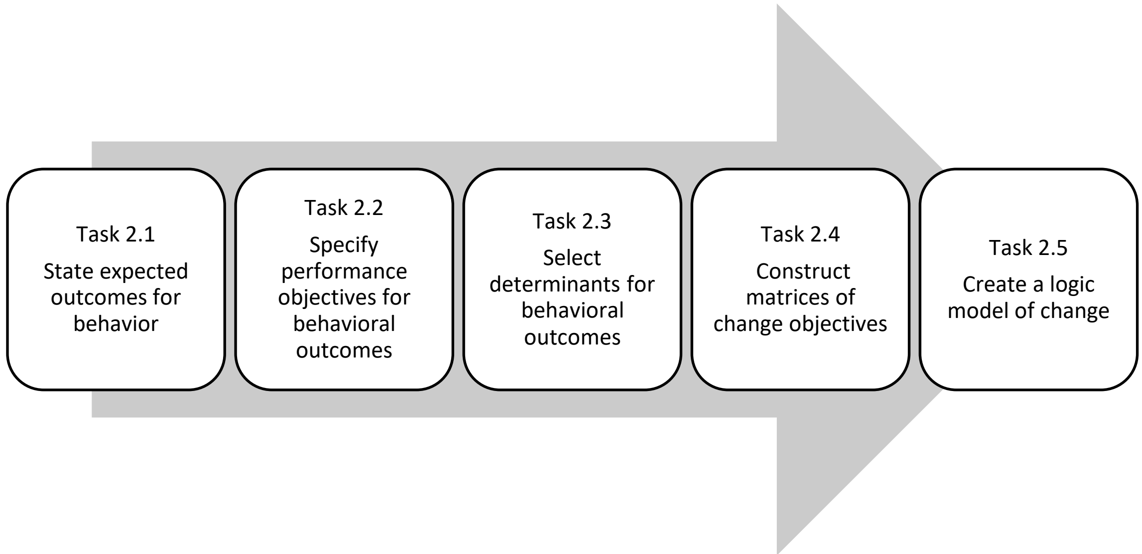

Figure 2.3:Tasks of Intervention Mapping Step 2
(adapted from Eldredge et al., 2016)

2.2.1 State expected behavioral outcomes (Task 2.1)

The first task of Intervention Mapping Step 2 tackled the question: "*What behavioral outcomes of women post-GDM (priority population) is the mHealth program intended to accomplish?".* We chose the five adapted outcomes of the large diabetes prevention trials (as mentioned in Chapter 2.1.4.) and added psychology, wellbeing, sleep, and adherence outcomes. The adherence outcomes were mostly derived from the behavioral theories discussed in Chapter 1.3.

The addictive nature of smoking and the relatively small proportion of women post-GDM who smoke led to our decision to exclude smoking as a target behavior. We further excluded breastfeeding due to the temporary nature versus our focus on long-term behavior change. Lastly, we excluded shift work from our target behaviors due to limited changeability and a limited number of affected women post-GDM.

The final list of behavioral outcomes comprised the following seven:

1) Physical activity of moderate to high intensity for ≥ 150 minutes per week
2) Dietary fiber intake of ≥ 15 g per 1,000 kcal
3) Percent fat intake of < 30% of total energy intake
4) Percent saturated fatty acid intake of < 10% of total energy intake

5) Body weight reduction of ≥ 5% if BMI is ≥ 23 kg/m^2, body weight maintenance if BMI is < 23 kg/m^2
6) Increased wellbeing and sleep, decreased stress perception
7) Program adherence and enhanced self-management

2.2.2 Specify performance objectives for behavioral outcomes (Task 2.2)

We formulated the so-called "performance objectives" following the question "*What specifically do women post-GDM need to do in this mHealth program to achieve the desired behavioral outcomes?".* Performance objectives are defined as concrete actions of a program participant to modify health behavior [116]. Hence, we delineated each behavioral outcome into sub-behaviors. We distinguished between preparatory performance objectives and habitual performance objectives. In this mHealth program, preparatory performance objectives comprise one-time actions, decisions, or communication. In contrast, habitual performance objectives represent repeated actions in the same context.

Most performance objectives mirror the risk behaviors and related recommendations outlined in Intervention Mapping Step 1. We reformulated most risk behaviors as health promotion behaviors with concrete actions and sub-actions for women post-GDM. We further adapted the health actions to the family context and to the flexible program setting. The sub-actions formed a logical behavioral sequence to learn a specific behavior. Behavioral theories and a topical search of the practice literature delivered further input for the choice of performance objectives. Besides, we addressed individual differences at the beginning of the intervention by subdividing performance objectives into different levels. This allows for an individualized start and a participant's stepwise progress. Regarding program adherence, we considered five out of seven days per week as threshold for habit formation due to differences in context cues for behavior on weekends.

Further, we explored the question *"Are performance objectives substantially different for subgroups of women post-GDM?".* Based on Intervention Mapping Step 1, we prioritized the two most common BMI categories "normal weight", and "overweight/obese" as tailored subgroups within the program. Still, we favored a "health, not weight loss, focused" approach for all participants that provided better outcomes in body satisfaction and restrained eating behavior in a recent meta-analysis on weight loss trials [800].Other subgroups will be considered during individualization.

We cut the initial list of performance objectives to those most essential for this project. Preparatory decisions only translated to a performance objective if related to a major lifestyle change, such as initiating an exercise routine. Otherwise, they presented a change objective as will be specified in Chapter 2.2.4. Many performance objectives were conditional for better individualization. Hence, the final list of 81 performance objectives remained extensive since we aimed for a tool box of actions for individual needs. This is in line with a study with women post-GDM suggesting tailored advice [776]. Our performance objectives for women post-GDM to prevent cardiometabolic disturbances are listed in Supplementary Table 2.

2.2.3 Select determinants for behavioral outcomes (Task 2.3)

In task 2.3, we approached the question "*Why would women post-GDM change their current behaviors for the specified performance objectives for a healthy nutrition, physical activity, stress management, sleep hygiene, and mHealth program adherence?".* We decided to retain the 11 determinants from Intervention Mapping Step 1 (Chapter 2.1.2.4) for four reasons:

1) The empirical literature confirmed the necessity to address the 11 determinants for health behavior post-GDM.
2) The theoretical foundation proofed essential due to limited empirical research on changeability and relevance of single determinants per performance objective.
3) We expected optimal intervention outcomes using the 11 determinants since determinants may vary in individual importance and changeability.
4) The 11 determinants are interrelated.

2.2.4 Construct matrices of change objectives (Task 2.4)

Based on the performance objectives and behavioral determinants, we generated the so-called "change objectives". Change objectives address the question *"What do women post-GDM have to learn or change in each determinant to meet or maintain the identified performance objectives?".* A change objective is thus defined as what needs to change in a determinant to accomplish a performance objective [116]. We crossed every performance objective with each of the determinants to produce the change objectives. The resulting matrices of change objectives uncovered the necessary changes in the behavioral determinants per performance objective for women post-GDM. For practical reasons, we grouped similar determinants – leading to seven columns per performance objective (Table 2.2.). The habitual nature of most performance objectives encouraged us to address this characteristic in other change objectives – complementary to those formed by the habit determinant. The matrices of change objectives for women post-GDM are listed in Supplementary Table 3.

Table 2.2: Clusters of behavioral determinants for the matrices of change objectives

Performance objective						
Commitment, behavioral **knowledge,** and perceived **risk** (CKR)	**Perceived barriers** (PB)	Perceived **skills** and **self-efficacy** (SSE)	**Outcome expectations** and **attitudes** (OEA)	Perceived **social norms** (SN)	**Self-image** and **habits** (SIH)	**Emotional reaction** to behavior (ER)

CKR=commitment, behavioral knowledge, and perceived risk, ER=emotional reaction to behavior, OEA=outcome expectations and attitudes, PB=perceived barriers, PO=performance objective, SIH=self-image and habit, SN=perceived social norms, SSE=skills and self-efficacy

Next, we explored the question *"Are determinants substantially different for subgroups?".* We concluded that substantial differences could be clustered into the two existing subgroups of normal weight and overweight/obese. Therefore, we decided to maintain these two subgroups and to address other subgroups by individualization.

2.2.5 Create a logic model of change (Task 2.5)

Based on the *cardiometabolic risk behavior model post-GDM* resulting from Intervention Mapping Step 1 (see p.51, Table 2.1) and the matrices of change (Supplementary Table 3), we created a *logic model of behavior change for cardiometabolic health post-GDM* (Table 2.3).

Table 2.3: Logic model of change for cardiometabolic health post-GDM

"What changes are expected to affect the behavioral outcomes?" →	***"What do women post-GDM who participate in this program or subgroups thereof need to do to perform the cardiometabolic health behaviors?"*** →	***"What is intended to change in women post-GDM to produce the desired cardiometabolic health outcomes?"***
PERSONAL DETERMINANTS FOR CHANGE OBJECTIVES	**MAIN PERFORMANCE OBJECTIVES PER BEHAVIORAL OUTCOME**	**BEHAVIORAL OUTCOMES**
• Commitment, behavioral knowledge, and perceived risk • Perceived barriers • Perceived skills and self-efficacy • Outcome expectations and attitudes • Perceived social norms • Self-image and habits • Emotional reaction to behavior	1) Gradually increase daily steps to ≥ 10,000; Disrupt longer sedentary periods; Initiate an exercise routine of ≥ 150 minutes of moderate to high intensity per week; Engage into active regeneration and active transportation 2) Gradually eat more plant-based non-to minimally processed food; Carefully read food labels; Replace unhealthy and keep healthy home food supplies; Establish and maintain weekly meal planning, healthy grocery shopping, and cooking; Eat main meals according to the healthy meal model to reach ≥ 2 fist size portions of whole grain products, ≥ 1 fist size portion of legumes, 2 hand size portions of fresh fruit and ≥ 3 hand size portions of fresh vegetable a day 3) Gradually limit or replace high-fat food products; Establish a low-fat meal preparation; Generously use fresh herbs and spices 4) Gradually limit or replace food products high in saturated fat 5) Monitor eating habits; Eat only when hungry; Avoid added sugar and sweeteners; Limit snacking to fresh fruit and vegetable twice a day; Drink ≥ 1.5-2 l of water a day and avoid other drinks; Eat regular sized portions; Gradually extend overnight fast to ≥ 12-16 h; Lose 1-2 kg of body weight per month until weight goal is reached; Remain flexible in eating behaviors 6) Practice mindfulness; Identify and engage into recreational activities; Enhance own and infant's sleep; Maintain a daily progressive muscle relaxation routine; Practice gratitude; Identify and replace automatic negative thoughts; Strengthen positive emotions; Use seven steps for problem solving; Learn how to prioritize with a decision matrix; Identify and focus on top three personal strengths 7) Participate in mHealth program on at least five out of seven days per week; Communicate with healthcare practitioners; Take questionnaires; Select and commit to health goals and health actions; Set reminders, schedule, or link chosen health actions to repeated contexts; Monitor own progress weekly; Reschedule missed or skipped health actions; Evaluate own performance; Adapt chosen health goals and health actions when necessary	1) Physical activity of moderate to high intensity ≥ 150 minutes per week 2) Dietary fiber intake ≥ 15 g per 1,000 kcal 3) Fat intake ≤ 30% of total energy intake 4) Saturated fat intake ≤ 10% of total energy intake 5) Body weight reduction ≥ 5% if BMI ≥ 23 kg/m^2, body weight maintenance/slight reduction ≤ 5% if BMI < 23 kg/m^2 6) Increased wellbeing and sleep, decreased stress perception 7) Program adherence and enhanced self-management ↓ **HEALTH AND QUALITY OF LIFE OUTCOMES** ***"What changes should the intervention produce related to type 2 diabetes and quality of life?"*** • 30% decreased incidence of type 2 diabetes at six years post-intervention • Increased overall quality of life, preserving or restoring all cardiometabolic disturbance-related aspects of quality of life

BMI=body-mass index, GDM=gestational diabetes mellitus

3. Develop a mobile health promotion program post-gestational diabetes mellitus (Intervention Mapping Steps 3 and 4)

3.1 Intervention Mapping Step 3 – Program design

In Intervention Mapping Step 3, we conceptualized program ideas for themes, components, scope, and sequence for a coherent mHealth app. The final product of Intervention Mapping Step 3 is the logic intervention model (Figure 3.1).

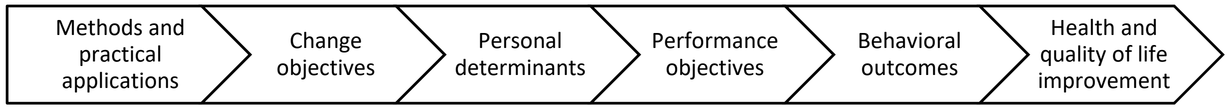

Figure 3.1: Logic intervention model

We simultaneously explored behavior change methods (Task 3.2) and practical delivery channels (Task 3.3) for the chosen determinants of behavior for optimal outcomes [116] (Figure 3.2). In the scope of this project, the question *"How many different types of target participants will the program have at what environmental levels?"* was limited to the priority population: women post-GDM. Hence, we focused on practical applications offering the best fit for the priority population's determinants for behavior. Similarly, we restricted the behavior change methods to the individual level.

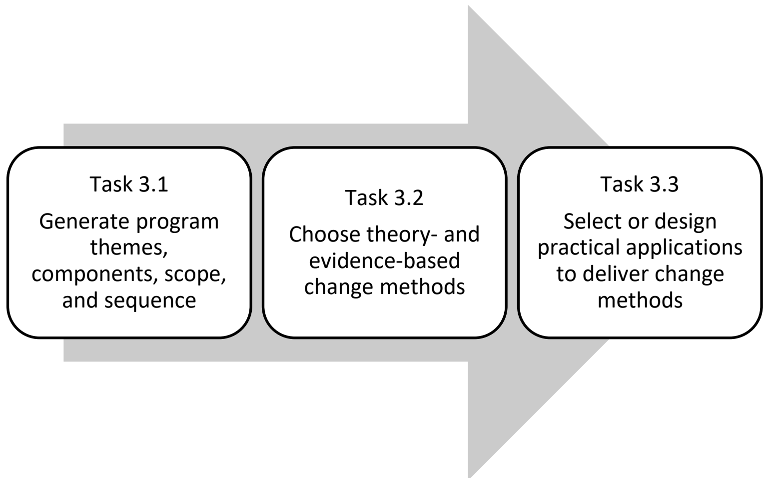

Figure 3.2: Tasks of Intervention Mapping Step 3
(adapted from Eldredge et al., 2016)

3.1.1 Generate program themes, components, scope, and sequence (Task 3.1)

For Task 3.1, we first specified minimum program requirements for women post-GDM to select the appropriate delivery channel and to guide the design of the mHealth program.

3.1.1.1 *Program requirements for women post-GDM*

We approached the question *"What would we do if we could do anything that comes to mind?"* in a pragmatic way and reviewed studies assessing the needs for health behavior change post-GDM. This led to a list of 16 program requirements by women post-GDM. We clustered them into the four topics "behavioral psychology and mental health", "family context", "individual content and participation", and "specific needs of women post-GDM":

1) Behavioral psychology and mental health

- Cover psychological and psychosocial factors such as behavioral psychology, mental health, and sleep next to nutrition and physical activity [17, 56, 64, 303, 488, 801]
- Address sustainable long-term behavior change via habits [802]
- Close the knowledge-behavior gap [19, 501, 770, 785]
- Include behavior change methods that target determinants of behavior [501, 802], such as constant individual or social support [64, 306, 488, 647, 767, 774] or self-monitoring [802]

2) Family context

- Align intervention with family context [67, 303, 306, 767, 802]
- Allow for flexible times and locations [55, 56, 797]
- Limit participation time as much as possible [54, 770, 791]
- Restrict face-to-face sessions between healthcare practitioners and participant [56], such as in home-based [54] and technology-based programs [797, 803]

3) Individual content and participation

- Provide individual content instead of group sessions [16, 55]
- Allow for a self-pacing [56] with individual small steps [802]
- Be practical for daily life, including skill training [54, 56, 303, 774, 791]
- Consider subgroups [488, 770, 794], e.g. by tailoring [770, 791, 797]

4) Specific needs of women post-GDM

- Ensure high reach and access by women post-GDM [54, 56, 64, 65]
- Continue care in the shift from GDM care to post-GDM care, starting three months postpartum [63]
- Secure high cost-effectiveness [303] and affordability for participants [54]
- Support small daily health decisions of a mother with at least one infant [58]

3.1.1.2 *Delivery channel*

The 16 requirements helped us address the question *"How will women post-GDM receive program materials?"*. The following delivery channels did not meet the requirements: traditional one-on one or group sessions, circulating or display print, online newsletters, videotape, computer-based, and social media-based interventions. We abandoned the idea of in-person counseling mainly due to the lack of success in earlier trials with women post-GDM, such as the Australian MAGDA trial [60]. In contrast, the six main benefits of mHealth apps as pointed out in Chapter 1.1.3 suited the 16 identified requirements for women post-GDM. They comprise low delivery costs, national and international dissemination, easy to use in daily life, holistic health coaching independent from the expert's location, multimedia appeal, and flexible systems based on behavioral psychology. Some additional advantages of mHealth include the interactive character, control over content, and an easy change of language. In contrast, the main disadvantages of mHealth lie in the high development costs, production time, dependence on programming expertise, demand for novelty, short attention span regarding smartphones, short life span of mHealth apps, screen limitations for design and characters, and data security issues [116]. Still, we decided that the disadvantages were manageable and outweighed the advantages. Besides, first evidence with mHealth-delivered diabetes prevention programs [804, 805] and weight loss programs [806, 807] showed efficacy comparable to community-based programs.

3.1.1.3 *mHealth specifications*

Once the delivery channel was set, we translated the requirements into specifications for the mHealth app. In line with the identified four requirement clusters and Intervention Mapping Steps 1 and 2, we decided to address:

1) Three lifestyle areas and behavioral psychology

- Include the three lifestyle areas physical activity, nutrition, and psychology/sleep
- Base behavior change and respective app features predominantly on the habit-goal interface
- Empower behavior change with an interactive system and notifications to close the knowledge-behavior gap
- Group and translate as many behavior change methods into app features as feasible

2) Family context

- Include specific tips and situational examples from family life in each performance objective
- Build a flexible content management system with content available at any time
- Break down health behaviors or offer effective alternatives with as little time requirement for participant as possible
- Limit face-to-face interaction between healthcare practitioners and participant to one initiation visit besides routine care

3) Individual content and participation

- Provide individual content
- Foster participation via joint decision making
- Match performance objectives with daily life
- Uncover necessary skills that need to be co-developed with health behaviors
- Tailor content in participant's smartphone app according to BMI and consider additional subgroups

4) Other specific needs of women post-GDM

- Promote participation of women post-GDM living in remote areas or having a low socioeconomic status
- Increase acceptability of the smartphone app by involving women post-GDM in the development process once a prototype is available
- Enable program participation starting three months postpartum
- Focus on cost-effectiveness and affordability of the smartphone app

3.1.1.4 *Small market analysis on evidence-based health apps*

For more insights into evidence-based apps, we conducted market research combined with a small literature review. We included evidence-based health apps such as the *Noom Health* app for T2D prevention based on the DPP [804], *Alive-Pre-Diabetes* for diabetes prevention and weight loss [808], *MobileMums* to improve physical activity in women with infants [809], *TXT2BFiT* for weight gain prevention of young adults [810], and *Vegethon* to promote vegetable consumption [811]. We checked available data on these and similar health apps. Most apps available in the app stores were neither evidence-based nor linked to a scientific publication, as indicated by a previous review of innovations in digital health technology for weight control [812]. Of those mHealth apps with scientific publications, most did not provide detailed program descriptions. Yet, the information provided was sufficient to measure existing programs against our 16 identified requirements for women post-GDM. Existing programs either lacked at least one of the four requirement clusters or single requirements. Hence, our combination of app specifications is unique to the best of our knowledge.

Further, we screened the literature for reviews and meta-analysis on mHealth efficacy or use cases related to our performance objectives. Reviews found first efficacy and feasibility of mHealth interventions for physical activity and mental health [813], and first perceived effectiveness of diet and physical activity apps [814]. Yet, knowledge on features responsible for behavior change was limited. We screened apps for stress reduction [815], nutrition [816-818], and combined nutrition and physical activity [806, 807, 814]. App features were often specific to one lifestyle area such as food logs [817]. In our case, such restrictive features per lifestyle area would have led to an overly complex system. Therefore, we decided to focus on simple features addressing behavioral commonalities at the habit-goal interface.

3.1.1.5 *Program themes and title*

For the question *"Will the program have one or more themes and a title?",* we followed the idea of a symbolic health triangle as program title, theme, app name *("TRIANGLE")*, and logo to stress the fusion of the three lifestyle areas physical activity, nutrition, and psychology/sleep (further referred to as "psychology"). The triangle mirrors the unified structure while accounting for differences specific to each lifestyle area.

We further decided to brand the program with a challenge system due to the challenging nature of multiple habit changes. The challenge system forms a recurring subtheme in the program that delivers five key messages related to the change objectives:

1) Take up the challenge of changing a specific behavior
2) Expect positive outcomes after the effort
3) Expect both struggle and fun at the same time
4) Feel good after having performed a health behavior
5) Commit to maintain the behavior

Further, an mHealth-based challenge system seemed to fit the learning style of the relatively young priority population.

3.1.1.6 *Program scope and components*

Next, we addressed the question "*What is the scope of the intervention (extent and duration)?".* The three lifestyle areas formed the scope for thematic modules. Each lifestyle area offers extensive research and practical wisdom. Hence, we defined the submodules early on to limit the scope of each module (Table 3.1). Most submodules were based on grouped performance objectives. Further, we included a fourth overarching module for the performance objectives on program adherence, self-regulation, and self-management behaviors [176, 819]. In line with the performance and change objectives, the scope of the program included:

- Knowledge transfer on cardiometabolic disease, related risk behaviors, and behavioral determinants in the three lifestyle areas physical activity, nutrition, and psychology
- Individual behavior change support primarily habit formation or habit change in the three lifestyle areas nutrition, physical activity, and psychology – including personal coaching
- Individual skill training in program adherence, self-management, and other behavior change methods

All essential program materials were to be delivered by a smartphone app. However, we considered three additional materials necessary:

1) Fitness tracker for daily step counts and heart rate monitoring during exercise units [820, 821]
2) Step tread for a fitness self-test at home
3) Paper notepad to support some of the psychological exercises

The decision to focus on habits required flexible options for the question "*How long will the program last overall?*". We designed one option for a duration of roughly six months of intervention for the intended pilot study. Yet, the program will be delivered with a flexible dosage due to different needs of different subgroups of women post-GDM. A flexible dosage further accounts for differences in the duration of individual habit formation [105, 162].

Table 3.1: TRIANGLE program modules and submodules

Physical activity	Nutrition	Psychology and sleep	Program adherence
Daily steps	Drinks	Mindfulness practice	Participatory decision making
Disrupting sedentary periods	Home food supplies	Recreational activities	Communication with healthcare practitioner
Endurance training	Grocery shopping	Sleep	Questionnaires and self-tests
Resistance training	Meal planning	Progressive muscle relaxation routine	Notifications
High intensity interval training	Healthy meal composition	Gratitude practice	Feedback
Flexibility training	Healthy snacks	Optimistic thinking	Scheduling and reminders
	Meal rhythm	Emotional positivity	Self-monitoring
	Mindful eating	Problem solving	Frequently asked questions
	Flexible control	Prioritization	
	Eating cues	Character strengths	
	Added sugar limit		
	Non to minimally processed food		
	Sufficient dietary fiber		
	Extended overnight fast		
	Caloric restriction		
	Healthy alternatives		
	Portion size		

3.1.1.7 *Program sequence*

Similarly, the questions *"Who will get what part of the program?"* and *"When will they get it?"* needed to account for joint decision-making and individualization in the program. Hence, we decided to keep the program sequence flexible to allow for individual coaching based on questionnaire results and self-pacing. We pre-set habitual challenges to a minimum of three successful weeks for completion, with the option of weekly prolongments until a behavior would become automatic for a participant

[105]. Further, those performance objectives related to skill training required a specific sequence of delivery. Hence, we planned sequences of chained challenges with increasing difficulty. After successful completion of a pre-set number of days and weeks for one challenge, the chained more difficult challenge will be suggested automatically for a participant.

3.1.2 Choose theory- and evidence-based change methods (Task 3.2) and select or design matching practical applications (Task 3.3)

The key questions for tasks 3.2 and 3.3 were "*What evidence-based behavior change methods and applications trigger or support the required changes?" and "Why would a particular application work, considering the methods' parameters?"*

We considered 39 behavior change methods necessary and feasible (Table 3.2, all methods as defined by Intervention Mapping) to target the change objectives defined in Chapter 2.2.4. The multitude of change objectives required a meta-level when translating the change objectives into behavior change methods and practical applications. We build on the 21 most common behavioral change objectives (Supplementary Table 3) without the specifics of one particular behavior. Thereby, we set place holders with an "x" for the performance objectives' and change objectives' numbers (*PO.x.x./CKR.x.x.a.* instead of *PO.1.1./CKR.1.1.a.,…, PO.7.10./ CKR.7.10.a.*) for three reasons:

1) To avoid a table with more than 7,000 repetitive items
2) To account for the similarity of change objectives for most performance objectives
3) To consider multiple behavior change methods for one change objective

During the translation into practical applications, we further considered ethical guidelines in mHealth [127], usability issues [822-824], security issues [129], app intervention design frameworks [825, 826], the behavioral intervention technology model [827], end user experiences [828], fully automated [829] versus semi-automated systems [804], adherence issues [830], and cultural sensitivity. Reviewing the literature helped us specify the scope of features with a focus on habit formation [831], personalized content [832], and combined self-tracking with online coaching [832]. We decided against social group features since evidence on social features and user engagement is limited [833]. Similarly, we excluded options bound to social media platforms such as Facebook (Facebook Inc., Menlo Park, USA) used in some interventions such as the *Mums Step It Up Program* [834] due to data issues. The gathered information along with the previous Intervention Mapping steps pointed us to three core features for the app: a challenge system, a library, and personal coaching. The simultaneous process of selecting behavior change methods and the respective practical applications helped us define the sub-features for the app.

Table 3.2 shows the behavior change methods [116] and their respective practical applications for *TRIANGLE* per meta-level change objective.

Table 3.2: Methods and practical applications for the TRIANGLE change objectives

Change objectives	Methods	Practical applications considering the method's parameters
CKR.x.x.a.* Get informed about the benefits of performing *PO.x.x*. and learn how to perform *PO.x.x.	**Tailoring** [835, 836]	**Personal coach** tailors the content to participant's BMI based on the initial paper and pencil questionnaire.
	Chunking [837, 838]	**Challenge system** translates *PO.x.x*. into C*hallenge(s) x(,y,z)* and divides related information into easily processable chunks that appear as a whole: motivation to perform action, course of action (what, when, where), action frequency, linked POs, detailed description of action and facilitators, benefits of action, and hyperlinks to related library articles **Library articles** provide supplementary information related to *Challenge x (PO.x.x.)* in easily processable chunks that appear as a whole: background information with topical subsections, including images, short audios or videos, benefits of action, and hyperlinks to related library articles
	Advance organizers [839]	**Challenge system** structures information on *Challenge x (PO.x.x.)* with colored headings, subheadings, enumerations, tips, hyperlinks, images, notes, and bold or italic font. **Library articles** provide supplementary information related to *Challenge x (PO.x.x.)* structured with colored headings, subheadings, enumerations, tips, hyperlinks, images, figures, tables, notes, and bold or italic font to give participant an overview of content and of related material.
	Using imagery [840]	**Challenge system, library articles,** and **coaching messages** contain familiar physical or verbal images as analogies to less familiar terms related to *Challenge x (PO.x.x.)*.
	Discussion [841]	**Personal coach** discusses and counsels on topics and concerns related to *Challenge x (PO.x.x.)* via text messaging.
	Framing [842, 843]	**Challenge system** and related **library articles** consistently provide gain-framed messages to stress the advantages of *Challenge x (PO.x.x.)* and of performing the challenge on a regular basis. **Personal coach** motivates participant with gain-framed messages.

BMI = body mass index, CKR = commitment, behavioral knowledge, and perceived risk; PO = performance objective

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
CKR.x.x.a.* Get informed about the benefits of performing *PO.x.x*. and learn how to perform *PO.x.x.	**Environmental reevaluation** [844]	**Challenge system** and related **library articles** draw participant's attention to the positive effects on own family and the social network when performing *Challenge x (PO.x.x.)*.
	Credible information [845]	**Library articles** provide evidence-based information by credible experts. **Authorized experts** can add new library categories and articles, including media files (images, audio, video).
	Individualization [846]	**Personal coach** matches content to characteristics of the participant: personal coach receives participant's information of an initial paper and pencil questionnaire and sends additional questionnaires to participant, participant completes questionnaires and sends results to personal coach, personal coach evaluates participant's results, communicates with participant via text messaging, views participant's progress and, depending on individual stage of change and current situation, sends participant library articles, or activates *Challenge x (PO.x.x.)* for the participant. **Authorized experts** can add new questionnaires for further individualization.
	Participation [847]	**Challenge system** allows participant to determine the pace of the intervention by providing information on recommended c*hallenges (PO.x.x., PO.y.y., PO.z.z.),* and supplementary library articles with freedom of choice. **Personal coach** encourages a high level of participant engagement on a daily basis.
	Technical assistance [848]	**Library** allows participant to search for keywords. **Personal coaching** allows participant to search for keywords in chat with personal coach. **Library articles** are accessible for participant at any time and clustered in thematic modules and categories.
***CKR.x.x.b.* Decide to commit to performing *PO.x.x*.**	**Persuasive communication** [189]	**Challenge system** and related **library articles** provide convincing benefits to prompt a participant to accept *Challenge x (PO.x.x.)*. **Personal coach** views a participant's challenge status and, depending on the status, argues about the individual importance to accept and schedule *Challenge x (PO.x.x.)* via text messaging.

CKR = commitment, behavioral knowledge, and perceived risk; PO = performance objective

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
***CKR.x.x.b.* Decide to commit to performing *PO.x.x*.**	**Individualization** [849]	**Personal coach** adapts *Challenge x (PO.x.x.)* to participant's characteristics by creating *Challenge y*.
	Technical assistance [850]	**Challenge system** allows participant to select, (re)schedule, and quit *Challenge x (PO.x.x.).* **Personal settings** allow participant to set reminders.
***CKR.x.x.c.* Acknowledge the habitual character of performing *PO.x.x*. and the need to change environmental cues to reach automaticity.**	**Consciousness raising** [88, 851]	**Challenge system** raises awareness on the habitual character of *Challenge x (PO.x.x.)* and, if applicable, unfavorable habits it intends to replace – including related environmental cues. **Personal coach** texts participant questions on existing habits and environmental cues related to *Challenge x (PO.x.x.)* and raises a participant's awareness for individual habits.
***PB.x.x.a.* Get informed about possible perceived barriers performing *PO.x.x*. and identify personal barriers.**	**Participatory problem solving** [852]	**Challenge system** contains *Challenge x (CO.x.x.)* to detect perceived personal barriers for *Challenge y (PO.y.y.).* **Challenge system** contains *Challenge z (PO.z.z.)* to train participant's problem-solving skills. **Library articles** inform about possible perceived barriers for *Challenge y (PO.y.y.)* and provide questions that prompt participant to think about own perceived barriers for *Challenge y (PO.y.y.)*. **Personal coach** supports participant in detecting perceived barriers for *Challenge y (PO.y.y.)*, raises consciousness, and fosters joint problem solving.

CO = change objective, CKR = commitment, behavioral knowledge, and perceived risk; PB = perceived barriers, PO = performance objective

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
***PB.x.x.b.* Get informed about possible solutions to overcome perceived barriers performing *PO.x.x*. and implement the most suitable solutions.**	**Participatory problem solving** [852]	**Challenge system** contains *Challenge x (CO.x.x.)* to detect and train suitable solutions to overcome perceived personal barriers performing *Challenge y (PO.x.x.)*. **Library articles** inform about solutions to overcome possible perceived barriers for *Challenge y (PO.x.x.)* and provide questions that prompt participant to think about own solutions to barriers for *Challenge y (PO.x.x.)*. **Personal coach** supports participant in detecting and training solutions to overcome perceived barriers performing *Challenge y (PO.x.x.)* via text messaging.
	Planning coping responses [853, 854]	**Challenge system** supports participant in detecting high risk situations and practicing skills to avoid or overcome high risk situations to perform *Challenge y (PO.x.x.)*. **Library articles** inform and question participant about high risk situations related to *Challenge y (PO.x.x.)*. **Personal coach** provides practical tips and advice on how to identify, avoid and overcome high risk situations related to *Challenge y (PO.x.x.)* via text messaging.
***PB.x.x.c.* Expect and resist hindering social pressure by family members or the wider social network when performing *PO.x.x*.**	**Resistance to social pressure** [855]	**Challenge system** contains *Challenge x (CO.x.x.)* to detect and train solutions to resist social pressure against performing *Challenge y (PO.x.x.)*. **Library articles** inform about skills to overcome social pressure against performing *Challenge y (PO.x.x.)*. **Personal coach** provides practical tips and advice, strengthens a participant's intention by linking the intention to personal values, and stresses the personal gains when resisting social pressure against performing *Challenge y (PO.x.x.)* via text messaging.
***SSE.x.x.a.* Feel confident about performing *PO.x.x*.**	**Guided practice** [856]	**Challenge system** provides step-by-step text instructions for *Challenge x (PO.x.x.)*, partly with audio or video support by a healthcare professional.
	Enactive mastery experiences [857]	**Challenge system** contains chained challenges with increasing difficulty, starting with *Challenge x (PO.x.x.),* automatically suggesting *Challenge y (PO.y.y.), Challenge z (PO.z.z.), etc.* once a sufficient number of repetitions has been reached. **Personal coach** activates a more difficult (chain of) *Challenge b (PO.b.b.)* once a sufficient number of repetitions has been reached in (chain of) *Challenge a (PO.a.a.).*

CO = change objective, PB = perceived barriers, PO = performance objective, SSE = skills and self-efficacy

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
***SSE.x.x.a.* Feel confident about performing *PO.x.x*.**	**Verbal persuasion** [858]	**Personal coach** strengthens participant's confidence in own capabilities regarding *Challenge x (PO.x.x.)* via text messaging.
	Improving emotional states [82]	**Challenge system** contains *Challenge y (PO.y.y.)* to strengthen participant's positive emotions and *Challenge z (PO.z.z.)* to manage negative emotional states. **Personal coach** strengthens participant's positive emotions related to *Challenge x (PO.x.x.)* via text messaging.
	Self-monitoring [859]	**Challenge system** allows participant to self-monitor performance in *Challenge x (PO.x.x.).* **Personal coach** encourages participant via text messaging to self-monitor performance in *Challenge x (PO.x.x.).*
	Technical assistance [860]	**Challenge system** reminds participant of *Challenge x (PO.x.x.)* at a selected time of day, allows participant to tick off *Challenge x (PO.x.x.)* when completed on a given day, and visualizes individual progress via streaks of successful days per week and per month. **Personal settings** allow for download of multimedia files such as audio or video instructions by a participant for offline skill training.
***SSE.x.x.b.* Express confidence in ability to correctly perform *PO.x.x.*, or to learn how to do so.**	**Goal setting** [861]	**Challenge system** is based on evidence-based goal setting strategies. **Library articles** provide information on goal setting strategies and how to apply these strategies. **Personal coach** encourages participant via text messaging to select own short-term *(Challenge x (PO.x.x.))* and long-term (for example body weight) health goals.
	Set graded tasks [862]	**Challenge system** contains versions of varying difficulty for *Challenge x (PO.x.x.).* **Personal coach** first recommends an easy version of *Challenge x (PO.x.x.)* according to participant's starting point before recommending versions of increasing difficulty.

PO = performance objective, SSE = skills and self-efficacy

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
SSE.x.x.c. **Feel capable of noticing automaticity and of altering cues that trigger *PO.x.x*.**	**Cue altering** [155, 171, 831]	**Challenge system** and **library articles** provide tips on how to create environmental cues that trigger performing *Challenge x (PO.x.x.).* **Personal coach** advises participant via text messaging how to notice automaticity, which environmental cues to change for *Challenge x (PO.x.x.)*, and how to change these cues.
OEA.x.x.a. **Expect that performing *PO.x.x*. will lead to numerous health benefits and reduce own cardiometabolic risk.**	**Arguments** [863]	**Challenge system** and **library articles** contain novel information and arguments for participant to perform *Challenge x (PO.x.x.)* to gain health benefits and to reduce cardiometabolic risk. **Personal coach** texts the latest facts on behavior and health benefits to prompt participant to perform *Challenge x (PO.x.x.).*
OEA.x.x.b. **Notice the advantages of performing *PO.x.x*.**	**Direct experience** [864]	**Challenge system** and **library articles** prompt participant to start and gain experience with *Challenge x (PO.x.x.).* **Personal coach** advises participant via text messaging to take action to experience the benefits of *Challenge x (PO.x.x.)*. Where perceived disadvantages are possible, personal coach counsels on coping and reframing strategies.
	Belief selection [865]	**Personal coach** texts participant questions on attitudes, beliefs, and outcome expectations for *Challenge x (PO.x.x.)* and selects those to be strengthened, weakened, or introduced based on individual results.
	Provide contingent rewards [866]	**Program implementer** provides a fitness tracker to be kept as reward for successful program participation.
OEA.x.x.c. **Feel positive about performing *PO.x.x*.**	**Elaboration** [867, 868]	**Personal coach** advises participant to think and feel positively about performing *Challenge x (PO.x.x.)* and to add personal meaning to the challenge – by asking questions and by repeating related information in simple ways via text messaging.

OEA = outcome expectations or attitudes, PO = performance objective, SSE = skills and self-efficacy

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
***SN.x.x.a.* Notice that most health-conscious individuals perform *PO.x.x*.**	**Information about others' approval** [869]	**Challenge system** and **library articles** sharpen participant's focus on health-conscious individuals who approve of *Challenge x (PO.x.x.)* and who expect positive outcomes. **Personal coach** advises participant on the effects of other's approval of performing *Challenge x (PO.x.x.)* via text messaging.
***SN.x.x.b.* Notice that regularly performing *PO.x.x*. does not need approval by others and is possible even if social network or culture do not support it.**	**Resistance to social pressure** [855, 870-872]	**Challenge system** and **library articles** sharpen participant's ability to detach from social pressure against performing *Challenge x (PO.x.x.)*. **Personal coach** prompts participant to realize that approval by others is helpful but that own behavior can also be changed without approval, given sufficient training of self-efficacy to resist social pressure.
SN.x.x.c. Notice own social resources and find role models or supporters in own or extended social network who regularly perform *PO.x.x*.	**Mobilizing social support** [873]	**Challenge system** includes tips for noticing resources for social support and for finding role models to perform *Challenge x (PO.x.x.)* in participant's social network. **Library articles** inform about the importance of talking to others about performing *Challenge x (PO.x.x.)* to mobilize social support. **Personal coach** builds a trusting and caring relationship with participant, provides social support and role modeling for *Challenge x (PO.x.x.)* via text messaging. **Personal coach** prompts participant to strengthen trusting and caring relationships in social network for additional social support to perform *Challenge x (PO.x.x.)*, and to accept social support once offered by the social network.

PO = performance objective, SN = perceived social norms

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
***SIH.x.x.a.* Maintain to consistently perform *PO.x.x*. until habitual.**	**Counterconditioning** [874, 875]	**Challenge system** and **library articles** prompt participant to learn a health behavior by consistently performing *Challenge x (PO.x.x.)* until habitual as a substitute for an existing risk behavior. **Personal coach** motivates participant via text messaging to substitute an existing risk behavior with *Challenge x (PO.x.x.)* until habitual.
	Implementation intentions [876, 877]	**Challenge system** allows participant to express implementation intention by accepting *Challenge x (PO.x.x.)* and prompts participant to decide when, where, and with whom to perform *Challenge x (PO.x.x.)* despite possible barriers (if-then plans). **Personal coach** motivates participant via text messaging to create if-then plans for *Challenge x (PO.x.x.)*.
	Stimulus control [878]	**Personal coach** asks for participant's cues to action and supports participant via text messaging to find and remove environmental cues that prompt automatic responses hindering *Challenge x (PO.x.x.),* or to replace existing cues with new cues triggering *Challenge x (PO.x.x.).*
	Early commitment [879]	**Challenge system** prompts participant to commit to *Challenge x (PO.x.x.)* for long-term health benefits. **Personal coach** motivates participant to commit to *Challenge x (PO.x.x.)* despite delayed rewards.
	Public commitment [880]	**Challenge system** prompts participant to commit to *Challenge x (PO.x.x.)* knowing that the personal coach views the progress. **Personal coach** motivates participant to announce commitment to *Challenge x (PO.x.x.)* in social network.
	Technical assistance	**Challenge system** allows participant to reschedule *Challenge x (PO.x.x.),* to (retrospectively) tick off *Challenge x (PO.x.x.)* when completed on a given day and to (retrospectively) undo ticking it.

PO = performance objective, SIH = self-image and habit

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
***SIH.x.x.a.* Maintain to consistently perform *PO.x.x*. until habitual.**	**Reinforcement** [881]	**Challenge system** allows participant to check individual progress in *Challenge x (PO.x.x.)* as weekly and monthly habit streaks of successful days – including an activity history for *Challenge x (PO.x.x.)* once completed. **Personal coach** views, inspects, and provides reinforcing feedback on participant's activity and progress in *Challenge x (PO.x.x.)* via text messaging.
***SIH.x.x.b.* Identify as a health-conscious person who usually performs *PO.x.x*.**	**Self-reevaluation** [882]	**Personal coach** supports participant via text messaging in revising unhealthy self-image towards a health-conscious identity that includes usually performing *Challenge x (PO.x.x.).*
***SIH.x.x.c.* Identify as a healthy homemaker who guides family to usually perform *PO.x.x*.**	**Environmental reevaluation** [883]	**Challenge system** prompts participant to act as a role model in own family and social network by consistently performing *Challenge x (PO.x.x.)*. **Personal coach** strengthens participant's self-image as a role model by pointing out the impact of participant's health and risk behavior on family and social network.
***ER.x.x.a.* Expect initial discomfort when starting to perform *PO.x.x*.**	**Self-reevaluation** [882]	**Challenge system** strengthens participant's positive emotions to expect ease over time when performing *Challenge x (PO.x.x.).* **Personal coach** points participant towards initial discomfort when changing a habit via *Challenge x (PO.x.x.)* before positive emotions arise. **Personal coach** counsels on solutions for reducing the time span of initial discomfort in habit change or habit formation.
***ER.x.x.b.* Notice that performing *PO.x.x*. can be fun and does not translate to constraints.**	**Improving physical and emotional states** [884, 885]	**Challenge system** and **library articles** raise participant's awareness that *Challenge x (PO.x.x.)* increases positive emotion on the long run and that the decision on whether or not to perform *Challenge x (PO.x.x.)* should not be influenced by negative moods. Physical states are addressed via challenges on physical training and mind-body exercises. **Personal coach** strengthens participant's positive emotions regarding *Challenge x (PO.x.x.)* via text messaging and informs about effective strategies to manage negative emotions.

ER = emotional reaction, PO = performance objective, SIH = self-image and habit

Table 3.2 (continued)

Change objectives	Methods	Practical applications considering the method's parameters
***ER.x.x.c.* Feel good about having performed *PO.x.x* on a given day.**	**Direct experience** [886]	**Challenge system** prompts participant to feel good when having performed *Challenge x (PO.x.x.)* and while ticking it off in the app after completion. **Personal coach** reminds participant via text messaging to savor the positive feelings during and after having performed *Challenge x (PO.x.x.)*.
	Feedback [887]	**Challenge system** provides participant automated positive feedback once *Challenge x (PO.x.x.)* is completed. **Personal coach** gives participant irregular but timely positive feedback on achievements.

ER = emotional reaction, PO = performance objective

Based on Table 3.2 (see p.72) and the related empirical literature, we further specified the three core features of the *TRIANGLE* app as follows:

1) Interactive and individualized challenge system with an activity screen [804], based on goal setting and habit formation principles [860, 888], self-monitoring with progress visualization [860, 888-890], and notifications or reminders [850]
2) Individual coaching based on positive psychology [884, 891], personal messaging with a healthcare practitioner [804, 851, 892, 893], in-app assessment forms to customize content [890], personalized education [894], personalized feedback [888], and keyword search
3) Content library [894] with keyword search

Table 3.3. shows exemplarily how we planned to match content with the three core features – including challenges or chained challenges that require the results of an assessment questionnaire or preparatory actions before they are activated.

The features of the smartphone app for participants required a coaching platform for healthcare practitioners mirroring these features. Hence, the coaching platform needed to include secure content management, tailoring, individualization, monitoring of a participant's in-app activities for coaching purposes, in-app questionnaires, and personal text messaging. A similar smartphone app – online platform concept was studied in a previous pilot trial [804]. Further, a review on mHealth technology suggested the inclusion of quantitative assessments of app usage and acceptability [895]. Overall, the interactions with the app, including personal coaching, were designed to be short.

Table 3.3: Exemplary TRIANGLE app content

Questionnaires	Challenges	Library articles
In-app questionnaire on the results in the fitness self-test	Challenge 1.7 "Conduct the fitness self-test at home" *If beginner level:* Challenge 1.10.1 "Daily 10-minute training", automatically followed by challenge 1.10.2 "Two daily 10-minute trainings" *If intermediate level:* Challenge 1.10.2 "2 daily 10-minute trainings" *If advanced level:* Challenge 1.10.3 "9-minute Tabata-training for starters", automatically followed by challenge 1.10.4 "15-minute Tabata-training"	Introduction to resistance training Guided practice for resistance training Supportive breathing during resistance training The perfect technique for basic resistance exercises Adaptation of the intensity in resistance training
Initial paper and pencil lifestyle questions include predominant meal preparation types	*If predominantly unhealthy meal preparation:* Challenge 3.4.1 "Choose a healthy meal preparation.", automatically followed by challenge 3.4.2 "Add flavor with herbs and spices"	Tips for an optimal meal preparation Herbs and spices

In orange: physical activity, in green: nutrition, in purple: psychology

Table 3.3 (continued)

Questionnaires	Challenges	Library articles
Initial paper and pencil lifestyle questions include relaxation routines	*If insufficient relaxation routines:* Challenge 6.3.1 “Discover your ideal relaxation type”, automatically followed by 6.3.2 “One recreational activity”, 6.3.3 “Two recreational activities”, and 6.3.4 “Three recreational activities” *If insufficient relaxation routines AND stressed:* Challenge 6.6.1 “18-minute Progressive Muscle Relaxation”, automatically followed by 6.6.2 “7-minute Progressive Muscle Relaxation”, and 6.6.3 “Muscle relaxation with a release word”	Introduction to relaxation Relaxation types Guided practice for Progressive Muscle Relaxation Tips for Progressive Muscle Relaxation

In orange: physical activity, in green: nutrition, in purple: psychology

3.2 Intervention Mapping Step 4 – Program production

In Intervention Mapping Step 4, we translated the ideas from program design into program materials (Figure 3.3). The final product was the pretested *TRIANGLE* app with additional program materials.

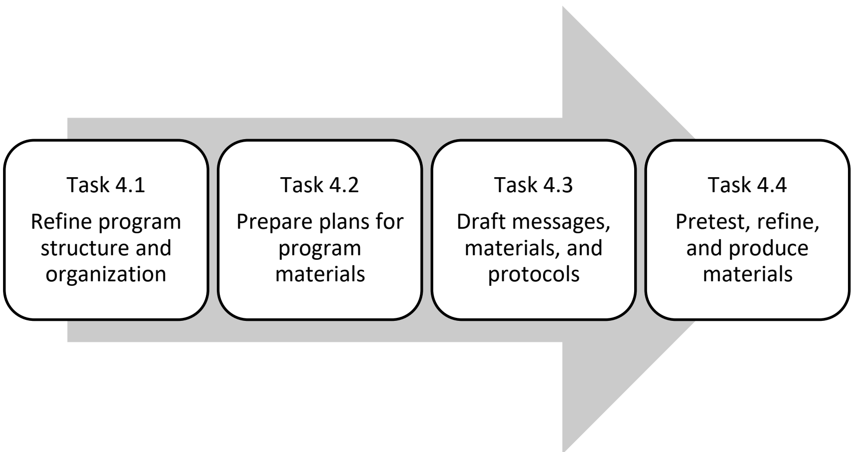

Figure 3.3: Tasks of Intervention Mapping Step 4
(adapted from Eldredge et al., 2016)

We added new creative team members such as software developers, graphic designers, a cameraman, and a user interface designer. Regarding the question *“Where are potential program participants going to interact with the program?”*, we considered a highly flexible intervention context in daily family life. We acknowledged different circumstances and settings both for the use of the *TRIANGLE* app and for the targeted habits. Being familiar with existing programs, we saw the need to produce new program materials. Therefore, we developed a set of design documents to guarantee that the content matches the *TRIANGLE* app features. In addition, we considered aspects of program implementation such as ease of use, low complexity, and as little staff requirements as possible while maintaining program goals and behavior change methods.

Once the first prototype of the *TRIANGLE* app was available, we included women post-GDM in the development process. Women post-GDM pretested the *TRIANGLE* app with limited content and further program materials in a user study (Chapter 3.2.4.1). After some adaptations, women post-GDM tested the full *TRIANGLE* program in the *Test TRIANGLE Pilot Study*, a six-month multicenter randomized controlled pilot study for preliminary data on clinical efficacy (Chapter 4).

Except for the mockups, all following tables and figures include material as tested in the *Test TRIANGLE Pilot Study* to avoid unnecessary duplication of similar materials after minor adaptations in different app development phases. Differences in program materials as tested in the *TRIANGLE* user study and the following adaptations are described in Chapter 3.2.4.2.

3.2.1 Refine program structure and organization (Task 4.1)

The question *"Are the program components and materials feasible given budget and time constraints?"* required the final definition of sub-features for the *TRIANGLE* app and the coaching platform as well as details for the content. This process took several iterative cycles with our external partners.

3.2.1.1 *Define technical core features and sub-features*

With the idea for the three core features in mind, we had a closer look at the apps and usability studies identified during the market research to learn about proven sub-features. This process helped us to decide between different alternatives. Further, we used an approach similar to the SIREN (SImple Reuse of softwarE requiremeNts) method to draw on previously established requirements and to ensure the reusability of our requirements [896]. Table 3.4 includes the technical features and sub-features of the *TRIANGLE* smartphone app and coaching platform as tested in the *Test TRIANGLE Pilot Study*.

3.2.1.2 *Define app content*

We prioritized the need for multimedia files (video, audio, and images) per lifestyle area. Given budget and time constraints, we decided to limit video production to an introduction video of the app [822], a medical background video, and 54 videos related to physical activity. We scripted 27 home fitness videos with an experienced female personal trainer to ensure guided practice suitable for women post-GDM. Five of the physical activity videos were planned for fitness self-tests and 22 for short tutorials within library articles. Further, we limited audio recordings to psychology. We considered guided audio practice crucial for six mindfulness and two progressive muscle relaxation exercises. Last, we decided to include at least one image per library article. Our final list included 241 images for 133 planned library articles. We aimed at guaranteeing a high quality of all media files. Therefore, we borrowed or obtained respective equipment and expertise.

Further, we limited the list of *TRIANGLE* challenges to 136 challenges. The list of challenges covers the intended performance objectives from Intervention Mapping Step 2 and offers some options for tailoring to BMI, preferences, and/or level of experience. Lastly, we decided to assess a participant's starting point in all three lifestyle areas with an extensive paper and pencil questionnaire prior to the intervention. Twelve additional short questionnaires were to be included directly in the *TRIANGLE* app. Hence, we first defined the required types of questions for the simple in-app questionnaire tool in accordance with the Apple® ResearchKit® (Supplementary Table 4). The resulting in-app questionnaires as tested within the *Test TRIANGLE Pilot Study* are listed in Supplementary Table 5, with limited free text input as suggested by a recent review [822].

Table 3.4: Technical core features and respective sub-features of the TRIANGLE app

Technical core feature	Technical sub-feature app	Technical sub-feature coaching platform
Challenge system	• Open and close challenge information • Accept challenges • Plan challenges in the morning, in the afternoon or in the evening; for weekly challenges also plan days of a week • Update challenge planning • Terminate challenges • Tick off challenges (retrospectively) • Undo ticked off challenges (retrospectively) • Play a video or audio file in a challenge • Grade a challenge upon completion	• Add challenges in an advanced organizer structure • Filter challenges per module and status per participant • (De-) activate challenges per participant • (Un-) recommend some of the activated challenges per participant • View challenge activities per participant
Progress visualization (part of challenge system)	• View weekly and monthly progress per active challenge • View history of completed challenges	• View progress per challenge per participant • Filter challenges by challenge status per participant
Coaching	• Receive/send text messages from/to coach • Search for keywords in text messages • Receive and fill in questionnaires • Send questionnaire results to coach • Receive and open recommended library articles	• Receive/send text messages from/to participant • Search for keywords in text messages per participant • Create and activate new questionnaires • Send questionnaires to participant • Receive questionnaire results per participant • Recommend library articles per participant
Library	• Access all articles grouped by themes at any time • Open and close a library article and linked library articles • Search for keywords in library • Play a video or audio file in a library article	• Add new categories for articles • Add new articles • Activate new articles • View opened articles per participant
Settings	• Set reminders • Download media files • Report technical bugs	• View registration and basic app activities per participant • Manage media files • Generate new login codes • Link 4-digit login code to a participant's chosen nickname • View error log per participant

3.2.2 Prepare plans for program materials (Task 4.2)

Once the scope of the program materials and the technical features were set, we started to create design documents and mockups per feature. Thereby, we adhered to the identified change objectives, behavior change methods, and the method-matched practical applications.

3.2.2.1 *Ensure sociocultural fit for women post-GDM in Germany*

We aimed at a sociocultural fit specific for women post-GDM in Germany with the following five measures: 1) We hired a female personal trainer in her mid-thirties for all fitness videos, corresponding to the average age of women post-GDM. Similarly, we chose females around their thirties or females with infants/families for all app images. 2) We composed an introductory article with an expert video stressing the heightened cardiometabolic risk despite the participants' young age. 3) We used an informal and colloquial linguistic style for all program materials appropriate for women post-GDM. Therefore, we included at least one female around her thirties in each work group. 4) We utilized our team's strong representation of females around their thirties. Those not being part of the project team gave us valuable informal feedback and suggested improvements for program materials. 5) We addressed sociocultural values in the behavioral and educational messages. They included Central European traditions (especially festivities such as Christmas or Easter), family responsibility, and care for family members. Considering time and budget, we excluded tailoring for cultural subgroups in the first version of the app.

3.2.2.2 *Prepare design documents for software development*

We based the initial design documents on a content management system to brief and contract a software company. The design documents included app features and desirable sub-features. The briefing also comprised:

1) Medical background with specific app requirements for women post-GDM
2) The three app themes
3) Data protection issues
4) Types of content for the data base
5) The work flow for user registration, user-coach interactions in the *TRIANGLE* app, and information flow between involved parties (Figure 3.4)

We met regularly and used the project management software Jira® by Atlassian (Sydney, Australia) for software development.

3.2.2.3 *Prepare design documents for lifestyle content*

The design documents for lifestyle content included style templates for questionnaires, challenges, and library articles. The documents specified layout and text requirements, advance organizers, chunking, multimedia file formats, and hyperlink options. Thereby, we addressed some of the mHealth-related challenges such as a short attention span regarding smartphones, and screen limitations for design and characters. Table 3.5 shows an exemplary design document for content as tested within the *Test TRIANGLE Pilot Study*. We briefed the lifestyle work groups in all feature-based design documents and stressed the importance of short, simple, and understandable texts to avoid excess reading and scrolling [822]. During follow-up meetings, we discussed the produced content to guarantee coherence between the three lifestyle areas in the separate work groups.

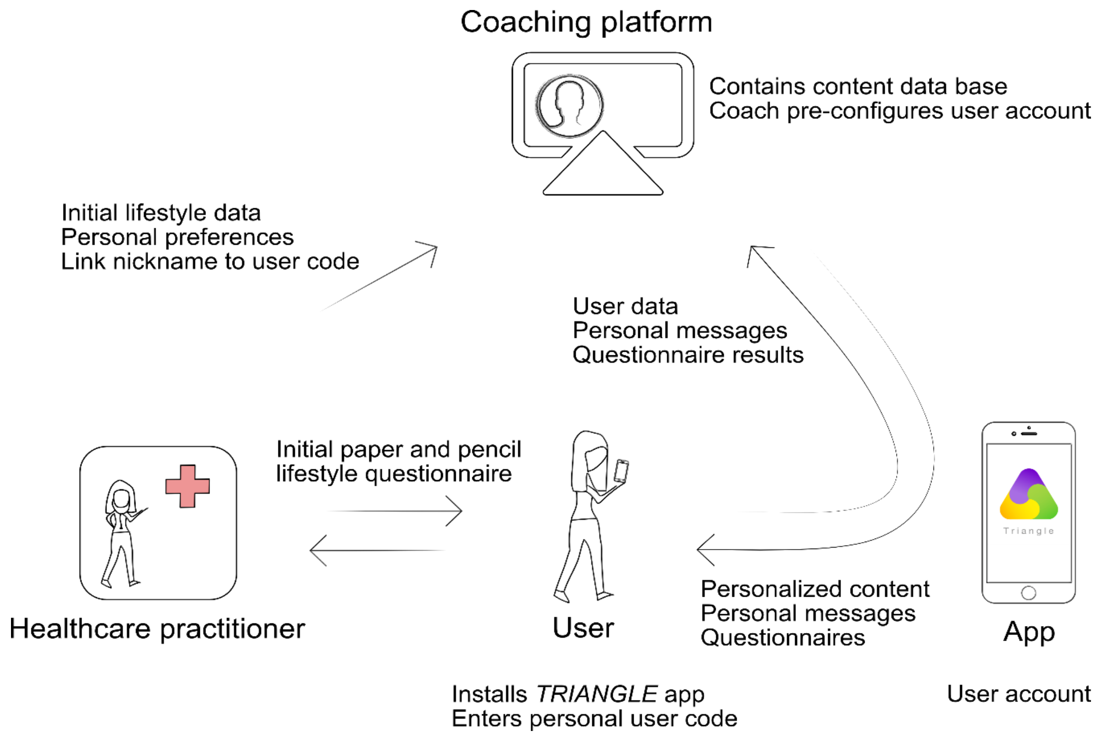

Figure 3.4: TRIANGLE app and coaching platform work flow

3.2.3 Draft messages, materials, and protocols (Task 4.3)

In task 4.3, the lifestyle work groups prepared all program materials and protocols in parallel to the software programming.

3.2.3.1 *Develop mockups of the TRIANGLE app features*

We decided to limit the initial software programming to the iOS system for iPhones based on the initial software engineering meetings, and time and budget limitations. Starting with the mockups, we considered a high traceability, interoperability, and software reuse for future similar mHealth projects in our documentation [824] – including guidelines such as the iOS Developer Human Interface Guidelines, as recommended in a review on mHealth apps [824]. Our goal was to ensure a high standard and usability for the *TRIANGLE* app. The user interface designer created first interactive mockups for our previously specified set of core features (Figure 3.5).

Table 3.5: Design document for TRIANGLE challenges, exemplary for the walking challenge

Change objectives per determinant	Methods	Message content *(required specifications)* and related information
Behavioral knowledge: Get informed about the benefits of walking at least 8,000 steps per day and learn how to do so.	Chunking and advance organizers	**Lifestyle area:** physical activity *(select physical activity, nutrition, or psychology)* **Title:** "Walk at least 8,000 steps" *(one-liner)* **Abbreviation** (visible in coaching platform only): ALLTGL32 *(maximum 17 characters)* **Text upon completion:** Keep going! You've already reached 8,000 daily steps for several days. If you'd like to go to the next level, you can now increase your steps to 10,000 per day. If the 8,000 steps are not habitual yet, then keep prolonging the current challenge until it feels normal to walk 8,000 steps per day. **Extension:** Yes *(yes/no)* **Icon:** Walking person *(choice of 37 icons)* **Required number of successful days per week:** 5 *(select number between 1 and 5)* **Required successful weeks until completion:** 3 *(select number between 1 and 8)* **Following challenge:** (visible in coaching platform only)**:** ALLTGL33 *(maximum 17 characters)* **Text appearing in app:** *(select and write text according to suitable behavior change methods below)*
	Using imagery	Walk as if pacing to a fast song. The suggested walking pace of at least 100 steps per minute is the pace used in many songs. Walking a fast pace is easier to maintain with musical support.
	Elaboration	Think about creative walking opportunities in own daily life during a usual day.
	Framing *(use gain frame)*	Health benefits arising from walking at least 8,000 steps per day *(list two to five)*: • Normal body weight: Facilitates body weight maintenance • Overweight: Supports slow and long-term body weight reduction
Commitment: Decide to commit to walk at least 8,000 steps per day.	Persuasive communication	Put the required time of 100 minutes for 8,000 steps per day into perspective compared to other usual activities.

Table 3.5 (continued)

Change objectives per determinant	Methods	Message content *(required specifications)* and related information
Commitment: Acknowledge the habitual character of walking at least 8,000 steps per day.	Consciousness raising	Daily walking is habitual and includes choosing stairs instead of the elevator and parking the car a little farther to walk the rest/alighting public transportation at least one station before the actual stop.
Self-efficacy: Feel confident about walking 8,000 steps per day.	Guided practice	Video with personal trainer on posture during walking.
	Enactive mastery experiences	App will automatically suggest the chained challenge "Walk at least 10,000 steps" upon successful completion.
Skills: Express confidence in ability to walk at least 8,000 steps per day, or to learn how to do so.	Goal setting	Information chunks and advance organizers as specified above contain goal-setting principles.
	Set graded tasks	Next easier version of "Walk at least 8,000 steps" is "Walk at least 5,500 steps", next more challenging version is "Walk at least 10,000 steps".
Outcome expectations: Expect walking at least 8,000 steps will lead to numerous health benefits.	Environmental reevaluation	Serve as a role model for family by walking at least 8,000 steps a day.
	Arguments	Get used to fast-paced walking. Initially use music as pacemaker to increase walking speed, shorten walking time, and maximize health benefits.
Habits: Maintain to consistently walk at least 8,000 steps per day until habitual.	Counterconditioning	Keep walking 8,000 steps every day. Replace seated leisure activities with walking and/or seated transportation with active transportation until habitual.
	Early and partially public commitment	Accept and commit to the challenge "Walk at least 8,000 steps" for long-term health benefits, knowing that the personal coach serves as commitment buddy. Involve your social network and walk with others.
	Reinforcement	Information chunks and advance organizers as specified above contain text upon completion.

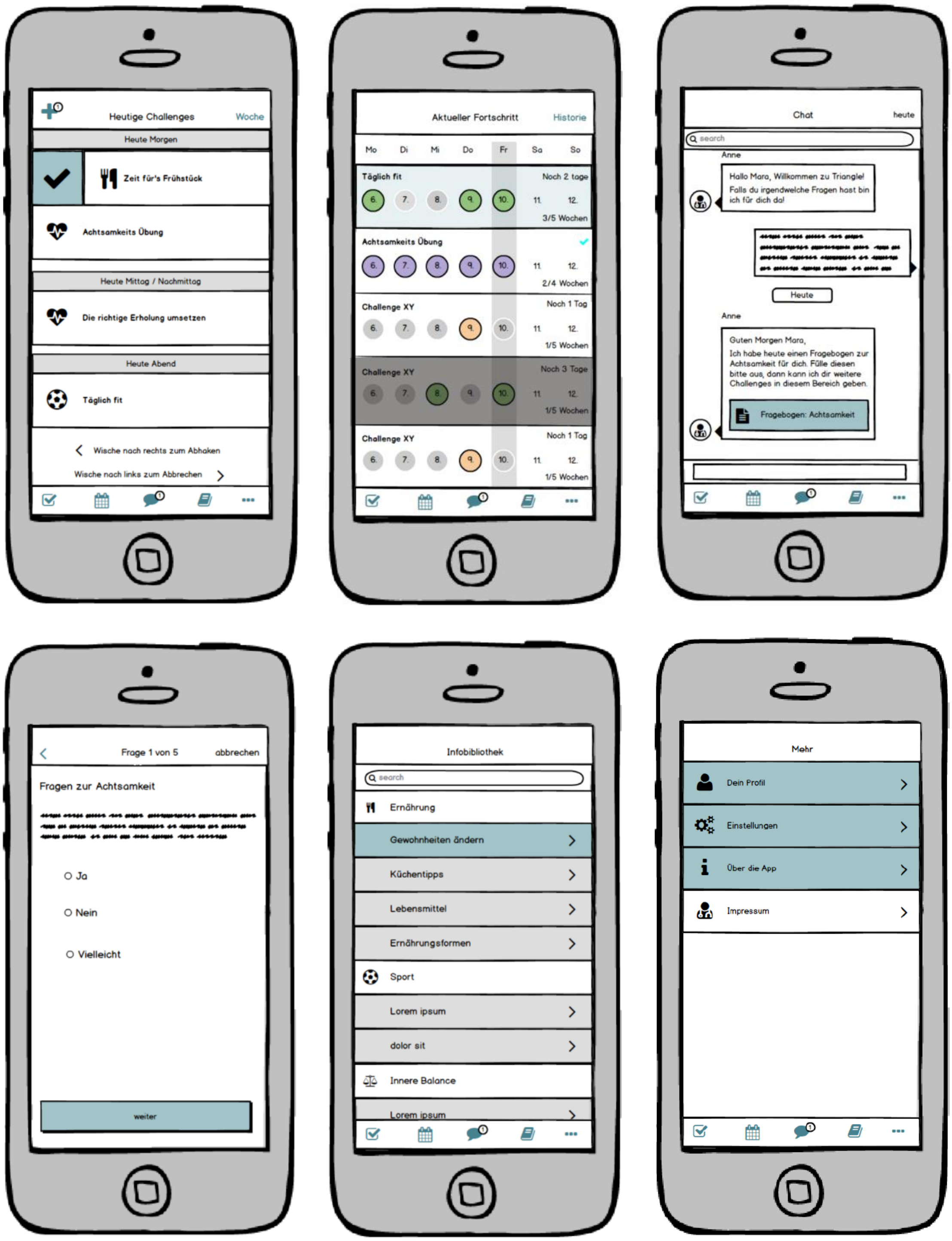

Figure 3.5: Mockups for the TRIANGLE core features and settings
From left to right top-down: *challenge system:* activity screen based on active challenges, weekly progress visualization per challenge; *coaching*: chat with personal coach, in-app questionnaires; *library* with categories per theme; settings

3.2.3.2 *Specify collected user data*

Next, we defined which type of motion data was essential for tailoring and individualization (Table 3.6). We specified our data collection in line with the General Data Protection Regulation. In the *TRIANGLE* privacy policy, we further specified that the user remains the owner of the data.

Table 3.6: Specification of the collected TRIANGLE app data per user

Technical core feature	Actor	Motion data of technical sub-feature with time stamp
Challenge system (including progress visualization and reminders)	Coach	• (Un-) marked challenge as suitable for user • (Un-) recommended challenge for user
	User	• Opened challenge description • Accepted challenge • Played video or audio file in challenge • Ticked off challenge (retrospectively) • Undo ticked off challenge (retrospectively) • Terminated challenge • Prolonged challenge • Completed challenge • Changed reminder
Coaching	Coach	• Sent text message to user • Sent questionnaire to user
	User	• Sent text message to coach • Completed questionnaire
Library	Coach	• Sent library article to user
	User	• Opened library article • Played video or audio file in library article
Other	User	• Registered with individual code

The following encryption and authentication measures were used to protect against data misuse by third parties:

- Web data exchange via Secure Sockets Layer (SSL)-encryption
- Key strength 2048 bit
- End-to-end encryption
- Authentication via personal four-digit login code

In addition, we informed participants of the remaining risk of data misuse by data linkage from different sources on mobile devices.

3.2.3.3 *Design app and logo*

Two graphic designers developed the *TRIANGLE* logo based on our sketches of an intertwined health triangle and the color scheme of the three lifestyle areas (Figure 3.6).

Triangle

Figure 3.6: TRIANGLE logo

We decided to match the color scheme of the app's content per lifestyle area with the *TRIANGLE* logo while granting sufficient contrast to the white background (Figure 3.7, left) [822]. For practical reasons of text coloring with a white background, we chose a very dark shade of yellow for physical activity that appears rather orange (Figure 3.7, left) [824]. For the overarching color scheme, we selected shades of dark gray for the text and a predominant light blue-white coloring often used for digital healthcare (Figure 3.7, right) since a predominant black coloring was found to be "repulsive" in mHealth apps [822].

Figure 3.7: Color scheme of the TRIANGLE app
Lifestyle modules (left), and overarching color scheme (right)

3.2.3.4 *Program the TRIANGLE app*

The software work group programmed the iOS app for iPhones. After each programming step, we tested the features. Once the programming was finished, both the involved researchers and the software engineers engaged into thorough alpha testing of the app prior to the *TRIANGLE* user study. Our goal was to identify and rectify technical issues before the study started.

3.2.3.4.1 Core features

The core features remained as specified in the mock-ups. Figure 3.8 shows the screenshots of the refined post-user study iOS app as used in the *Test TRIANGLE Pilot Study*.

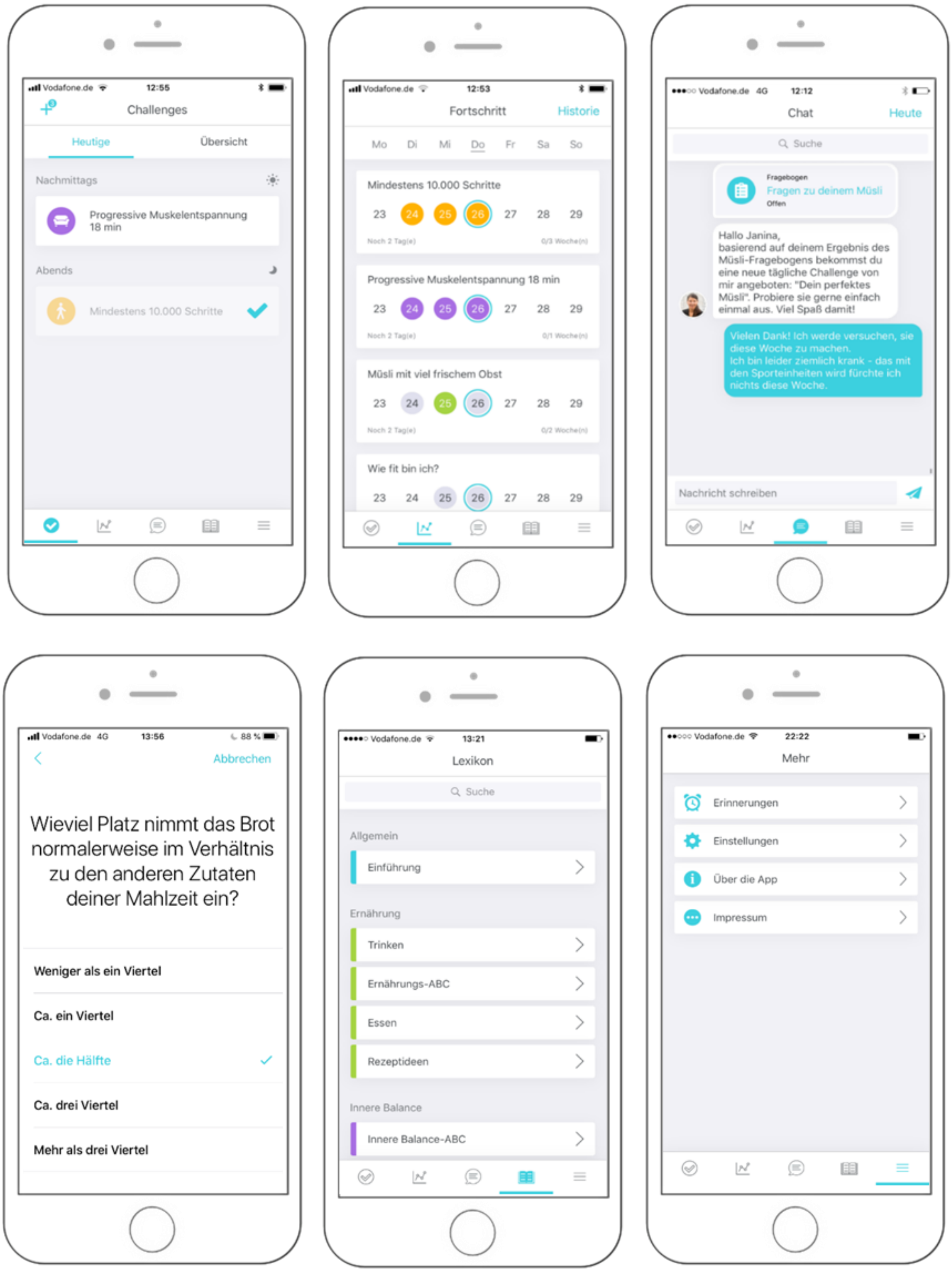

Figure 3.8: Screenshots of the TRIANGLE app core features and settings
From left to right top-down: *challenge system:* activity screen based on active challenges, weekly progress visualization per challenge; *coaching*: chat with personal coach, in-app questionnaires; *library* with categories per theme; settings

3.2.3.4.2 Challenge system

For the activity screen, we included the sub-features as specified in Table 3.4. Regarding the icons, we differentiated between challenges of daily frequency (round) versus those of lower than daily frequency (quadratic) (Figure 3.9). We further decided to individualize both a broader set of challenges a participant can access (“all”) and a narrower set of challenges (“recommended”) – to enable choice, but to prevent overwhelm. In line with the research on habit formation described in Chapter 1.3.1, we allowed for challenge planning and respective reminders at three times of the day (morning, afternoon, and evening). Weekly challenges additionally required selected days of a week.

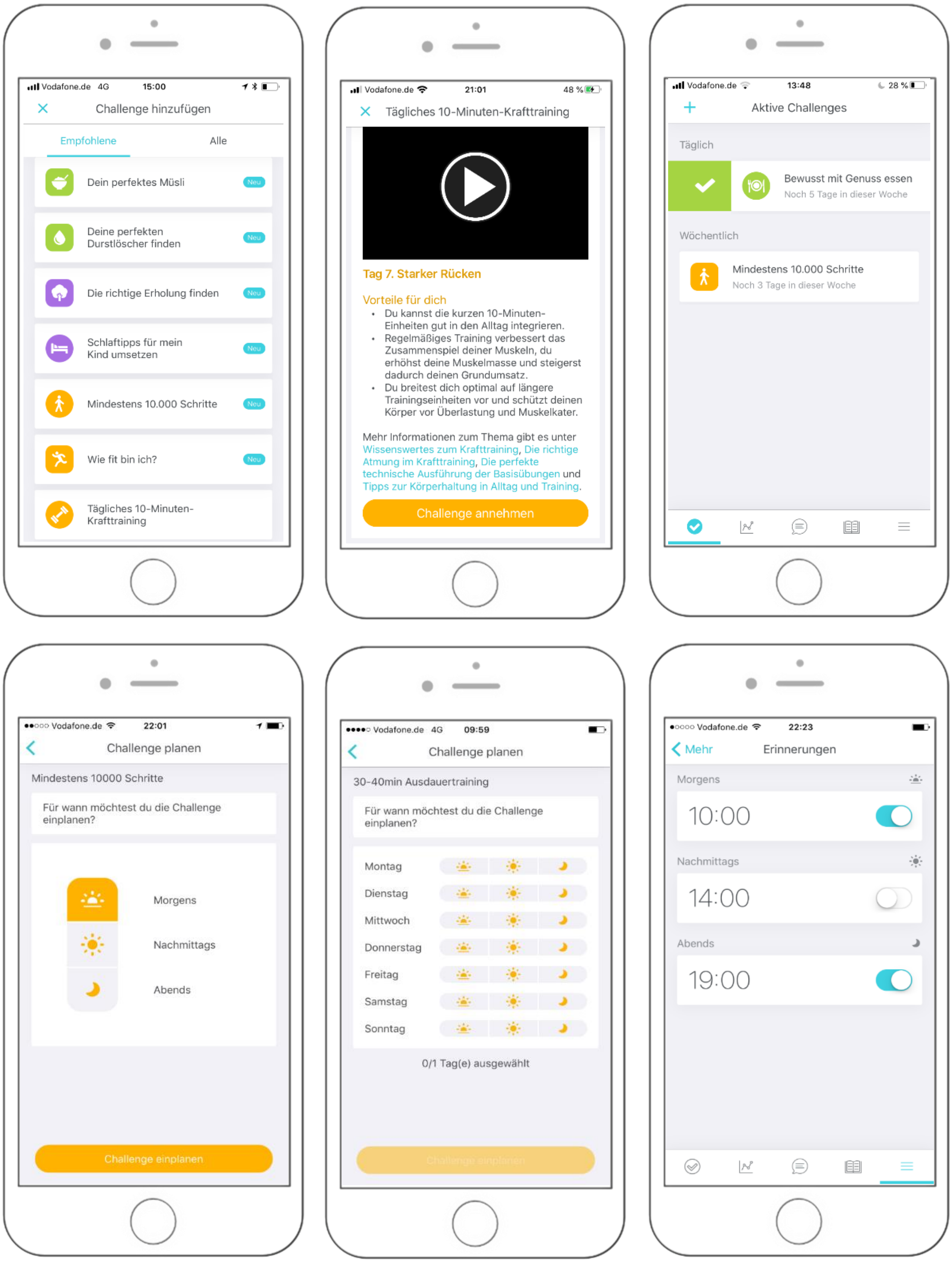

Figure 3.9: Screenshots of the sub-features of the TRIANGLE app challenge system
From left to right top-down: challenge selection, acceptance, ticking off, planning of a daily challenge, planning of a weekly challenge, and setting reminders

The progress visualization contained weekly and monthly progress streaks per active challenge. Successful days and weeks appear in the color of the respective lifestyle area (Figure 3.10). A week of a daily challenge is labeled “successful” if five out of seven days were ticked off. A weekly challenge is labeled “successful” if the pre-set number of days was ticked off in a given week. Beneath the monthly streak, a progress bar shows the successful weeks in relation to the requried number of successful weeks for challenge completion. Once a challenge is completed, the participant receives a pop-up message to either end or prolong the challenge for another week. If the participant prolongs a challenge, the progress bar extends, too. The participant receives a summary of every challenge with the start and end date, the total number of active days, and the number of successful days.

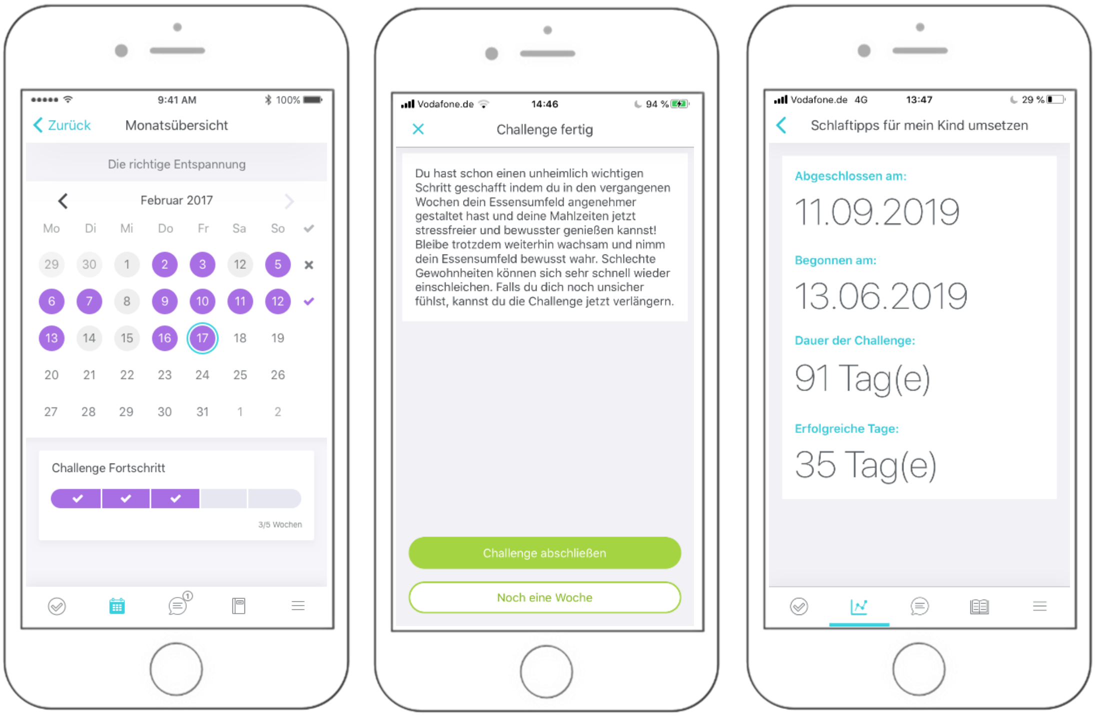

Figure 3.10: Screenshots of the sub-features of the TRIANGLE app progress visualization for challenges
From left to right: monthly progress, option to prolong a challenge upon completion, and challenge history

3.2.3.4.3 Coaching

Next to the mentioned chat (see above, Figure 3.8), the coaching feature includes a search for keywords in previous text messages and allows for the reception of library articles and questionnaires from the coach (Figure 3.11). The coaching option to send single library articles allows for tailored information while the chat allows for individual and interactive feedback, as required for apps promoting health behaviors [897]. The participant can directly fill in questionnaires in the app and send the results to the coach. To get notified of coaching activities, the participant can allow to receive push notifications for new coaching messages, challenges, library articles, or questionnaires.

3.2.3.4.4 Library

Next to the search feature within the library and different thematic categories (see above, Figure 3.8), the library includes articles with different types of multimedia files (Figure 3.12).

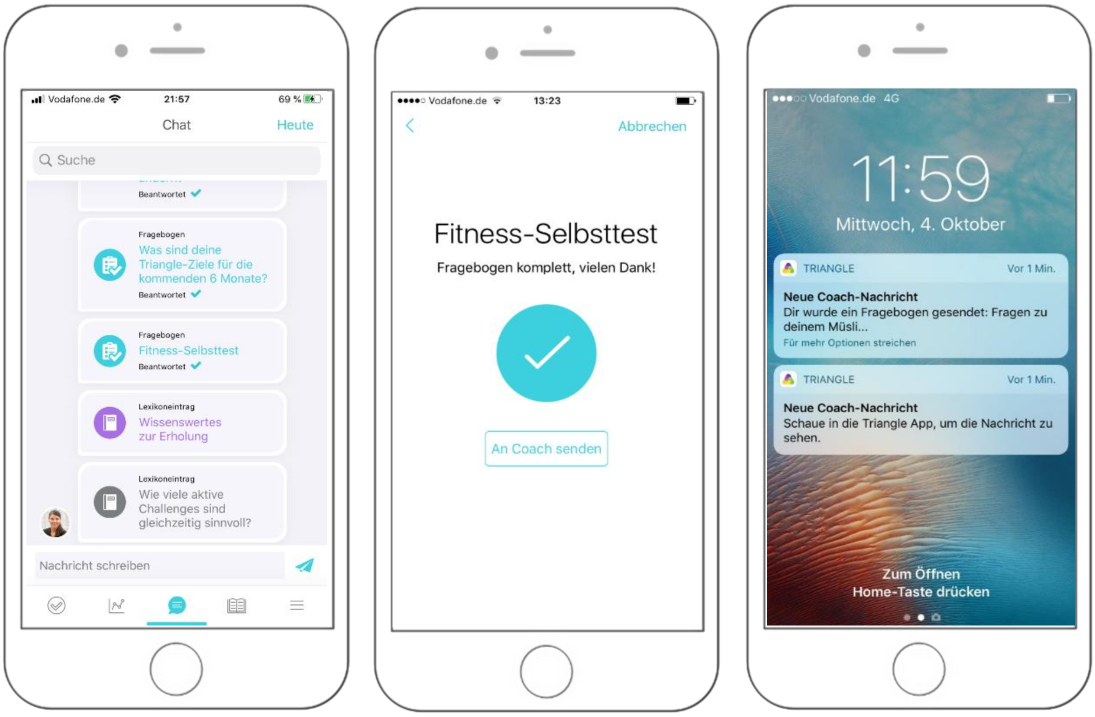

Figure 3.11: Screenshots of the coaching sub-features of the TRIANGLE app
From left to right: personal chat with text, keyword search, and received library articles and questionnaires; confirmation for a completed questionnaire, coaching notifications on the iPhone home screen

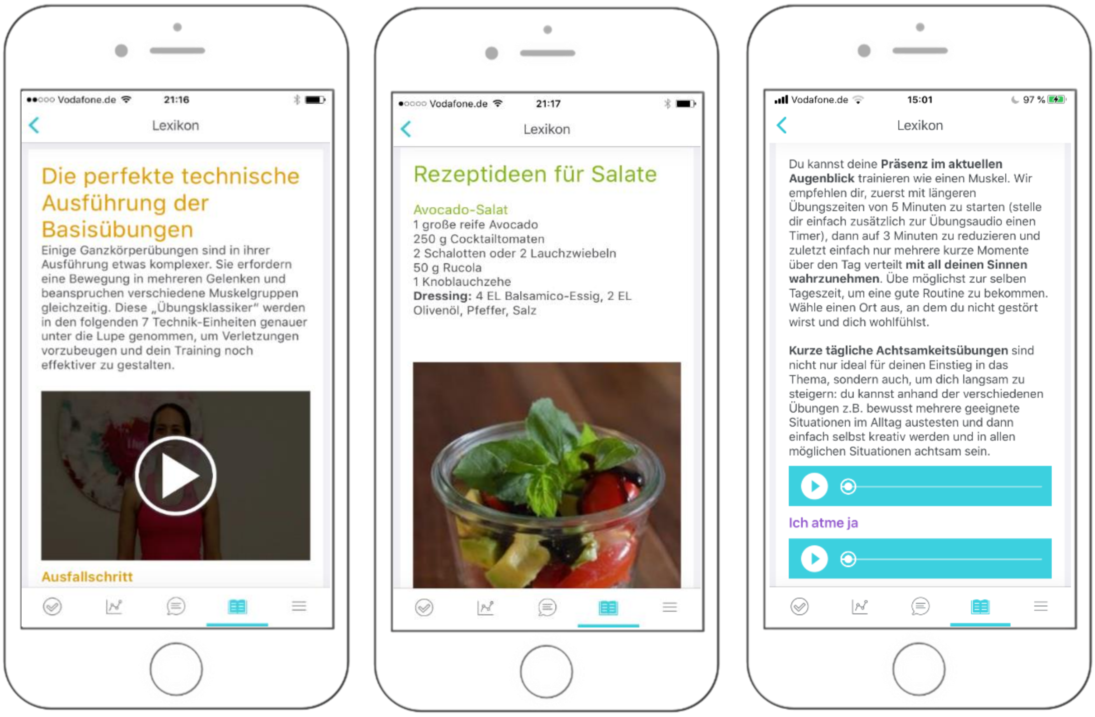

Figure 3.12: Screenshots of multimedia elements in the TRIANGLE app library
From left to right: video, image, and audio

3.2.3.4.5 Online content management and coaching platform

All *TRIANGLE* app sub-features are mirrored in the coaching platform (challenges, library, questionnaires), with additional features for the management of users, tokens, media files, and data export. Figure 3.13 exemplarily shows the underlying content management system for multimedia files.

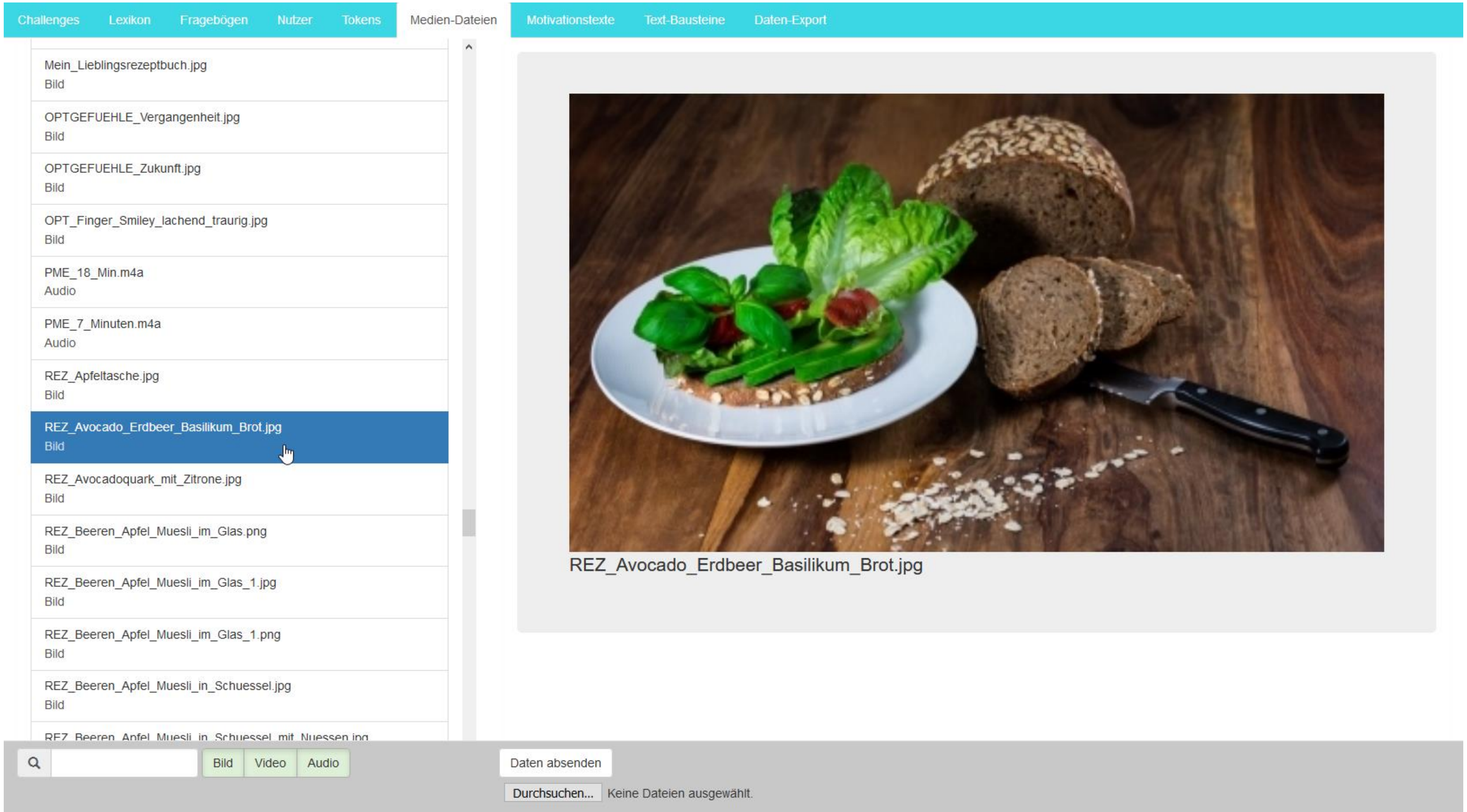

Figure 3.13: Exemplary screenshot of the TRIANGLE coaching platform

3.2.3.4.6 The onboarding process

We schemed a step-by-step guide for participants to support their app registration (Figure 3.14).

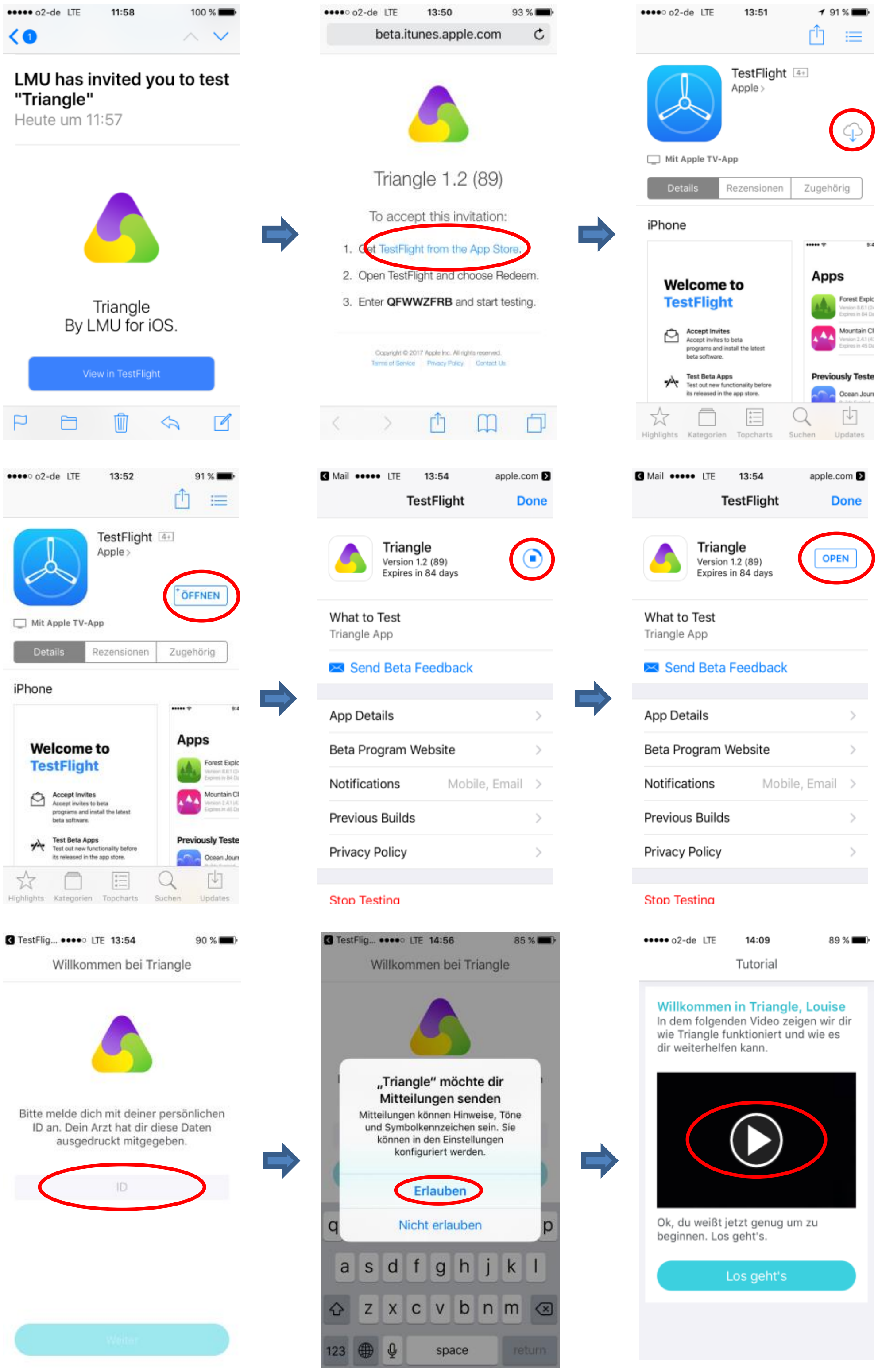

Figure 3.14: Step-by-step user guide for the TRIANGLE app registration

3.2.3.5 *Design the initial paper and pencil questionnaire*

Once the lifestyle work groups completed a first version of content, we were able to create the initial paper and pencil questionnaire for tailoring and individualization of the *TRIANGLE* program. The questions addressed past and current habits, stages of change, outcome expectations, attitudes, self-efficacy, social norms, individual preferences, and personal goals in the three lifestyle areas (Supplementary Table 6).

3.2.4 Pretest, refine, and produce program materials (Task 4.4)

We pretested all main *TRIANGLE* intervention components in a small-scale (n = 11) user study. A high app usability in mHealth is crucial for user engagement and intervention success [830, 898-900]. The findings helped us to refine the design documents, to produce user-approved program materials, and to adapt the *TRIANGLE* app.

3.2.4.1 *TRIANGLE user study*

The *TRIANGLE* user study was a monocentric single-arm first user evaluation of the *TRIANGLE* intervention with an explorative multi-methods design. It aimed at testing user acceptance and first usage patterns of the iOS *TRIANGLE* app and other program materials. We formulated the following three clusters of research questions:

1) <u>User acceptance</u>: *"Is the TRIANGLE app accepted by the intended users (women post-GDM)?", "What is the user's perceived impact of the TRIANGLE app on behavior in a test period of a) approximately one week and b) approximately four weeks?"*
2) <u>Usage</u>: *"How frequently do users operate the TRIANGLE app, its features, sub-features, and themes in a test period of a) approximately one week and b) approximately 4 weeks?", "During what time of the day is the app used?", "Are all TRIANGLE sub-features used across the three lifestyle areas?"*
3) <u>Observational and qualitative feedback</u>: *"Can the TRIANGLE app be used intuitively by women post-GDM or are there any confusing or help-requiring features, sub-features, or content?", "Is the TRIANGLE app content clear and understandable for women post-GDM?", "Do TRIANGLE app features and content meet users' expectations?"*

3.2.4.1.1 Materials and methods

The *TRIANGLE* user study contained two test rounds with at least five participants per group since this is the number of participants to detect about 80% of the issues during usability testing [901, 902]. The mixed methods design was based on validated questionnaires on user acceptance, user logs, and think aloud sessions with semi-structured interviews (Table 3.7). A combination of subjective and objective methods is recommended for studies on mHealth usability [822] and has been applied in similar projects [834, 899, 903]. We pretested the protocol for the one-on-one sessions on two individuals from the study team who were not involved in the project. The user study included two visits at the study center of one to two hours of duration. At the beginning of visit 1, each participant gave written informed consent to participate in this study. The *TRIANGLE* app was used for a predefined period between the two study visits. The first group tested the app for approximately one week (7 days + maximum 7 days) and the second group tested the app for approximately four weeks (± maximum 7 days). The study was approved by the Ethics Committee of the Medical Faculty of the Ludwig-Maximilians-Universität in Munich, Germany. Risks were negligible for participants since all recommendations of the provided intervention materials are in line with evidence-based guidelines and standard recommendations by healthcare practitioners. App recommendations do not exceed common behaviors or leisure activities. Participants were insured for accidents for the duration of their clinical visits and the direct way between their home address and the study site. The study was funded by the Else-Kröner-Fresenius-Stiftung in the scope of the development of this mHealth intervention.

Table 3.7: Mixed methods design of the TRIANGLE user study

	Visit 1	App testing	Visit 2
	3-60 months post-GDM	Group 1: for 1 week Group 2: for 4 weeks	Group 1: after 1 week Group 2: after 4 weeks
Verification of in- and exclusion criteria	X (prior to visit 1)		
Informed consent	X		
Anamnesis	X		
System Usability Scale (SUS) and user Mobile Application Rating Scale (uMARS)	X		X
User registration app	X		
In-app questionnaires		X (optional)	
User logs	X	X	X
One-on-one "think alouds" with subsequent semi-structured interview	X		X

GDM = gestational diabetes mellitus

3.2.4.1.1.1 Participants

The study team recruited participants consecutively via phone interviews from the patient base of the Medical Center of the University of Munich between mid-June and mid-July 2017. The inclusion criteria were a medical diagnosis of GDM in a recent pregnancy, three months to five years postpartum, completed rebuilding after delivery with no major sporting restriction, ownership of an iPhone model 5 to 7 Plus, and fluent German skills. The exclusion criteria comprised age below 18 years, current pregnancy (anamnestic), cardiopulmonary disease or restrictions in the locomotor system contradicting a sports intervention, gastrointestinal disease contradicting a nutrition intervention, psychiatric disease requiring psychotherapy or medical therapy, other serious illness contradicting a lifestyle intervention according to the principal investigator, and alcohol or drug abuse. The study team verified in- and exclusion criteria prior to the initial visit. Participants could terminate the study by withdrawing their consent. They were compensated for travel expenses and received the following incentives for study participation: one children book per visit, the *TRIANGLE* paper note pad, and a step tread. In addition, a Garmin vívosmart® HR fitness tracker (Garmin Ltd., Olathe, USA) was provided for the duration of the study.

3.2.4.1.1.2 Measurements

Measurements for the *TRIANGLE* user study comprised:

1. Validated questionnaires on user acceptance
2. User logs *TRIANGLE* app
3. Protocols from the think alouds with semi-structured interviews

The questionnaires during visit 1 included a social anamnesis, a medical history comprising the pregnancy, smartphone and app usage, and two validated questionnaires on app acceptance. (the System Usability Scale (SUS) [904] and the user version of the Mobile Application Rating Scale (uMARS) [905]). The questionnaires on app acceptance were also assessed during visit 2.

The SUS Score is based on 10 items on a five-point Likert scale ("strongly disagree" to "strongly agree"). Participant's scores for every SUS item are converted according to the SUS analysis protocol (for items 1, 3, 5, 7, and 9: scale position minus one, for items 2, 4, 6, 8, and 10: five minus the scale position). The respective numbers are summed and multiplied by 2.5 to reach a participant's SUS score ranging from 0 to 100 [904].

The uMARS is suitable for collecting user feedback during app development and early app testing. It delivers insights on app quality for developers [905]. We decided to incorporate the uMARS in addition to the SUS and despite the lacking validation of the German uMARS version due to its high specificity for mHealth apps. We cooperated with the Department of Clinical Psychology and Psychotherapy in Goettingen for translation and back-translation of the questionnaire by four persons, respectively. The uMARS contains three main parts: The App Quality Mean Score, the App Subjective Mean Quality Score, and the Perceived Impact Mean Score. In total, the uMARS contains 26 items based on 5-point Likert scales with different labels per item. The App Quality Mean Score includes 16 items across four subscales on engagement, functionality, aesthetics, and information. The App Subjective Mean Quality Score comprises four subjective items on individual recommendation, usage frequency, monetary value, and overall rating of the app. The Perceived Impact Mean Score is based on behavioral awareness, knowledge, attitudes, intention to change, help seeking, and health behavior change related to the app.

During visit 1, participants received all program materials – the *TRIANGLE* app, a Garmin vívosmart® HR fitness tracker including the user manual, a step tread for the fitness self-test, the *TRIANGLE* paper note pad, and an individual login code for the *TRIANGLE* app. For data security issues, we offered participants to use the Garmin vívosmart® HR fitness tracker without the respective app. Participants signed a non-disclosure agreement and a form confirming the provisional receipt of the Garmin vívosmart HR® fitness tracker. All participants received standardized instructions for the test period:

1) To test the app on a daily basis
2) To conduct the fitness self-test
3) To use all supplementary materials

During the approximately one (group 1) or approximately four weeks (group 2) of app testing, <u>user logs</u> captured user and coach activities in the *TRIANGLE* per participant. User logs included user code, nickname, activity type, questionnaire results, and time stamps of predefined app activities (Table 3.8).

The two groups received the *TRIANGLE* intervention via the app as specified in the previous chapters. In the *TRIANGLE* user study, the app content was limited to two in-app questionnaires, 27 challenges and further 14 variations thereof, and 36 library articles (Supplementary Table 7). The challenges and library articles for the user study included 35 images, six audio files, and 36 videos. At the end of visit 2, participants deinstalled the app.

Table 3.8: Tracked activities in TRIANGLE app user logs

User activities	Coach activities
• Opened challenge information • Planned challenge • Updated challenge planning • Ticked off challenge • Prolonged challenge • Postponed challenge • Terminated challenge • Completed challenge • Opened library article • Played guided practice (video or audio in library or challenge) • Sent text message • Completed questionnaire • Changed reminders	• (Un-) marked challenge as suitable for user • (Un-) recommended challenge for user • Sent text message to user

The think alouds aimed at identifying potential user problems with the app's user interface. Further, we wanted to gain more insights on problem-solving behaviors by women post-GDM when using the app, starting with the installation. During the one-on-one think alouds followed by a semi-structured interview, the users solved 30 small tasks in the *TRIANGLE* app according to a test protocol – similar to previous trials applying this method [834, 906]. The tasks included app installation, registration, watching the introductory video, and working with all *TRIANGLE* sub-features. Thereby, participants were instructed to comment on their actions and impressions (think aloud) [907, 908]. For standardization of the think alouds, all participants received the same challenges under "suitable" and "recommended". Further, every participant received a standardized introduction to the test method. The introduction involved a short online video of an exemplary think aloud session to get familiar with the procedure before the test started.

All think aloud sessions were conducted by one investigator (the author). The investigator read aloud each task, observed participants while completing the task, and ticked off a checklist with free spaces to take notes. The notes included observations such as a participant's navigation process, noticeable problems, behaviors or body language, questions, and expressed thoughts per task. The investigator interrupted the participant only in case of difficulties in maintaining to think aloud. The prompts to support thinking aloud included *"What is on your mind?", "Tell me what you are thinking."* or *"What are you looking at?"*. Each session was audio-recorded, with an additional record of the smartphone screen activities with prior consent by the participant (Figure 3.15.). In the experimental set-up, the investigator was seated outside the participant's field of vision to minimize visual influences.

The semi-structured interview at visit 1 contained 13 questions on the overall impression and subjective experience with the *TRIANGLE* app, and two questions on *TRIANGLE* challenges. The questions for the semi-structured interview at visit 2 comprised 24 general questions on the overall impression and subjective experience with the *TRIANGLE* intervention, seven questions on *TRIANGLE* challenges, three questions on expectations and initial successes in habit change, and four questions on the didactic design of the *TRIANGLE* app. The semi-structured interviews were audiotaped with prior consent by a participant.

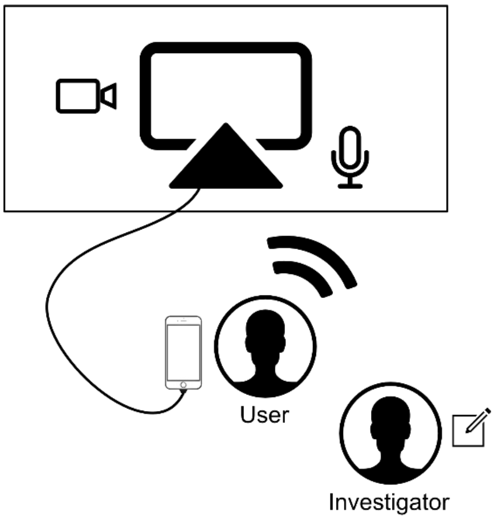

Figure 3.15: Test set-up of the think aloud sessions in the TRIANGLE user study

In preparation for the qualitative data analyses of the think alouds with semi-structured interviews, the investigator added notes from the screen and audio recordings to the existing notes taken during the session. We did not aim at transcribing the full recordings since our goal was to gain timely insights and important user feedback for the planned clinical pilot study rather than conducting a full qualitative data analysis.

3.2.4.1.1.3 Data handling

All collected data were treated confidentially and pseudonymized (four-digit code). All *TRIANGLE* app data was collected on the clinic server of the Medical Center of the University of Munich and encrypted as specified in Chapter 3.2.3.2. Participants signed the *TRIANGLE* app privacy statement. Both the *TRIANGLE* app and the privacy statement were approved by the data protection officer of the Medical Center of the University of Munich. All original files such as the case report forms and informed consents are kept at the study site for 10 years. All *TRIANGLE* app user data will be kept at the clinic's server for 10 years and may be used for pseudonymized or anonymized analyses. A publication of study results will only be conducted in aggregated form.

3.2.4.1.1.4 Statistical analyses

We analyzed all data in Microsoft® Excel® 2016 MSO (Redmond, USA) and Tableau Desktop 2019.3 (Tableau Software, LLC, Seattle, USA) using descriptive statistics. Values are presented as total numbers (n) or percent for categorial variables and means ± standard deviation for normally distributed metric variables. For the analyses of the *TRIANGLE* app user logs, we excluded all app activities collected during the think aloud sessions.

Usability issues such as app navigation during the think alouds and statements during the semi-structured interviews were analyzed in an explorative rapid thematic analysis with the respective numbers (n) of participants per statement [909, 910]. An inventory of all statements with an investigation of recurring themes formed the basis for all qualitative analyses.

3.2.4.1.2 Results

The analyses included all participants with complete measures at visit 2, with three exclusions in the uMARS analyses due to incomplete uMARS questionnaires. The first test round included five participants and the second test round included six participants. One participant of the first round was only able to attend the second visit after 33 days, but complied to the instruction to limit the test days to approximately one week. Hence, she remained in the first group for analyses.

The first group of users (n = 5) tested the *TRIANGLE* app for approximately one week (test range of 8 to 13 days) in July 2017. The second group of users (n = 6) tested the *TRIANGLE* app for approximately four weeks (test range of 22 to 32 days) in July and August 2017. The demographic characteristics were distributed as shown in Table 3.9.

Table 3.9: Demographic characteristics of participants of the TRIANGLE user study

		Total	Group 1	Group 2
n		11	5	6
Age	Mean age [years]	36.6 ± 2.2	35.4 ± 1.5	37.7 ± 2.3
Partner status	Partner	10 (90.9%)	5 (100.0%)	5 (83.3%)
	No partner	1 (9.1%)	0 (0.0%)	1 (16.7%)
Children	1 child	5 (45.5%)	3 (60.0%)	2 (33.3%)
	2 children	6 (54.5%)	2 (40.0%)	4 (66.7%)
Work status	Not working or on maternity leave	2 (18.2%)	1 (20.0%)	1 (16.7%)
	Working	9 (81.8%)	4 (80.0%)	5 (83.3%)
	Mean work hours	27.4 ± 6.7	24.5 ± 5.3	29.8 ± 7.2
Language level	Native speaker	9 (81.8%)	5 (100.0%)	4 (66.7%)
	Non-native speaker	2 (18.2%)	0 (0.0%)	2 (33.3%)
Education	High school diploma	3 (27.3%)	0 (0.0%)	3 (50.0%)
	College or university degree	8 (72.7%)	5 (100.0%)	3 (50.0%)
Treatment gestational diabetes mellitus	Insulin	7 (63.6%)	2 (40.0%)	5 (83.3%)
	No insulin	4 (36.4%)	3 (60.0%)	1 (16.7%)
iPhone usage	> 10 times per day	9 (81.8%)	4 (80.0%)	5 (83.3%)
	1-10 times per day	2 (18.2%)	1 (20.0%)	1 (16.7%)
Health app usage	Current	2 (18.2%)	2 (40.0%)	0 (0.0%)
	Previous	5 (45.5%)	3 (60.0%)	2 (33.3%)
	Never	4 (36.4%)	0 (0.0%)	4 (66.7%)
Gadget usage	Current	1 (9.1%)	1 (20.0%)	0 (0.0%)
	Previous	1 (9.1%)	0 (0.0%)	1 (16.7%)
	Never	9 (81.8%)	4 (80.0%)	5 (83.3%)

n (percent) for categorial variables, mean ± standard deviation for normally distributed metric variables

1) <u>User acceptance</u>: *"Is the TRIANGLE app accepted by the intended users (women post-GDM)?", "What is the user's perceived impact of the TRIANGLE app on behavior in a test period of a) approximately one week and b) approximately four weeks?"*

The overall mean SUS score (n = 11) was 87.3 (visit 1) and 87.5 (visit 2) out of 100 (Figure 3.16). Group 1 (n = 5) showed a lower SUS score compared to group 2 during both visits, with lower values during visit 2 compared to the visit 1. In contrast, group 2 (n = 6) reached a higher SUS score during visit 2 compared to visit 1.

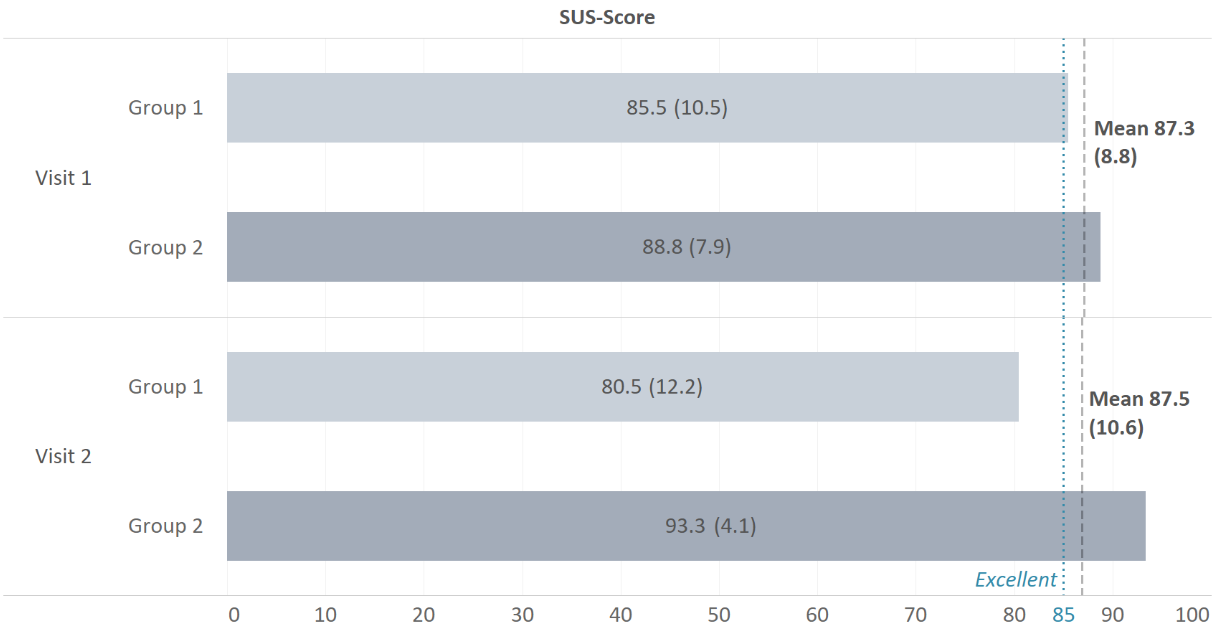

Figure 3.16: Results of the System Usability Scale (SUS) in the TRIANGLE user study
Stratified by visit and by test group, n = 5 in group 1, n = 6 in group 2; all values as mean (± standard deviation); blue dotted line represents threshold for adjective rating "excellent"

The uMARS (n = 8, three missing) App Quality Mean Score averaged 4.1 out of 5.0 points in visit 1 and 4.2 in visit 2. The highest of the four uMARS objective quality subscales for the *TRIANGLE* app was the Information Mean Score of 4.5 in both visit 1 and visit 2 while the lowest subscale was the Engagement Mean Score of 3.9 (visit 1) and 4.0 (visit 2) (Figure 3.17). The App Subjective Mean Quality Score increased from 3.8 at visit 1 to 4.3 at visit 2. Similarly, the Perceived Impact Mean Score increased by 0.5 points from 3.9 at visit 1 to 4.4 at visit 2 (Figure 3.17).

2) <u>Usage</u>: *"How frequently do users operate the TRIANGLE app, its features, sub-features, and themes in a test period of a) approximately one week and b) approximately 4 weeks?", "During what time of the day is the app used?", "Are all TRIANGLE sub-features used across the three lifestyle areas?"*

Figure 3.18 shows that most participants tested the app regularly with limited coaching activity. Of the five participants in the first group (test range of 8 to 13 days), three used the app on at least six days. Of the six participants in the second group (test range of 22 to 32 days), five used the app on at least 20 days. Participants responded differently to coaching in their activities (Figure 3.18).

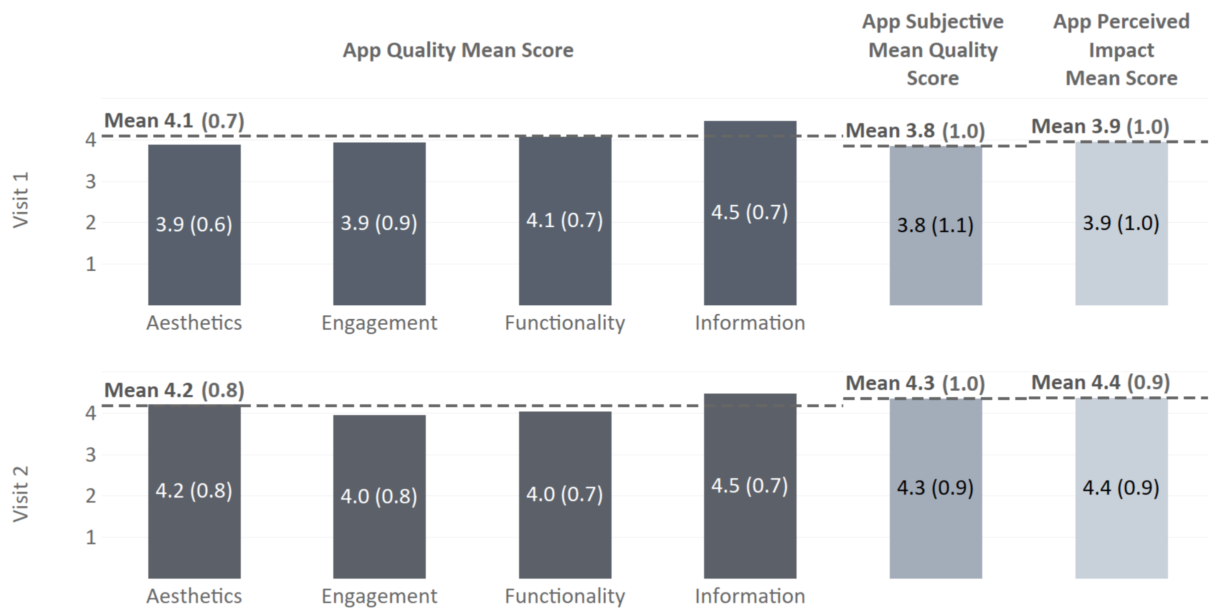

Figure 3.17: Results of the user Mobile Application Rating Scale (uMARS) in the TRIANGLE user study
Stratified by visit and by subscale; n = 8, all values as mean (± standard deviation)

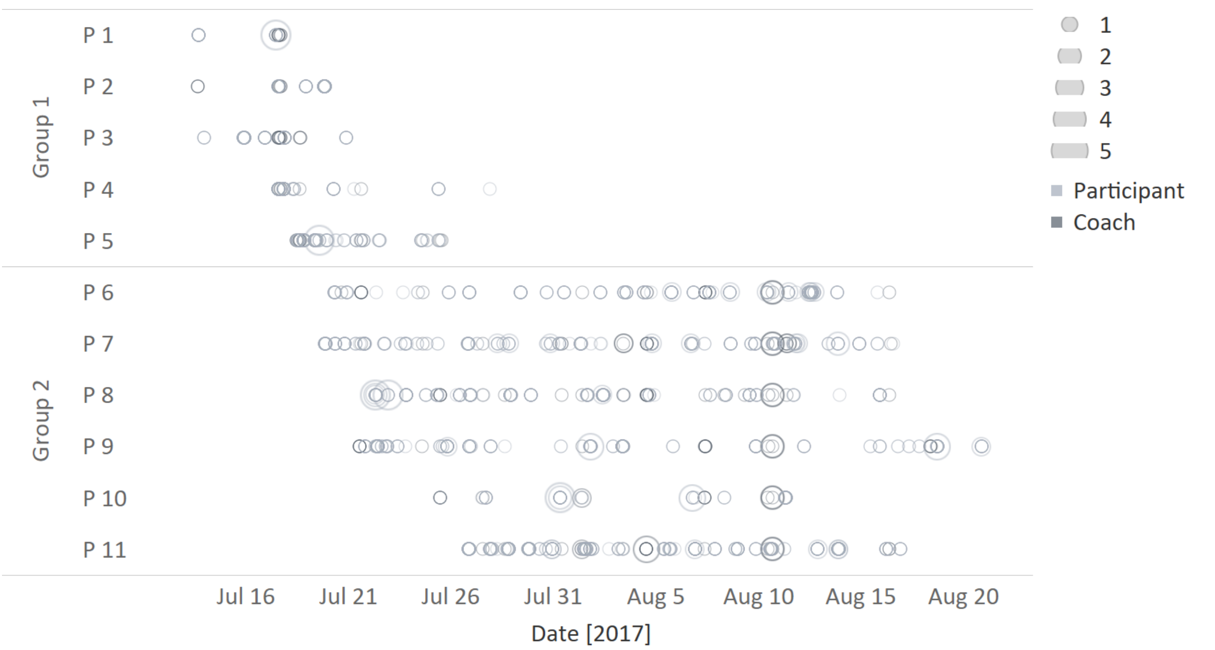

Figure 3.18: Number of app activities per participant over time in the TRIANGLE user study
Stratified by coach and participant activities, n = 5 in group 1, n = 6 in group 2; one circle per active day, circle size reflects number of activities, P = participant

Overall, participants were active in the app at almost any time of the day, with the highest number of activities in the evening and a nocturnal pause between 0 and 4 am (Figure 3.19). The coach was active between 7 am and 4 pm.

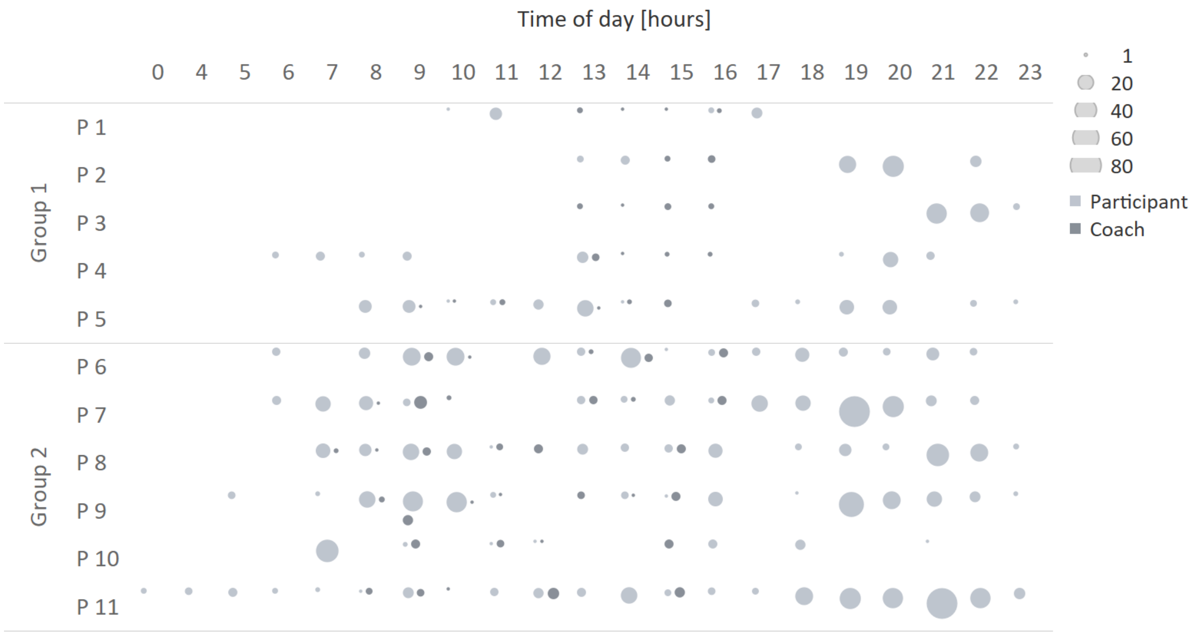

Figure 3.19: Total number of app activities per participant and time of the day in the TRIANGLE user study
Stratified by coach and participant activities, n = 5 in group 1, n = 6 in group 2; one circle per active hour, circle size reflects number of activities, P = participant

Participants' app activities per feature were highest for the interactive challenge system, followed by the library and text messaging with the personal coach (Figure 3.20). The coach showed a comparable number of activities in personalizing challenges and texting coaching messages.

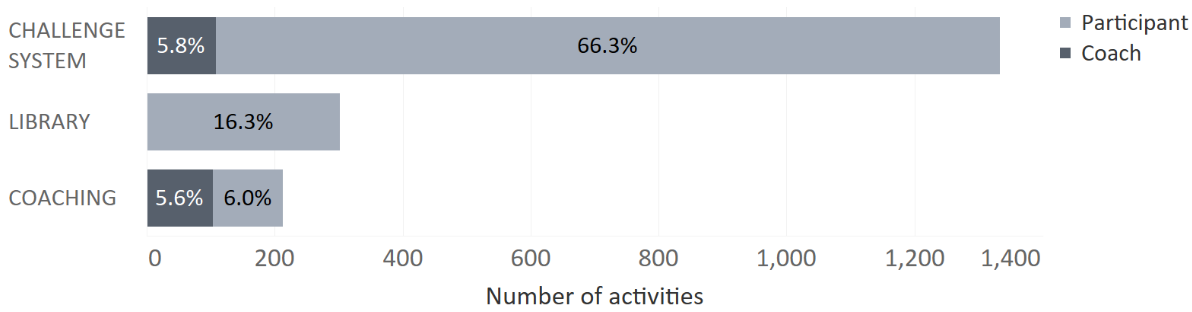

Figure 3.20: Total number and percentage of app activities per feature in the TRIANGLE user study
Stratified by coach and participant activities, n = 11

Regarding the sub-features, participants primarily ticked off challenges, followed by opened challenge descriptions, opened library articles, and played guided practices (Figure 3.21). The coach primarily sent text messages.

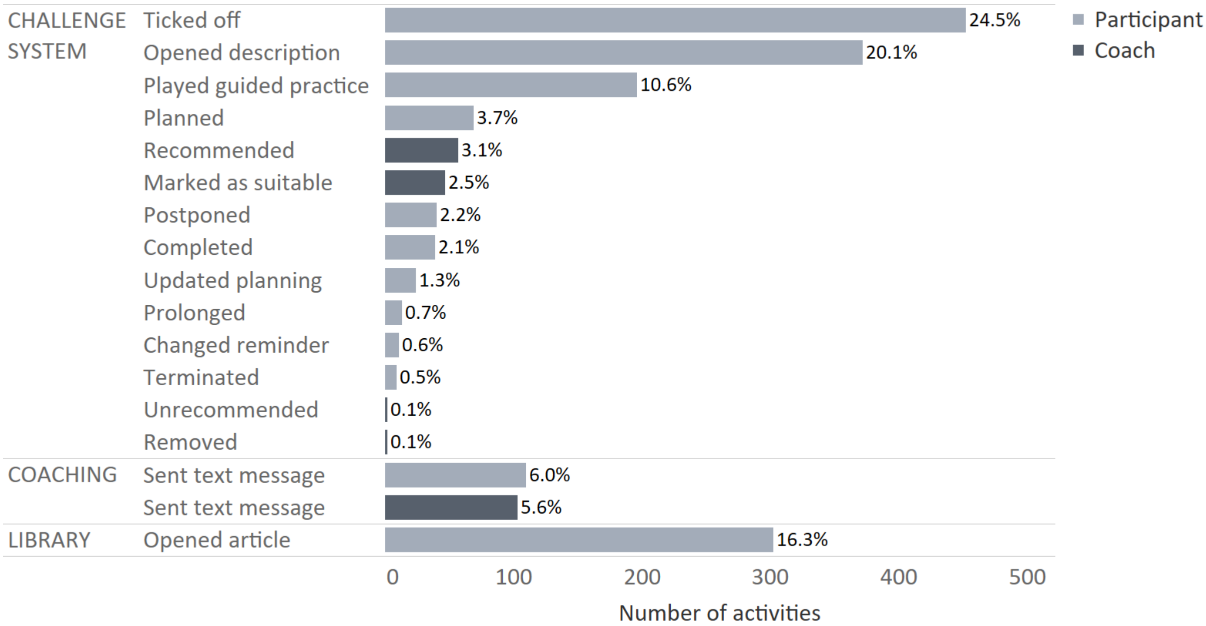

Figure 3.21: Total number and percentage of app activities per sub-feature in the TRIANGLE user study
Stratified by coach and participant activities, n = 11

The total number of app activities ranged between 27 and 115 between participants in group 1 and between 64 and 316 between participants in group 2 (Figure 3.22, in light grey). The highest percentage of app activities by the coach compared to all activities for one participant was 24% (Figure 3.22).

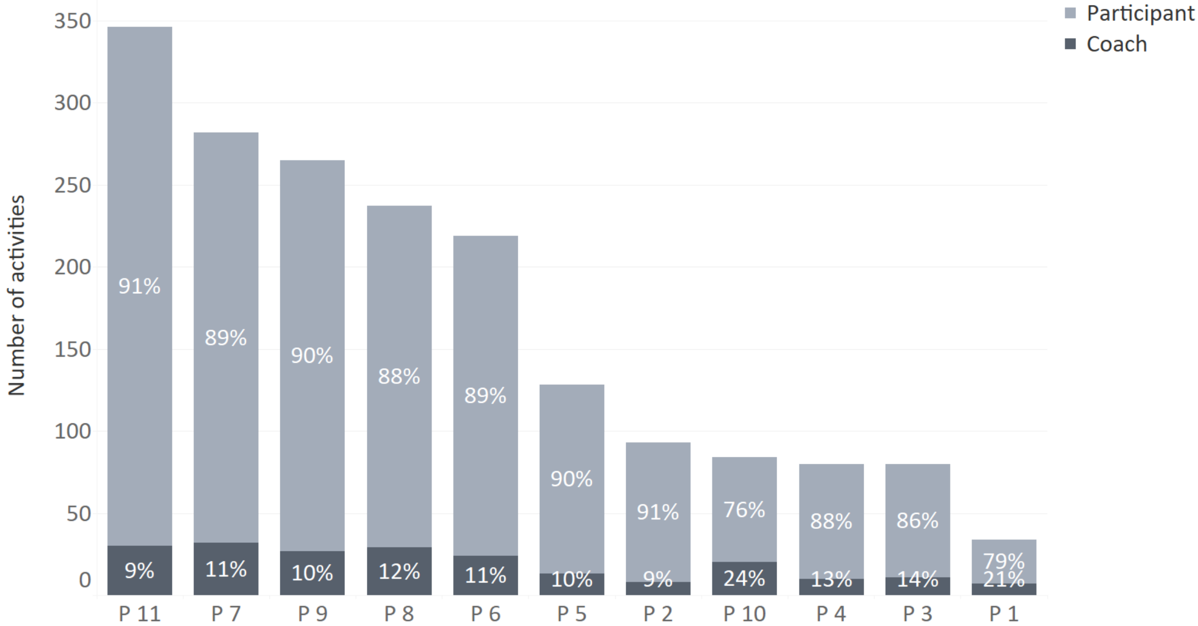

Figure 3.22: Total number of app activities per participant in the TRIANGLE user study
Percentages of total app activities per participant stratified by coach and participant activities, n = 11, P = participant

The total number of activities in each lifestyle area accumulated similarly over time (Figure 3.23, left). Opened challenge information and sent text messages were non-assignable to the lifestyle areas in this version of the *TRIANGLE* app. All participants tested all three lifestyle areas (Figure 3.23, right).

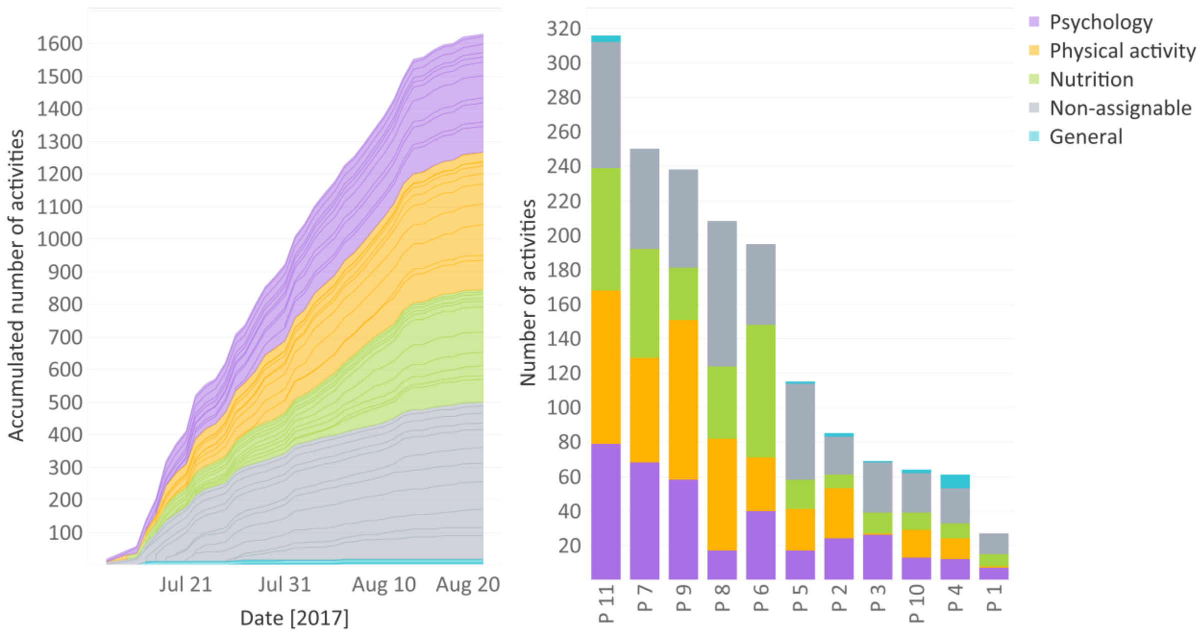

Figure 3.23: Number of app activities accumulated over time in the TRIANGLE user study
Stratified by theme (left), and by participant and theme (right), n = 11, P = participant

Participants used the assignable sub-features for all lifestyle areas (Figure 3.24). Guided practice videos were only available for physical activity while guided practice audios were only available for psychology. Participants postponed, prolonged, ticked off, and completed nutrition challenges more frequently when compared to physical activity and psychology challenges. In contrast, participants updated challenge planning, opened library articles and played guided practice videos more frequently for physical activity when compared to nutrition and/or psychology, respectively. Participants terminated an equal amount of nutrition and psychology challenges, yet few physical activity challenges (Figure 3.24).

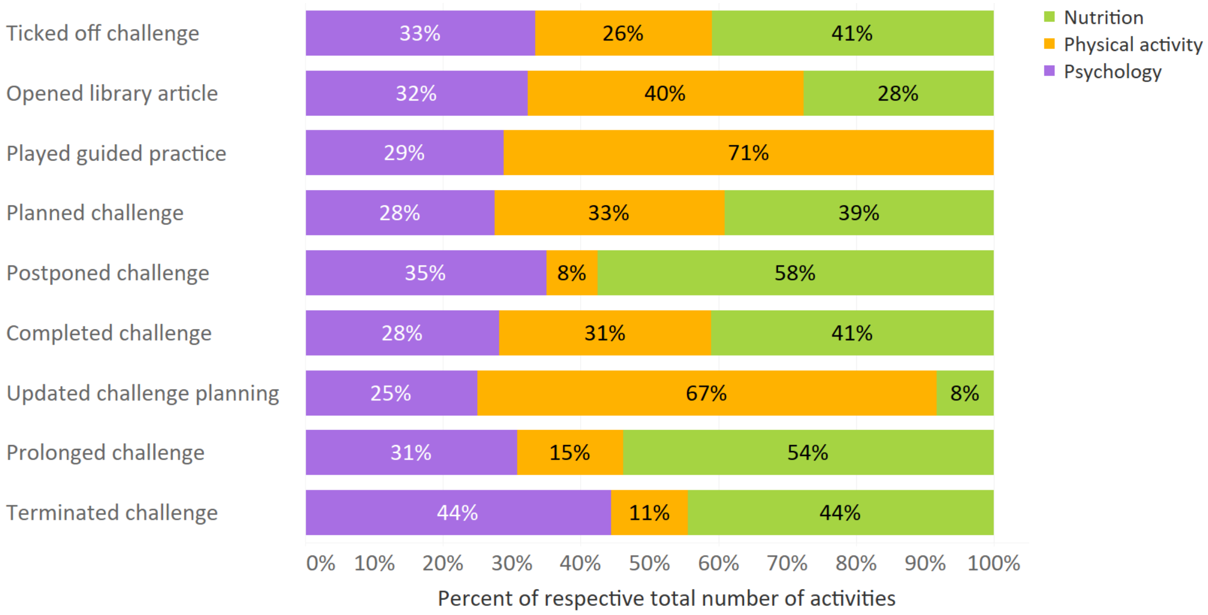

Figure 3.24: Percentage of total number of app activities per sub-feature in the TRIANGLE user study
Stratified by lifestyle area, n = 11

3) <u>Observational and qualitative feedback</u>: *"Can the TRIANGLE app be used intuitively by women post-GDM or are there any confusing or help-requiring features, sub-features, or content?", "Is the TRIANGLE app content clear and understandable for women post-GDM?", "Do TRIANGLE app features and content meet users' expectations?"*

Overall, participants were positive about the look and feel of the *TRIANGLE* app and some stated that the app exceeded their expectations. Our direct observation of participants using the *TRIANGLE* app for the first time showed their ability to navigate the app for all 30 tasks in the think-aloud sessions. Participants showed no delays in task performance except for one participant with initial problems performing the swiping gesture. In general, scrolling was perceived as something to be avoided.

During the semi-structured interviews, participants stressed the ease of use regarding the three core features. All but one participant viewed the presence of a medically trained personal coach as necessary or pleasant add-on. Most participants enjoyed tracking their progress, yet suggested improvements for the progress screen. Many suggested improvements were based on diverging expectations linked to the icon of the progress screen in the navigation bar. Participants liked the aesthetics, such as the theme colors, the *TRIANGLE* logo, and the icons. Two participants were missing additional rewards such as badges or trophies. Regarding the *TRIANGLE* content, participants stated that the information was clear and understandable both in the library articles and in the challenge descriptions.

We combined the data from the think alouds and semi-structured interviews for the exploratory thematic analysis. Positive and negative statements could be clustered into the following seven categories:

1) Onboarding process
2) Navigation bar
3) Sub-features challenge system
4) Sub-features coaching
5) Sub-features library
6) Settings
7) Other feedback

Table 3.10 shows an exemplary analysis (n=11) for the onboarding process.

Table 3.10: Exemplary analysis of the think alouds with semi-structured interviews for the onboarding process in the TRIANGLE user study

Onboarding sub-themes	Positive statements	Number of participants	Negative statements	Number of participants
Introductory video overall	Acceptable length	9	Static image at the beginning is confusing	6
	Good overall	1	Non-professional speaker	1
	Answers all relevant questions	1	Male voice for female app	1
	Good explanation of the features	1	Marginally lengthy	1
			Too little animation	1
			Should be available at any time	1

Table 3.10 (continued)

Onboarding sub-themes	Positive statements	Number of participants	Negative statements	Number of participants
Introductory video content	Contains everything important	3	Missing explanation of successful week algorithm	1
	Informative value	2	Missing specifications of fitness tracking	1
	Stresses the essential	2	Marginally dense content for length	1
	Very good content	1	Too technical	1
	Acceptable content	1	Requires multiple viewing	1
			Intervention procedure not entirely clear	1
			Missing specification of coaching response times	1
Introductory video layout	Clear overview	1	Navigation not clear enough	2
	Nice layout	1	Physical fitness color not “yellow”, but “orange”	1
	Good	1	Color themes not explained in right order	1
Chat screen as start page after the video	Nice welcome	5	Not suitable	2
	Looks familiar	1	Confusing	2
	Positively surprised	1		
	Personal	1		
	Pleasantly simple	1		
First impression app	Appears like regular app	1	Empty home screen before adding challenges is confusing	1
	Nice overall layout	1		
	Pleasantly simple	1		

The other six thematic usability categories are addressed in Chapter 3.2.4.2 via problem descriptions (corresponding to the negative statements only) and solutions for refined program materials and an improved version of the *TRIANGLE* app.

3.2.4.1.3 Discussion

The *TRIANGLE* user study aimed at pretesting all main program components with women post-GDM to refine the design documents for user-approved program materials and to adapt the *TRIANGLE* app where necessary. The results of the different types of data highlight the value of combining validated questionnaires on app acceptance with user logs, think alouds, and semi-structured interviews. This is in line with other studies stressing the importance of mixed methods usability testing in iterative mHealth program development to uncover salient user needs and usability issues [822, 899, 911].

Participants’ SUS ratings indicated a high system usability of the *TRIANGLE* app, corresponding to “excellent” in adjective ratings [912]. Similarly, a recent review on lifestyle apps during pregnancy showed that most of the apps achieved a high user satisfaction [823]. The same accounts for two novel mHealth interventions for or including women post-GDM [43, 66]. The contradictory variations in the *TRIANGLE* app SUS scores between visit 1 and visit 2 in both groups reflected small group effects.

Further, the uMARS App Quality Mean Score of 4.1 (visit 1) and 4.2 (visit 2) out of 5.0 was high, yet below the top range scores of health apps for other populations, which start at values of 4.3 out of 5.0 [913, 914]. This indicated some room for improvement to reach the top category. The lower Engagement Mean Scores of 3.9 (visit 1) and 4.0 (visit 2) might be related to the restricted interactivity due to both the short test period and the limited content for the user study and needs further investigation. The increase in the App Perceived Impact Mean Score between visit 1 and visit 2 by 0.5 points indicates a higher perceived impact after having used the app for several days than initially expected.

In general, the number of test days out of the available days per participant was relatively high and showed no decline in testing over the short time span of about one and four weeks, respectively, in the two test groups. A good adherence for about one month was seen in other mHealth app studies with longer durations [897, 915, 916]. The number of active test days per participant indicated that our planned usage was feasible, defined as five active days out of seven possible active days per week. However, these results may not translate to a longer usage and need further investigation. In a similar user trial with overweight women after pregnancy complications including GDM, participants opened the *Fit After Baby* app an average of 21 out of 28 days, with an average of three coaching contacts and five weight entries in 28 days [66]. In addition, participants tracked their diet a median of 14 out of 21 recommended days on *MyFitnessPal* (Under Armour Inc., San Francisco, USA), and physical activity via Fitbit (Fitbit Inc., San Francisco, USA) or the exercise tracker within the *Fit After Baby* app for a median of 16 out of 21 recommended days [66]. Overall, a smartphone app seemed to meet the needs of women post-GDM since participants used the *TRIANGLE* app and similar apps [66] regularly, at almost any time of the day, outside the usual counseling hours, and with limited human coaching.

As expected, the app activities per feature pointed to the use of the interactive challenge system as main feature with coaching support and add-on information in the library. Similarly, the *Fit After Baby* and *Health-e Mums* mHealth user studies reported excited participant feedback towards checking off completed tasks on the app's home screen [66] or the health tracker dashboard [43], respectively. Further, women post-GDM requested graphs and other visual aids [43], confirming the importance of the *TRIANGLE* progress screen. The activity ratio in the *TRIANGLE* app between coach and participant implied that coaching time and according staff requirements for healthcare professionals may be needed to a lesser extent than we assumed. Yet, the reasons for limited chatting with the coach may be due to the short test setting and participants feeling unsure of what to talk about – as indicated by testers of the *Fit After Baby* app [66]. Overall, the *TRIANGLE* app activity varied widely between participants, as in similar trials [66], so that engagement and adherence remain issues to be addressed. Every participant tested every lifestyle area in the *TRIANGLE* app and thus showed a principle interest in the additional lifestyle areas of psychology and sleep beyond nutrition and physical activity. This is in line with the requests of content beyond nutrition and physical activity for postpartum mental health and respective exercises in the *Fit After Baby* user study [66]. Still, we cannot exclude a possible bias in *TRIANGLE* content usage given the overall limited content for the user study. All sub-features have been used for all lifestyle areas, yet with differences in usage frequency depending on the lifestyle area. This indicated on the one hand to keep the current sub-features. On the other hand, it confirmed differences in importance of different behavior change methods and respective practical applications per lifestyle area and behavior, as implied by the Intervention Mapping approach [116]. In line with these findings, the *Health-e Mums* user study found an interest in real-time food choice support, personalized library for certain food products, and traffic light color coding for the nutrition domain [43].

The qualitative analyses revealed that overall, participants used the *TRIANGLE* app intuitively and appreciated the features so that no major changes in the app were required. Yet, we identified a need for improvements in seven domains that will be addressed in the following Chapter 3.2.4.2. Similarly, the *Fit After Baby* app underwent minor improvements after each iterative round [66]. Further, a focus group-based analysis of the *Health-e Mums* app for women post-GDM revealed navigation problems and required improvements in most app components [43]. The same study identified the need of women post-GDM for personalized settings for push notifications and for reminders specific to activities [43]. In line with these findings, some women testing the *TRIANGLE* app desired challenge-specific push notifications instead of general reminders for all challenges to be completed in the morning, afternoon, and evening. In addition, women using the *Fit After Baby* app expressed their frustration about having to switch between three different apps and about the lengthy nutrition tracking [66]. In contrast, the *TRIANGLE* app solution based on habit formation seems to fulfill the criterion of a simple and unified support system for behavior change across lifestyle areas.

3.2.4.1.4 Strengths and limitations of the TRIANGLE user study

The uncovering of usability issues and salient user needs when interacting with an mHealth system remains challenging [822]. Yet, the *TRIANGLE* user study addressed some of these challenges and gained valuable insights on *TRIANGLE* app usability and acceptance by women post-GDM. Two different user groups allowed to explore possible differences arising from a different test period of one week versus four weeks. Each type of data in the mixed methods approach shed light on different usability aspects and accounted for limitations of each method. The study included both objective (observations during think alouds and user logs) and subjective (questionnaires, think alouds, and semi-structured interviews) data. The data provided insights on user acceptance, usage, and user experience of the *TRIANGLE* program that allowed for specific user-driven adaptations. User logs indicated that a smartphone app is a suitable delivery channel for an intervention post-GDM since we tested with the priority population, as recommended by a review on usability testing of mHealth apps [822]. Further, user logs allowed for detailed analyses of the usage of the available content in the scope of this study and of the app features.

The *TRIANGLE* user study and each of the applied methods has limitations. Regarding the user study overall, the sample was rather homogenous: iPhone users only, most of which were highly educated, living with a partner, having one or two children, being a native speaker, and never having used a gadget before. Potential users participated voluntarily, with a possible higher proportion of those motivated to participate in an mHealth program. Hence, the sample's interaction with the app and suggested adaptations may not apply to the entire population of women post-GDM or to specific subgroups. Further, the test results for one participant in group 1 with the delayed visit 2 may be biased due to the longer period with no app usage prior to visit 2.

Regarding the questionnaires on user acceptance, the results of the uMARS need to be interpreted with caution. One user considered the test duration of the first think aloud session too short for appropriate uMARS ratings. The original uMARS validation study with robust values over six months started ratings after one month of app usage [905]. This pointed to a non-ideal duration of the *TRIANGLE* user study for the uMARS despite delivering valuable insights for possible improvements and direct feedback by the priority population. Further, the German version of the uMARS has not been validated in earlier studies. We therefore had to rely on the suitability of the current translated and back-translated version.

User logs tracked user activities per sub-feature, yet no durations of usage. Hence, users accidentally opening a library article or challenge description could not be distinguished from those staying longer on a page to read the content. Further, opened challenge descriptions were not linked to the respective lifestyle area. Proportions in activities per sub-feature and lifestyle area may thus shift when including this information. Similarly, the distribution of activities per lifestyle area may have been biased due to the limited overall content in the user study that may have led to using everything available. In addition, the user logs did not capture participant activities on the progress screen. Hence, we were not able to evaluate the use of this sub-feature. Due to the restriction to the iOS system for the iPhone, we will not be able to transfer the results to Android usability of the *TRIANGLE* app.

The think aloud method created an unfamiliar setting for most participants since they were not used to thinking aloud, to verbalize thoughts in front of an investigator, and to be audio-recorded. This may have generated subconscious reactions or unintentional statements by participants. However, we tried to reduce these effects by showing all participants a video of a think aloud session, by letting them practice before starting, and by removing distractions from the test room. To limit situational stress for participants, we did not capture facial expressions via video during the think alouds, which limited possible observations. Further, the qualitative data analysis did not include a full transcription of all records but was limited to a rapid exploratory thematic analysis. Hence, some information – especially the more salient ones – may have been lost or misinterpreted for the think alouds with semi-structured interviews.

3.2.4.1.5 Conclusions

The *TRIANGLE* user study assessed the usability and acceptance of the *TRIANGLE* app, a new mHealth program for habit change in physical activity, nutrition, and psychology to prevent T2D and related cardiometabolic disturbances in women post-GDM. Our findings showed that women post-GDM accepted the mHealth program, perceived a high impact on behavior, and engaged with all available lifestyle themes and features of the *TRIANGLE* app. The results further indicated that users got familiar with the app quickly and were able to use it intuitively. The unique combination of the three core features “challenge system”, “coaching”, and “library” appeared feasible in practice since the interactive challenge system was used the most and human coaching the least. Hence, the *TRIANGLE* app seemed to fulfill the demand of an app post-GDM that is highly functional, responsive, and personalized [43].

Overall, the *TRIANGLE* user study confirmed the need to test usability during iterative app development prior to a clinical efficacy study. The detection of some additional needs of the priority population allowed for user-centered design adaptations and will form the basis for later implementation success. Key usability issues were formulated as problem statements to refine program materials before the full program production. A clinical RCT is required to show a stable functioning of the *TRIANGLE* app over longer periods in time, to assess the program’s acceptance in a more representative sample, program effects on behavior change, and clinical efficacy.

3.2.4.2 *Refined materials and program production*

We prioritized revisions of program materials and the *TRIANGLE* iPhone app based on the frequency and relevance of user feedback and feasibility in the scope of this project. Thereby, we maintained the seven domains identified in the user study:

1) Onboarding process
2) Navigation bar
3) Challenge system
4) Coaching
5) Library
6) Settings
7) Other feedback

First, the following user feedback helped us redesign the original introduction video for the *TRIANGLE* app (Figure 3.25) for a revised version (Figure 3.26):

- Address habit change before explaining the app
- Clearly mark the respective feature during explanations
- Thin out content in relation to the length of the video
- Add information on program sequence, response time of the personal coach, role of the personal coach, and criteria for a successful week
- Increase animation (software VideoScribe © 2016 Sparkol Limited (Bristol, England))
- Use a female voice
- Rectify icon-triggered expectations of an-interactive progress screen
- Explain the colors for the lifestyle areas in the right order, use the word "orange" for physical activity
- Ensure that both introduction video and sub-sections are available in the library

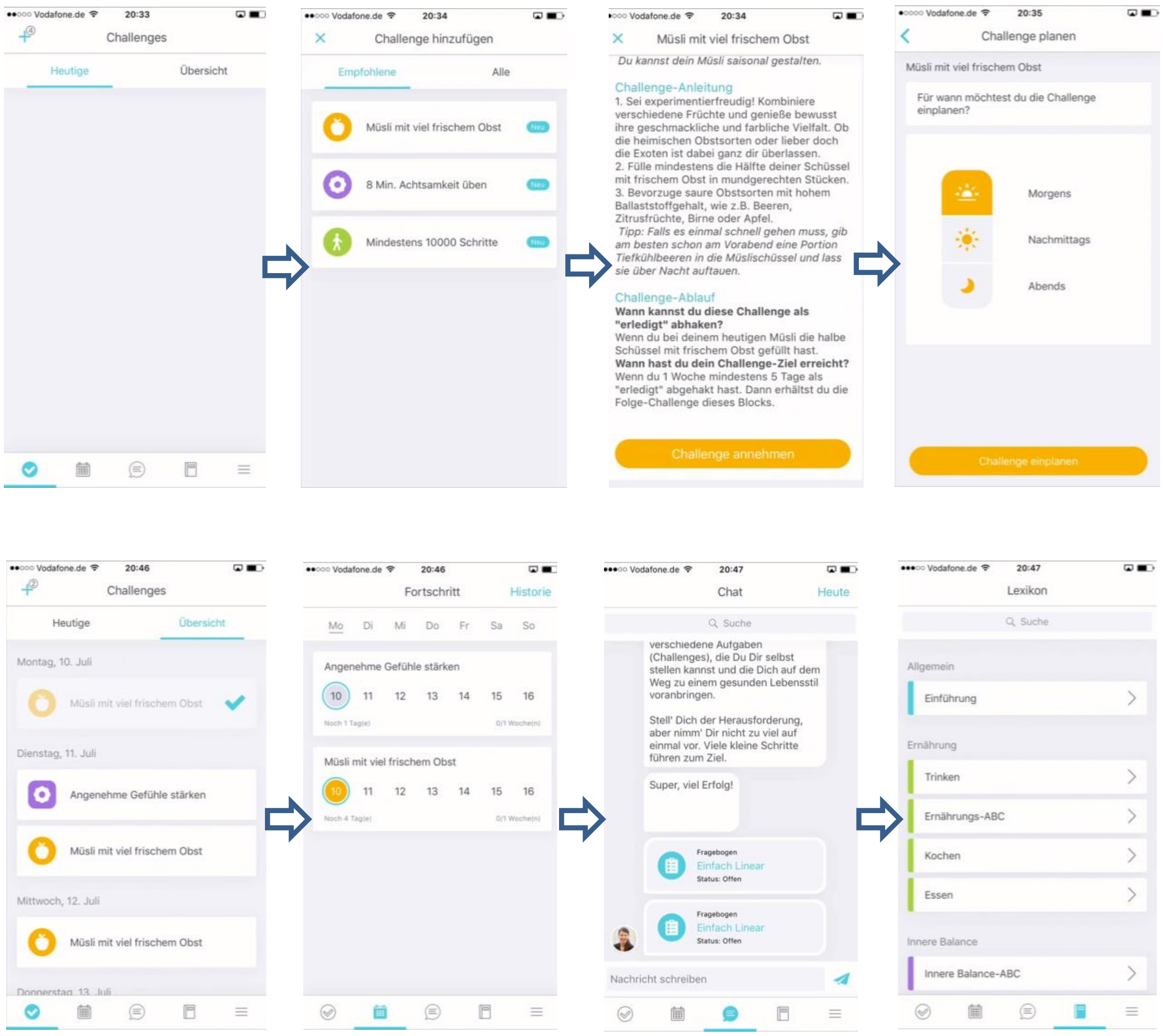

Figure 3.25: Exemplary screenshots of the original TRIANGLE introduction video
As implemented in the TRIANGLE user study

The revision led to an extended 14-minute version of the *TRIANGLE* introduction video (Figure 3.26), with access to shorter sub-sections of the video in the library, ranging from 1:47 to 3:45 minutes.

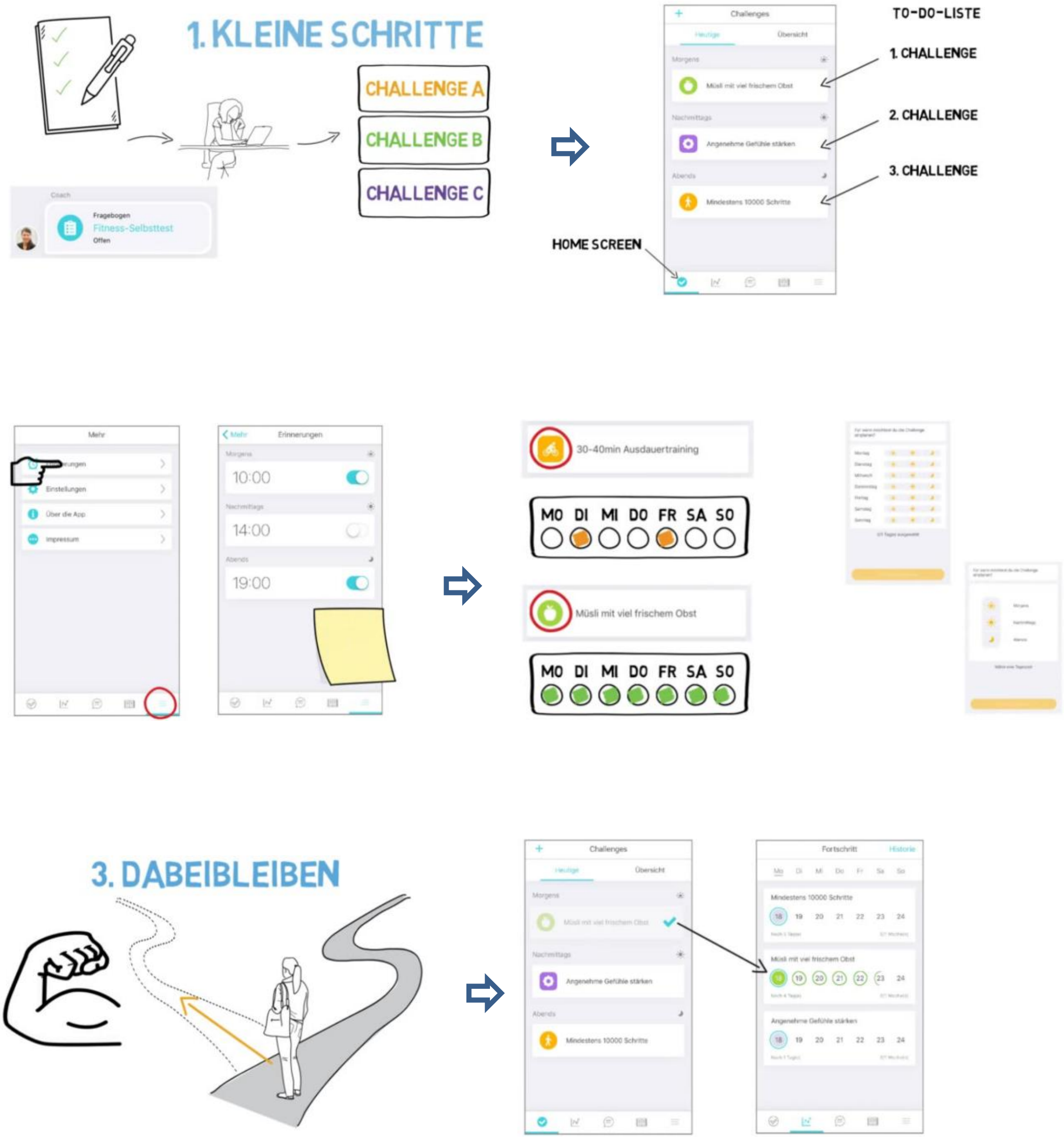

Figure 3.26: Exemplary screenshots of the revised VideoScribe-animated TRIANGLE introduction video
As implemented in the Test TRIANGLE Pilot Study

Second, we adapted the icons for the library and progress feature in the navigation bar according to user expectations (Table 3.11) and (Figure 3.27).

Table 3.11: Usability issues related to the TRIANGLE icons and resulting changes after the TRIANGLE user study

Problem description	Resulting changes
Calendar icon raised user expectations of a calendar with similar interactive sub-features to the iPhone calendar	Progress graph icon for the progress visualization of challenges (Figure 3.27)
Closed book icon raised user expectations of an interactive note pad	Open book icon for the library (Figure 3.27)

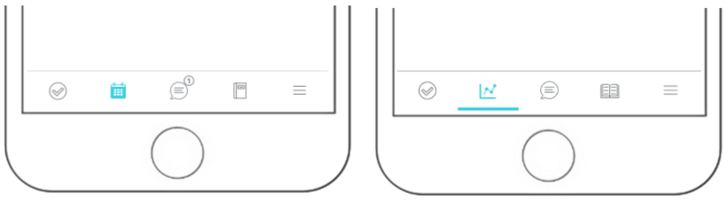

Figure 3.27: Icons of the TRIANGLE features
Before (left) and after (right) the TRIANGLE user study

Third, we modified the challenge system as described in Table 3.12.

Table 3.12: Usability issues related to the TRIANGLE challenge system and resulting changes after the TRIANGLE user study

Problem description	Resulting changes
Users did not immediately notice newly available challenges	Colored number of new challenges
Users were confused by diverging order of challenges between the home screen and the weekly challenge overview	Synchronized challenge order of home screen and weekly challenge overview
Users viewed the "postpone challenge" button as unnecessary given the "terminate challenge" button	Removed "postpone challenge" button
Users considered the location of the challenge buttons at the end of a challenge description as impractical and complicating access to action	Restructured order of text and buttons in a challenge description, buttons located at the beginning of an accepted challenge
Users thought the challenge text with a question-answer structure was marginally lengthy	Reduced challenge text with a simplified chunking and advance organizer structure; adapted design document
Users indicated an overuse of structuring elements such as capital letters, bold letters, and italics	Minimal use of structuring elements; adapted design document
Challenge-specific: 1) Challenge 1.4.1 "Walk at least 3,000 steps" did not apply to any user, 2) Challenge 6.1 "8 minutes of mindfulness" was considered too long by users, 3) Challenges 6.5.1 "Keep a sleep diary", automatically followed by challenge 6.5.2 "Analyze your sleep diary" meant too much work for users	Removed challenges 1.4.1, 6.1, 6.5.1, and 6.5.2 from the list of challenges and from respective chained challenges

Fourth, we revised the coaching sub-features according to Table 3.13 and Figure 3.28.

Table 3.13: Usability issues related to the TRIANGLE coaching feature and resulting changes after the TRIANGLE user study

Problem description	Resulting changes
Users did not immediately notice a new coaching activity	Colored number of new coaching activities in the navigation bar (Figure 3.28)
Some users were unmotivated without a sufficient number of motivational messages	Extended data base of motivation texts, including some specific for each lifestyle area
The difference between the "cancel" button in a questionnaire and the "cancel" button for exiting the cancelling procedure was not clear	Renamed second "cancel" button in questionnaire tool
Users were confused by the automatic transfer of questionnaire results to the coach upon completion without further notice	Added button for actively sending questionnaire results to the personal coach and a notification for successful transfer

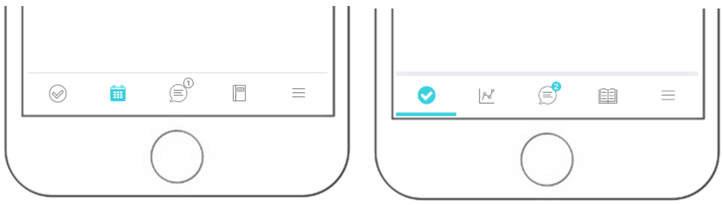

Figure 3.28: Display of the number of new coaching messages attached to the icon
Before (left) and after (right) the TRIANGLE user study

Fifth, we extended the library with a recipe section, some additional videos such as pelvic floor training, and more examples specific to women post-GDM. These themes also occurred in another user study including women post-GDM [66]. The importance of a recipe section was confirmed in a recent habit-based mHealth pilot trial for weight loss [917] and in a user study on a novel app post-GDM [43]. Sixth, we added the planned information section about the app with the chunked introduction video. Seventh, we changed the layout of headings and sub-headings in challenges, library articles, and questionnaires to the respective color of the lifestyle area, recorded revised high-quality versions of the audio files, and added the number of new coaching activities to the *TRIANGLE* app icon (Figure 3.29).

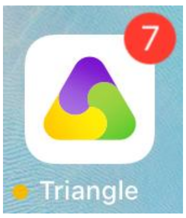

Figure 3.29: Display of the number of new TRIANGLE coaching activities
Linked to the TRIANGLE icon on the iPhone's home screen

Lastly, we modified the initial paper and pencil questionnaire (Supplementary Table 8). We removed items due to total response duration and redundancies when paired with the expected information of the initial medical examination. We added items due to the higher likelihood to receive answers compared to in-app questionnaires. Based on the revisions named above, we produced all remaining program materials for the Test *TRIANGLE* Pilot Study.

4. The Test TRIANGLE Pilot Study

The six-months multicenter randomized clinical pilot study aimed at testing the effects of the *TRIANGLE* intervention on cardiometabolic health behavior compared to standard care (with additional recommendations for sleep and psychosocial wellbeing) in women post-GDM with a mixed methods approach. The five adapted DPP goals (Chapter 2.1.4) served as primary outcome [40] in a binary composite score (at least three versus less than three out of five points). Other possible intervention effects on cardiometabolic health and quality of life were analyzed exploratively. Further, the study tested user acceptance of the intervention and its components – including *TRIANGLE* app features and content. We formulated the following five clusters of research questions:

1) DPP score: "Does a) the assignment (modified intention-to-treat), and/or b) the regular use (per protocol) of the TRIANGLE program for six months result into a higher proportion of women post-GDM who achieve at least three out of five DPP points after six months of intervention when compared to standard care?"

2) Cardiometabolic health status and wellbeing: "Does a) the enrollment, and/or b) the regular use of the TRIANGLE program for six months lead to better glucose tolerance, insulin sensitivity, physical fitness, body composition, wellbeing, and stress perception in women post-GDM when compared to standard care?"

3) TRIANGLE app usage and acceptance: "Is the TRIANGLE app accepted by women post-GDM?", "What is the user's perceived impact of the TRIANGLE app on behavior?", "How frequently do users operate the TRIANGLE app, its core features, sub-features, and themes during an intervention period of approximately six months?", "Are there changes in usage frequency over time?", "During what time of the day is the app used most frequently?", "Which of the TRIANGLE challenges are completed most frequently?", "What does the qualitative feedback add to the understanding of app acceptance, possible improvements, and the app's suitability for similar at-risk populations?"

4) TRIANGLE additional program material usage and acceptance: "How many of the participants use the additional TRIANGLE program materials and consider the materials helpful?"

5) Implications for a larger clinical trial: "What can be learned from this pilot study for future clinical trials?", "Is the current binary DPP endpoint suitable to test the TRIANGLE app's clinical efficacy or does it have to be revised for a large intervention trial? Which parameters would be suitable for a power calculation?"

Regarding any of the five clusters of research questions, we explored the question *"Are there differences between subgroups, such as overweight/obese vs. normal weight?"*

4.1 Materials and methods

4.1.1 Study design

The *Test TRIANGLE Pilot Study* is a multicenter, two-armed randomized controlled pilot trial with a mixed methods approach. Next to our main study site at the Medical Center of the University of Munich, two additional study centers under the umbrella of the German Center for Diabetes Research (DZD) participated in this study: the German Diabetes Center Duesseldorf and the Institute for Diabetes Research and Metabolic Diseases in Tuebingen. The intervention arm received six months of the *TRIANGLE* app-based behavior intervention targeting the lifestyle areas physical activity, nutrition, and psychology/sleep (further referred to as "psychology"). Software support and online coaching for all participants were based in Munich. The control arm received a leaflet with information on the lifestyle changes addressed in the *TRIANGLE* app at the baseline visit (V1). Participants of the control group were offered the full scope of the *TRIANGLE* program free of charge after study completion at the final visit (V2). Each study center randomized participants to the two groups in a 1:1 ratio, stratified by study center.

We used a binary DPP endpoint as primary outcome for the power calculation: the proportion of participants reaching less than three versus the proportion of participants reaching at least three out of five diabetes prevention goals (Table 4.1). Based on previous findings in an intervention with women post-GDM [60] and the assumptions that mHealth will increase both adherence and exposure to intervention materials, we assumed a success rate of 15% in the control group versus 50% in the intervention group. The analyses were conducted with an uncorrected chi-square test with a significance level of 5% (two-sided) and a power of 90%. With the expected difference in the primary outcome, 27 participants had to be included in each study arm. Assuming a dropout rate of 15%, 32 participants needed to be randomized per group.

Table 4.1: Statistical analysis plan for the primary outcome of the Test TRIANGLE Pilot Study

Intervention goal	1 point if	Additional condition
Increased physical activity	≥ 150 minutes of moderate to high intensity per week at V2	
Increased dietary fiber intake	≥ 15 g per 1,000 kcal at V2	
Decreased dietary fat intake	≤ 30% of total energy intake at V2	
Decreased dietary saturated fat intake	≤ 10% of total energy intake at V2	
Body weight management	Body weight at V2 ≤ 95% of V1	If BMI at V1 ≥ 23 kg/m$^{2\,*)}$
	Body weight at V2 ≤ 100% of V1	If BMI at V1 = 20 - 22.9 kg/m^2

***) Current guidelines contain a threshold of a BMI ≥ 25 kg/m^2 to classify overweight as risk factor for diabetes prevention. However, we chose a threshold of BMI ≥ 23 kg/m^2 since our priority population is considerably younger when compared to traditional type 2 diabetes prevention cohorts.**

BMI = body mass index, V1 = visit 1, V2 = visit 2

The study was approved by the ethics committee of the Medical Faculty of the Ludwig-Maximilians-Universität and by the respective ethics committees of the other study centers. The team of the main study site in Munich conducted an in-person site initiation at each study site. These included all standard operating procedure forms, case report forms, questionnaires, check lists for single tasks per staff member during V1 and V2, study logistics, and the delivery and step-by-step configuration of all required *TRIANGLE* intervention materials. Risks in the scope of the planned examinations were negligible for participants. The recommendations included in the intervention were in line with evidence-based guidelines and standard recommendations by healthcare practitioners. Participants were insured for accidents for the duration of their clinical visits and the direct way between their home address and the study sites. The study was funded by the DZD.

4.1.2 Participants

Participants were primarily recruited by phone from the patient base of the respective university medical center between end of June 2017 and end of May 2018. Further recruitment measures included leaflets at healthcare practitioners' including gynecologists, diabetologists, and postnatal exercise instructors; displays in public transportation, and leaflets at mother child courses. Incentives for participants included a Garmin vívosmart® HR fitness tracker, a step tread, a *TRIANGLE* paper note pad, and six months *TRIANGLE* app usage with personal coaching free of charge. Besides, a participant's travel costs to the study site were reimbursed.

The inclusion criteria for participants were a diagnosis of GDM validated by a medical doctor according to the German guidelines in a recent pregnancy, three to eighteen months postpartum, completed rebuilding after delivery with no major sporting restriction despite some postpartum ailments including rectus diastasis, ownership of an iPhone model 5 to 7 Plus, and fluent German skills. The exclusion criteria comprised age below 18 years, current pregnancy, planned pregnancy within the next six months, cardiopulmonary disease or restrictions in the locomotor system contradicting a sports intervention, gastrointestinal disease contradicting a nutrition intervention, psychiatric disease requiring psychotherapy or medical therapy, other serious illness contradicting a lifestyle intervention according to the principal study investigator, planned inpatient hospital stay, alcohol or drug abuse, planned lifestyle changes other than the study intervention in the areas of physical activity, nutrition or psychosocial wellbeing, antidiabetic drug treatment, or diabetes mellitus. A participant's early termination criteria were pregnancy, severe illness contradicting a lifestyle intervention according to the principal investigator or withdrawal of a participant's consent.

4.1.3 Measurements

Measurements for the study comprised questionnaires, nutrition protocols, clinical assessments, and user logs (Table 4.2).

Table 4.2: Overview study workflow in the Test TRIANGLE Pilot Study

	V1	Intervention vs. standard care	V2
	At 3-18 months post-GDM	For 6-8 months	At 6-8 months after V1
Verification of in- and exclusion criteria	X (prior to V1)		
Informed consent	X		
Nutrition protocols	X (at least 4 days prior to V1)		X (at least 4 days prior to V2)
Set of questionnaires 1	X		
Fasting blood sampling	X		X
Five-point oGTT	X		X
Physical examination and bioelectrical impedance analysis	X		X
Ergospirometry (optional)	X		X
Standard care lifestyle leaflet	X (control group only)		
Initial paper and pencil questionnaire *TRIANGLE* app, all *TRIANGLE* intervention materials	X (intervention group only)		X (control group only, optional)
User logs *TRIANGLE* app		X (intervention group only)	
Set of questionnaires 2 (in-app, optional)		X (intervention group only)	
Set of questionnaires 3			X

GDM = gestational diabetes mellitus, oGTT = oral glucose tolerance test, V1 = visit 1, V2 = visit 2

About four days prior to V1, the study team called each participant to remind her of the visit and required preparatory actions, and to ensure that she starts in time with the nutrition protocols. In an additional email, each participant received the following information:

- Regular nutrition during the days prior to the test, with a recommended carbohydrate intake of about 150 g per day
- No intense physical activity or alcohol consumption during the day prior to the test
- No smoking in the morning prior to the test
- No active transportation with physical strain to the test location
- Regular medication in the morning prior to the test, yet no on-demand medication

During V1, the study team verified the in- and exclusion criteria and informed the participant about the specifics of the study before the participant gave her written informed consent. The study nurse further verified the following with each participant prior to starting the test: fasted state for at least eight hours, except for water or plain herbal tea; no acute illness, no pregnancy.

Participants were randomized via Randoulette version 3.1 (Institute for Medical Information Processing, Biometry, and Epidemiology, Ludwig-Maximilians-Universität, Munich, Germany) into the intervention or the control group.

4.1.3.1 *Questionnaires*

The first set of questionnaires at V1 included the anamnesis and medical history, family history, current disease and medication, smoking or previous smoking, quality of life, perceived stress, and physical activity, and involved the following validated questionnaires:

The WHO-5 Well-Being Index (WHO-5) assesses subjective emotional wellbeing and detects symptoms of sub-clinical depression via five items [918]. The five-point Likert scale for each item ranges from 0 (“at no time”) to 5 (“all of the time”). After summing up the values of the five items, a WHO-5 score of 0 reflects the lowest possible wellbeing while 25 stands for the highest level of wellbeing. A WHO-5 score of less than 13 indicates poor wellbeing or depressive symptoms, a WHO-5 score of less than seven indicates clinical depression [918].

The Perceived Stress Scale (PSS-10) measures the degree to which a person perceives different situations in life as stressful [919]. The PSS-10 contains 10 questions targeting the past month as time frame for individual stress perception. We reversed the scores (0 = 4, 1 = 3, 2 = 2, 3 = 1, 4 = 0) of the four positively stated items (items 4, 5, 7, and 8) according to the instructions before summing up all scale items. A total PSS score of 0 stands for no stress and 50 for maximum stress.

The International Physical Activity Questionnaire (IPAQ, 2002) quantifies regular health-related physical activity or inactivity in adults between 15 and 69 years of age [920, 921]. The long version of the IPAQ as applied in this study consists of the following five domains of physical activity: 1) job-related, 2) transportation-related, 3) household, house maintenance, and family care-related 4) recreation, sport and leisure-time related, and 5) time spent sitting (at work, home, during leisure time). The measured time frame includes the seven days prior to the assessment. The sum of moderate to vigorous physical activity in the first four domains represents an individual’s weekly physical activity in minutes. For better readability and conduct, we adapted the following in the IPAQ: 1) shortened introduction with bold key words, 2) description of the question scheme, 3) highlighted that the bouts of physical activity must be at least of 10 minutes duration, 4) examples for estimating averages, 5) minute-unit instead of hour-unit, and 6) priority population-specific examples instead of examples for the general population.

The second set of questionnaires was programed in the *TRIANGLE* app and was optional for coaching purposes during the intervention, with some program evaluation questions (Supplementary Table 5). Respective data was collected in the app.

The third set of questionnaires during V2 included a final anamnesis, changes in medication since V1, illnesses since V1, the occurrence of any premature termination criterion, (serious) adverse events, WHO-5, IPAQ, and PSS-10. In addition, the intervention group received the uMARS questionnaire on user acceptance of the app (Chapter 3.2.4.1.1.2), and additional questions on the usage of the other program materials, perceived monetary value of the app, the app's suitability for other at-risk groups, and perceived missing content. Both the intervention and the control group answered questions on perceived habit change, prognosis for habit maintenance, and the usage of non-program materials or apps during the study.

4.1.3.2 *Nutrition protocols*

The nutrition protocols covered four days of food and drink journaling. Participants were instructed to record dietary intake at the time of consumption [922]. Participants completed the nutrition protocols prior to each visit and submitted the protocols at the beginning of each visit. The main study site collected the protocols after each visit. In case of non-completion, the participant was instructed to complete the nutrition protocols within seven days following the visit. Non-completers randomized into the intervention group during V1 had to postpone the start of the intervention until submission of complete protocols. Similarly, non-completers in the control group had to postpone the use of the *TRIANGLE* app at V2 until completion. For the nutrition protocols, participants were further instructed to: 1) eat as usual, 2) pick regular days in temporal proximity and exclude unusual days such as a wedding celebration, 3) be honest and precise, 4) include all consumed foods and drinks during the day as well as chewing gums and spices, 5) journal during meal preparation, during or directly after consumption, 6) include all details such as fat content, type of bread, fruit content of juices, etc. as specified by the manufacturer, and the type of food as purchased such as fresh, frozen or smoked, 7) mention brands or branded products, 8) describe exact quantities for each type of food or drink consumed, 9) estimate or inquire quantity and types of ingredients when eating food prepared by others, and 10) use a standardized template for the protocol. Nutrition protocols were checked according to these criteria by the respective study nurse. In case of missing information, the participant was asked for details during the visit or by phone after the visit.

All nutrition protocols were entered into the Software PRODI® 6 Basis (Nutri-Science GmbH, Hausach, Germany) by one nutritionist in consultation with a nutritional scientist (doctoral student) at the main study site to ensure consistency. A study nurse further checked all items for plausibility and consistency. The software analyzed the following averages per participant at V1 and at V2:

- Average daily calorie intake [kcal]
- Average daily fiber intake [g]
- Average daily total fat intake [g]
- Average daily saturated fat intake [g]

4.1.3.3 *Oral glucose tolerance test and fasting blood sampling*

The five-point oGTT was based on 75 g of oral glucose intake with blood drawings at 0 (fasted blood sample), 30, 60, 90, and 120 minutes via a venous peripheral catheter for assessments of plasma glucose (Glucose HK Gen.3, Roche Diagnostics, Mannheim, Germany) and serum insulin (CLIA, DiaSorin LIASON systems, Saluggia, Italy). Additional measures during the fasted blood sample included a small blood count, differential blood count, creatinine, glutamate pyruvate transaminase, γ-glutamyl transferase, C-reactive protein, ferritin, triglycerides, LDL-C, HDL-C, HbA1c, and thyroid-stimulating hormone (Supplementary Table 9). After the fasted blood drawing, participants were advised to drink the 75 g of glucose solution (AccuChek Dextrose O.G-T., Roche Diagnostics, Mannheim, Germany) within three to five minutes. After the participant had finished, the timer was started.

In case of a diabetes mellitus diagnosis (HbA1c ≥ 6.5%, fasting plasma glucose ≥ 126 mg/dl or two-hour oGTT plasma glucose ≥ 200 mg/dl) during V1 of the study, the participant was excluded from the study.

For the secondary outcomes, we calculated the difference between V1 and V2 in the following measures:

1. Δ area under the glucose curve during the five-point oGTT (AUC glucose)
2. Δ Insulin Sensitivity Index (ISI)
3. Δ Disposition Index (DI)
4. Δ peak oxygen uptake (VO_2peak)
5. Δ body fat mass [kg]
6. Δ wellbeing (WHO-5)
7. Δ stress perception (PSS-10)

We calculated the AUC glucose of the five-point oGTT with the trapezoidal method and the ISI according to Matsuda and De Fronzo (ISI = 10,000/√[fasting glucose x fasting insulin x (mean glucose x mean insulin)]) [923]. Further, we calculated the rise in serum insulin during the first 30 minutes of the oGTT (Δ ins 30') as measure of insulin secretion [924] as basis for the DI, calculated as Δ ins 30' x ISI to measure insulin sensitivity-adjusted β-cell function.

4.1.3.4 *Physical examination*

The physical examination after the oGTT included resting blood pressure and resting heart rate, height, body weight, body fat mass, waist circumference, and auscultation of the heart and lungs. For resting blood pressure and resting heart rate measurements, the participant was seated for at least 15 min. Measures were taken with an electronic device and a suitable upper arm cuff for the participant. During V1, resting blood pressure was measured on both arms. The arm with the higher systolic value was measured twice, with at least 15 minutes between measurements and at least 10 minutes after a blood drawing. Blood pressure at V2 was measured on the arm with the higher systolic value of V1 and was also measured twice during V2. Resting heart rate was taken from the second measurement. The participant was instructed not to move or speak during measurements. For the height measurement to the nearest cm, participants were standing upright without shoes, with their back to the measuring stick on the wall, the feet touched the wall and the hair was loose. Body weight and body fat mass was measured via a bioelectrical impedance analysis (Tanita BC-418, Tanita Corporation) to the nearest 0.1 kg [925], without shoes or accessories, and with 0.5 kg subtracted for clothes. We calculated the BMI [kg/m^2] as the ratio of weight [kg] to the square of height [m]. Waist circumference was measured to the nearest cm while standing, in the center between the iliac crest and the costal arch, with normal breathing and an uncovered waist. The auscultation was performed either seated or standing, with an inspection of the thorax, auscultation of the heart in the second intercostal space, Erb's point, cardiac apex and additional flowing sounds in the carotid artery and abdominal aorta. It also included an examination of the heart rate deficit between the auscultated heart rate and palpated heart rate of the arteria radialis. For the auscultation of the lung, the participant breathed normally through the open mouth. Anomalies were documented and considered for a possible exclusion from exercise testing.

4.1.3.5 *Ergospirometry*

For those women participating in the stepwise ergospirometry on a bicycle ergometer, the peak volume of oxygen that the body can utilize during physical exertion (VO_2peak) was measured. The ergometer of the ergospirometry system MasterScreen CPX (CareFusion, Höchberg, Germany) was calibrated according to the manufacturer's instructions and pulmonary function was tested according to the software's instructions. The participant was equipped with an electrocardiogram and a breathing mask. The test started with a three-minute resting phase during which respiratory gas was measured. This was followed by a three-minute reference phase without load at a cycling pace of 60 to 70 rotations per minute. Afterwards, the stepwise protocol increased by 25 W every three minutes. At the end of each step, the participant rated her perceived level of exertion by pointing to the value on the BORG scale (6 to 20, whereby 6 = no exertion at all, 20 = maximal exertion) [926-928]. The participant was instructed to give a hand signal when she was exerted and gave a final BORG scale rating before the load was removed. The main exertion criterion was a respiratory exchange ratio (VCO_2/VO_2) of 1.05 or higher. Secondary criteria for exertion were a BORG value of 17 or higher, 90% of the maximum heart rate (corresponding to 200-age), respiratory insufficiency/shortness of breath or a plateau of the VO_2 curve. The test was stopped in case of medical reasons of termination, including ST depression or elevation indicating ischemic alterations, symptoms of angina pectoris, progressive atrial or ventricular arrhythmia or block images, signs of a circulatory problem such as cyanosis or paleness, excessive dyspnea, disturbance in coordination, disorientation or severe dizziness. The cycling pace was reduced during the three-minute recovery phase without load. The main study site evaluated VO_2peak [ml/min], and the maximum respiratory exchange ratio (VCO_2/VO_2). VO_2peak marks an approximation of the maximal oxygen uptake (VO_2max) [929]. All study sites documented the maximum BORG value and the necessary parameters for analyses on case report forms. Outliers of 200 ml/min or higher in VO_2peak were excluded. The maximum respiratory exchange ratio was the highest measured respiratory exchange ratio during the loading phase, excluding the initial high respiratory exchange ratio when applying the first load.

4.1.3.6 *TRIANGLE intervention and app usage*

During V1, participants of the intervention group filled in the initial paper and pencil questionnaire for the *TRIANGLE* app (Supplementary Table 6). They received a Garmin vívosmart HR® fitness tracker including the user manual, a step tread, the *TRIANGLE* paper note pad, and an individual login code for the *TRIANGLE* app. For data security issues, we offered participants to use the Garmin vívosmart® HR fitness tracker without the respective app. Study nurses measured a participant's step length in a standardized 10 m distance with a participant's natural walking style. The distance [cm] was then divided by the number of steps to form the average step length [cm]. The average step length of a participant was used for individual settings in the Garmin vívosmart HR® fitness tracker. Further, participants of the intervention group signed a non-disclosure agreement and a form confirming the reception of the Garmin vívosmart HR® fitness tracker.

The intervention group received the *TRIANGLE* program as specified in the previous chapters for six months. The physical activity module was adapted to individual needs in the late postpartum phase due to cases of perineal laceration, sectio caesarea, and rectus diastasis. User logs included the user code, nickname, and date stamps of app activities as outlined in Table 3.8. (Chapter 3.2.4.1.1.2). Participants were instructed to use the *TRIANGLE* app for at least five out of seven days per week for six months. At the end of V2, participants in the intervention group deinstalled the app.

4.1.4 Data handling

All collected data were treated confidentially and pseudonymized (five-digit code) in each study site. A copy of all case report forms was sent to the main study site by mail. All *TRIANGLE* app data was collected on the university medical center's server of the main study site and encrypted as specified in Chapter 3.2.3.2. Participants in the intervention arm had to sign the *TRIANGLE* app privacy statement. The privacy statement was approved by the data protection officer of the Medical Center of the University of Munich. Participant's allocation forms of their individual four-digit login codes were kept at the study sites. This was necessary to merge the data collected during V1 and V2 with the logged user data in the *TRIANGLE* app for the intervention group. The main study site managed the list of login codes for the *TRIANGLE* app. All original case report forms are kept at the study sites for 10 years. All *TRIANGLE* app user data is kept at the university medical center's server of the main study site in Munich for 10 years and may be used for pseudonymized or anonymized analyses. A publication of study results will only be conducted in aggregated form.

4.1.5 Statistical analyses

Values are presented as total numbers (n) or percent for categorial variables, means ± standard deviation for normally distributed metric variables, and median (first and third quartile) for non-normally distributed metric variables. We compared different groups with the Chi-Square or Fisher-Exact Test for categorial and with the Mann-Whitney-U Test for metric variables. P-values below 0.05 were considered statistically significant. We analyzed and visualized all data with the SAS statistical software package version 9.4 (SAS Institute Inc., Cary, USA) and Tableau Desktop 2019.3 (Tableau Software, LLC, Seattle, USA).

The primary analysis was based on all randomized participants with complete primary outcomes at V2 (predefined modified intention-to-treat analysis). In addition, we conducted per protocol analyses. In the study protocol, we defined two different per protocol groups: per protocol group 1 that started using the *TRIANGLE* app and used the app's three core features (challenges, coaching, library) at least once, and per protocol group 2 that used the *TRIANGLE* app and each of the app's three core features throughout the study period (about ≥ 1 per month). However, all participants matched the criteria for the predefined per protocol group 1. We thus only performed one per protocol analysis with those participants who used each of the three core features of the *TRIANGLE* app about ≥ 1 per month throughout the study period.

The qualitative data was coded in a rapid thematic analysis per text element. We removed duplicates of same statements by one participant in different questionnaires. We further differentiated between positive and negative statements and counted respective responses as total numbers (n).

4.2 Results

In total, 66 out of 70 screened participants were included in the study. Both the intervention and the control group initially contained 33 participants (intention-to-treat group [930]) (Figure 4.1). 27 participants completed the primary outcomes in both the intervention and the control group (modified intention-to-treat group).

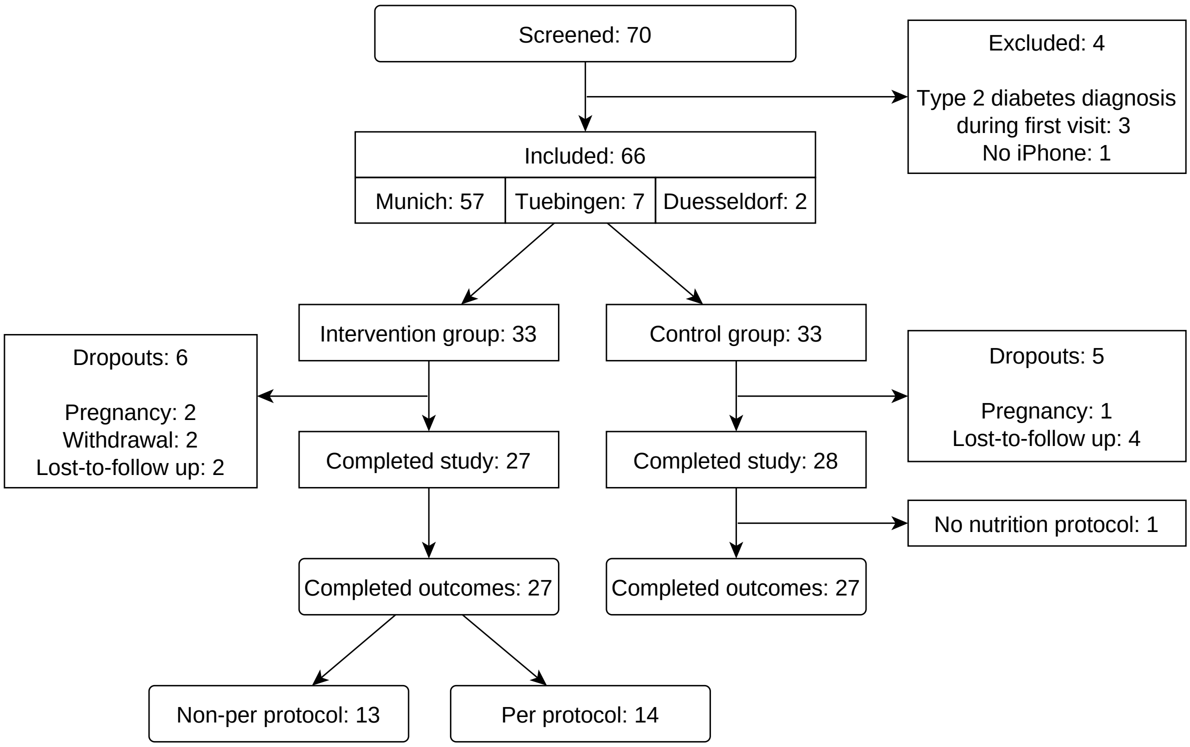

Figure 4.1: Participant flow chart for the Test TRIANGLE Pilot Study

4.2.1 Demographic and baseline characteristics

Table 4.3 shows the demographic characteristics of participants included in the study stratified by group: control (modified intention-to-treat, n = 27), intervention (modified intention-to-treat, n = 27), and per protocol (subset of the intervention group that used the app regularly, n = 14). The control and the intervention group were not significantly different in either of the analyzed demographic characteristics. The per protocol group contained significantly more native speakers compared to the control group. Compared to the control group, the per protocol group tended to contain more women with a paid job.

Neither the intervention nor the per protocol group showed significant differences to the control group in baseline criteria for primary or secondary outcomes (Supplementary Table 10).

Table 4.3: Demographic characteristics for the control, intervention, and per protocol group in the Test TRIANGLE Pilot Study

		Control	Intervention	p-value a)	Per protocol	p-value b)
n		27	27		14	
Age [years]		35.8 ± 4.4	37.3 ± 2.9	0.11	37.6 ± 3.5	0.11
Highest degree	Secondary school	5 (18.5%)	4 (14.8%)	0.90	3 (21.4%)	0.73
	A-levels	5 (18.5%)	6 (22.2%)		4 (28.6%)	
	College degree	17 (63.0%)	17 (63.0%)		7 (50.0%)	
German as native language		18 (66.7%)	24 (88.9%)	0.10	14 (100.0%)	***0.02***
Active smoker		1 (3.7%)	1 (3.7%)	1.00	1 (7.1%)	1.00
Currently in a job		3 (11.1%)	6 (22.2%)	0.46	5 (35.7%)	*0.10*
Time since delivery [months]		6 (5-8)	6 (5-11)	0.47	6 (5-16)	0.17
Insulin for GDM during pregnancy		12 (44.4%)	14 (51.9%)	0.59	10 (71.4%)	0.19
Sectio caesarea		13 (48.2%)	10 (37.0%)	0.41	4 (28.6%)	0.32
Current breast feeding	None	9 (33.3%)	6 (22.2%)	0.60	4 (28.6%)	0.84
	Partial	9 (33.3%)	12 (44.4%)		6 (42.8%)	
	Full	9 (33.3%)	9 (33.3%)		4 (28.6%)	
Oral contraceptive use		3 (11.1%)	3 (11.1%)	1.00	0 (0.0%)	0.54
Family history of diabetes		9 (33.3%)	7 (25.9%)	0.55	5 (35.7%)	1.00

n (percent) for categorial variables, mean ± standard deviation for normally distributed metric variables; a, b) Chi-Square or Fisher-Exact Test for categorial and Mann-Whitney-U Test for metric variables; p-value a) for comparison of control and intervention subjects (modified intention-to-treat group); p-value b) for comparison of control and per protocol subjects. The per protocol group is a subset of participants of the intervention group who used the core features of the app regularly throughout the study. GDM = gestational diabetes mellitus

4.2.2 Primary outcome

1) <u>DPP score</u>: "Does a) the assignment (modified intention-to-treat), and/or b) the regular use (per protocol) of the TRIANGLE program for six months result into a higher proportion of women post-GDM who achieve at least three out of five DPP points after six months of intervention when compared to standard care?"

The primary outcome at V2 (three out of five DPP points) was reached by three (11.1%) women in the control group and by six (22.2%) women in the intervention group, four thereof in the per protocol group (28.6%) (Table 4.4). The differences between groups were not significant.

The differences in the single components of the DPP score were not significant between the control and the intervention group (Table 4.4 and Figure 4.2). Yet, in the per protocol group, fiber intake was significantly higher compared to the control group (Table 4.4 and Figure 4.3). Additionally, we saw a positive trend in the per protocol group for a lower saturated fat intake compared to the control group (Table 4.4 and Figure 4.3).

Table 4.4: Group comparisons in the primary DPP outcome between the control, intervention, and per protocol group in the Test TRIANGLE Pilot Study

		Control	Intervention	p-value a)	Per protocol	p-value b)
n		27	27		14	
DPP score	0-2 pts.	24 (88.9%)	21 (77.8%)	0.47	10 (71.4%)	0.20
	3-5 pts.	3 (11.1%)	6 (22.2%)		4 (28.6%)	
Components of the DPP score						
Physical activity at V2 [min per week]		743 (360-1,340)	680 (520-1,125)	0.87	868 (375-1,125)	0.97
Fiber intake at V2 [g per 1,000 kcal]		8 (7-11)	10 (8-12)	0.14	12 (10-13)	***0.007***
Fat intake at V2 [% of total kcal]		39 (31-42)	36 (33-42)	0.99	36 (32-42)	0.78
Saturated fat intake at V2 [% of total kcal]		13 (11-16)	13 (10-14)	0.39	11 (10-14)	*0.10*
Δ body weight V1 to V2 [% of V1]	BMI ≥ 23	-1.4 (-4.3-2.4)	-1.4 (-5.6-2.5)	0.76	-3.9 (-9.4-0.9)	0.22
	BMI < 23	-0.6 (-1.2-0.3)	0.3 (-2.5-0.8)	0.44	0.3 (-2.8-0.9)	0.42

n (percent) for categorial variables, mean ± standard deviation for normally distributed metric variables, median (first and third quartile) for other metric variables; [a, b)] Chi-Square or Fisher-Exact Test for categorial and Mann-Whitney-U Test for metric variables; p-value [a)] for comparison of control and intervention subjects (modified intention-to-treat group); p-value [b)] for comparison of control and per protocol subjects. The per protocol group is a subset of participants of the intervention group who used the core features of the app regularly throughout the study; DPP = Diabetes Prevention Program, V1 = visit 1, V2 = visit 2, BMI = body mass index

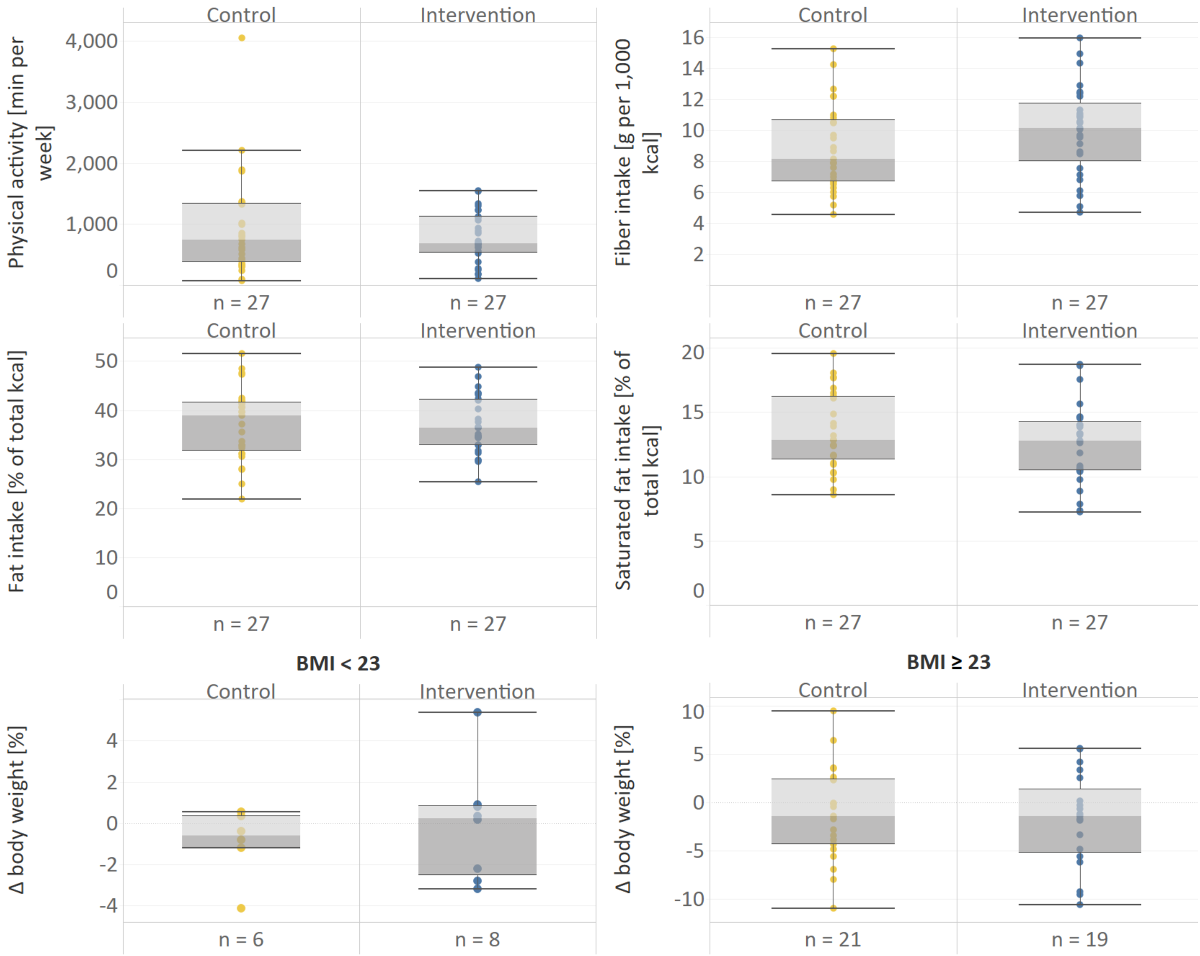

Figure 4.2: Group comparisons in the DPP criteria between the control and intervention group in the Test TRIANGLE Pilot Study

Values at visit 2 for physical activity, fiber intake, fat intake, and saturated fat intake; values of the difference between visit 1 and visit 2 for Δ body weight, stratified by BMI category

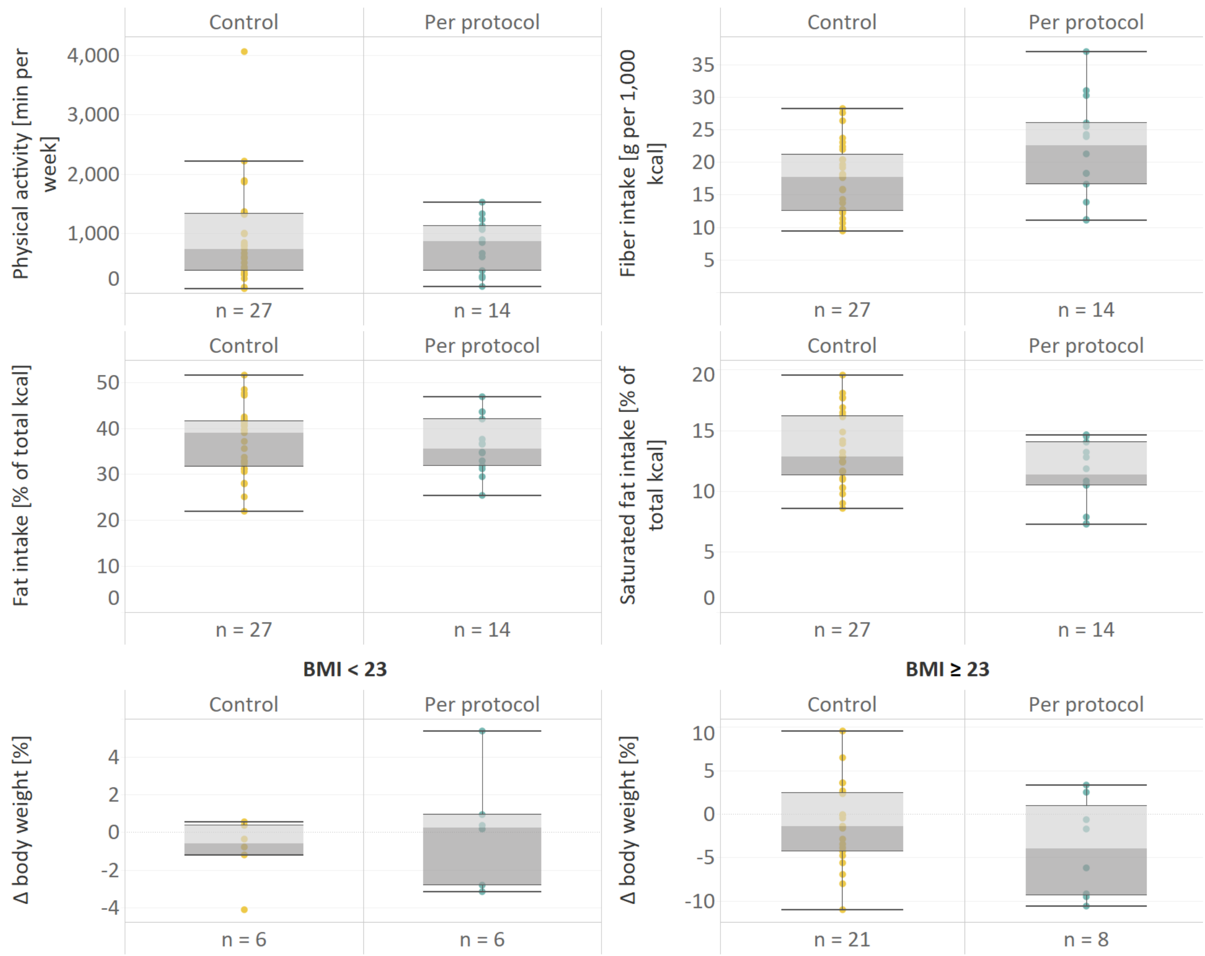

Figure 4.3: Group comparisons in the DPP criteria between the control and per protocol group in the Test TRIANGLE Pilot Study
Values at visit 2 for physical activity, fiber intake, fat intake, and saturated fat intake; values of the difference between visit 1 and visit 2 for Δ body weight, stratified by BMI category

Controlling for other risk behaviors showed that of the two active smokers (one intervention, one control) at V1, the participant in the control group quit smoking, yet two previous smokers (both in the intervention group) started smoking again between V1 and V2.

4.2.3 Secondary outcomes

2) <u>Cardiometabolic health status and wellbeing</u>: "Does a) the enrollment, and/or b) the regular use of the TRIANGLE program for six months lead to better glucose tolerance (Δ AUC glucose), insulin sensitivity (Δ ISI, Δ DI), physical fitness (Δ VO_2peak), body composition (Δ body fat mass), wellbeing (Δ WHO-5), and stress perception (Δ PSS-10) in women post-GDM when compared to standard care?"

The secondary outcomes did neither differ significantly between the control and the intervention group nor between the control and the per protocol group (Table 4.5). Yet, the data pointed towards a positive trend in the per protocol group in Δ VO_2peak compared to the control group (Table 4.5 and Figure 4.4). Further, we explored that the plasma glucose at 60 minutes in the oGTT showed a positive trend in the per protocol group compared to the control group (Table 4.5 and Figure 4.4).

In addition, two women in the control group developed T2D during the study while no woman in the intervention group developed T2D (Table 4.5).

Table 4.5: Group comparisons in secondary outcomes as differences between V1 and V2 for the control, intervention, and per protocol group in the Test TRIANGLE Pilot Study

		Control	Intervention	p-value a)	Per protocol	p-value b)
n		27	27		14	
Δ AUC glucose V1 to V2 [mg/dl*min] missing = 3		-752 ± 6,475	-2,328 ± 5,779	0.76	-4,110 ± 6,972	0.25
Δ ISI V1 to V2 missing = 7		-0.1 (-1.9 - 0.9)	-0.3 (-0.7 - 0.3)	0.93	0.0 (-0.3 - 0.7)	0.50
Δ DI V1 to V2 missing = 7		-11 (-49 - 93)	3 (-54 - 40)	0.43	8 (-45 - 39)	0.52
Δ VO_2peak V1 to V2 [ml/min] missing = 15		0 (-132 - 119)	15 (-137 - 190)	0.51	102 (-70 - 269)	*0.10*
Δ body fat mass V1 to V2 [kg] missing = 1		-0.5 ±3.7	-0.6 ±2.5	0.96	-0.9 ±2.6	0.74
Δ WHO-5 total score V1 to V2 missing = 1		0.0 (-3.0 - 3.0)	+1.0 (-2.0 - 3.0)	0.29	+1.5 (-2.0 - 4.0)	0.19
Δ PSS-10 total score V1 to V2 missing = 1		-1.5 (-4.0 - 3.0)	-1.0 (-3.0 - 3.0)	0.53	-3.0 (-4.0 - 0.0)	0.21
Additional analyses						
Δ plasma glucose oGTT 60’ [mg/dl] missing = 3		-12 (-24 - 20)	-13 (-14 - 11)	0.41	-31 (-53 - (-7))	*0.06*
Glucose tolerance status at V2	NGT	14 (51.9%)	15 (55.6%)	0.70	10 (71.4%)	0.69
	IFG	7 (25.9%)	8 (29.6%)		3 (21.4%)	
	IGT	3 (11.1%)	4 (14.8%)		1 (7.1%)	
	IFG+IGT	1 (3.7%)	0 (0.0%)		0 (0.0%)	
	T2D	2 (7.4%)	0 (0.0%)		0 (0.0%)	

n (percent) for categorial variables, mean ± standard deviation for normally distributed metric variables, median (first and third quartile) for other metric variables; a, b) Chi-Square or Fisher-Exact Test for categorial and Mann-Whitney-U Test for metric variables; p-value a) for comparison of control and intervention subjects (modified intention-to-treat group); p-value b) for comparison of control and per protocol subjects. The per protocol group is a subset of participants of the intervention group who used the core features of the app regularly throughout the study; AUC glucose = area under the glucose curve, V1 = visit 1, V2 = visit 2, ISI = insulin sensitivity index, DI = disposition index, VO_2peak = peak oxygen uptake, WHO-5 = World Health Organization-5 Well-Being Index, PSS-10 = Perceived Stress Scale-10 items, oGTT = oral glucose tolerance test, NGT = normal glucose tolerance, IFG = impaired fasting glucose, IGT = impaired glucose tolerance, T2D = type 2 diabetes

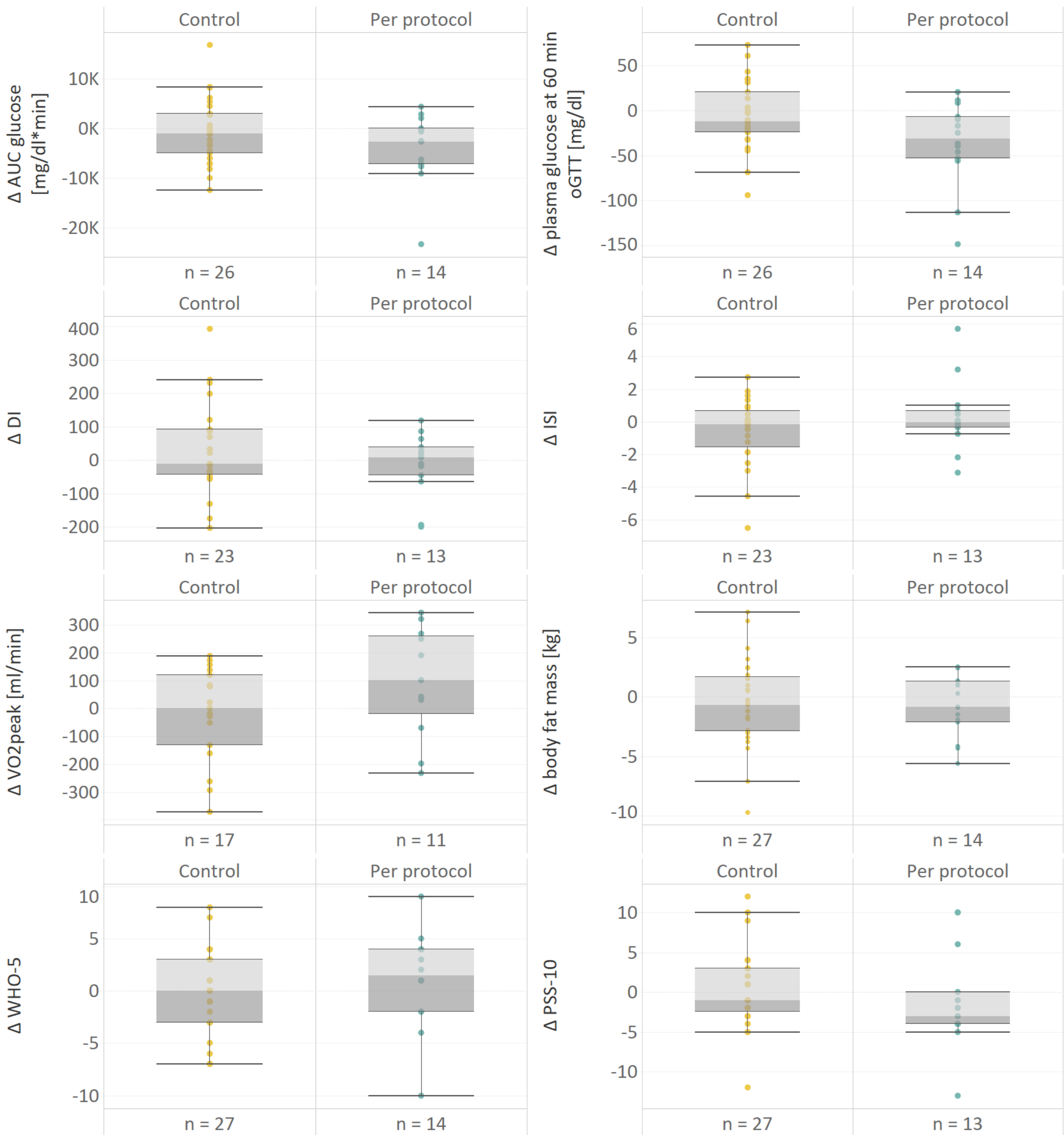

Figure 4.4: Group comparisons in secondary outcomes between the control and the per protocol group in the Test TRIANGLE Pilot Study
Values of the difference between visit 1 and visit 2, AUC glucose = area under the glucose curve, oGTT = oral glucose tolerance test, DI = disposition index, ISI = insulin sensitivity index, VO_2peak = peak oxygen uptake, WHO-5 = World Health Organization-5 Well-Being Index, PSS-10 = Perceived Stress Scale-10 items

4.2.4 TRIANGLE app usage and acceptance

3) TRIANGLE app usage and acceptance: "Is the TRIANGLE app accepted by women post-GDM?", "What is the user's perceived impact of the TRIANGLE app on behavior?", "How frequently do users operate the TRIANGLE app, the core features, sub-features, and themes during an intervention period of approximately six months?", "Are there changes in usage frequency over time?", "During what time of the day is the app used most frequently?", "Which of the TRIANGLE challenges are completed most frequently?", "What does the qualitative feedback add to the understanding of app acceptance, possible improvements, and the app's suitability for similar at-risk populations?"

TRIANGLE app users (intervention group, n = 25, two missing) rated the app with an average of 4.3 out of 5.0 points on the App Quality Mean Score, the App Subjective Mean Quality Score, and the Perceived Impact Mean Score. The highest of the four uMARS objective quality subscales for the *TRIANGLE* app was the Information Mean Score of 4.7, the lowest was the Engagement Mean Score of 4.0 (Figure 4.5).

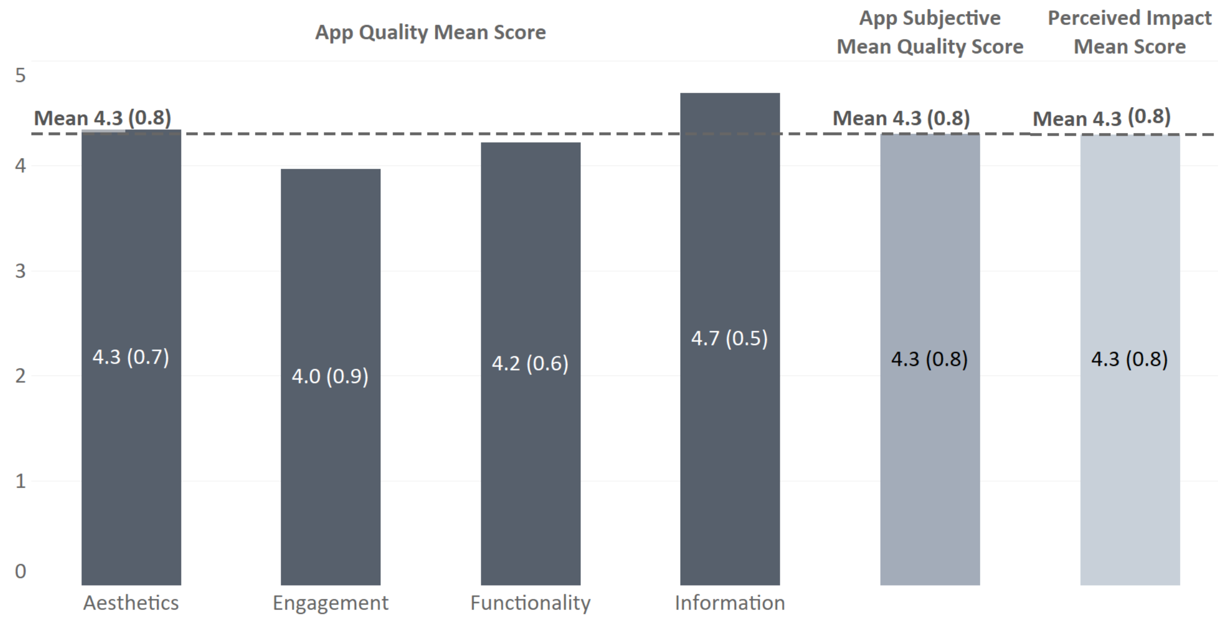

Figure 4.5: Results of the user Mobile Application Rating Scale (uMARS) in Test TRIANGLE Pilot Study
Stratified by subscale; n = 25, all values as mean (± standard deviation)

The per protocol group (n = 12, two missing) and the non-per protocol group (n = 13) evaluated the *TRIANGLE* app comparably in the three main uMARS scores (Figure 4.6).

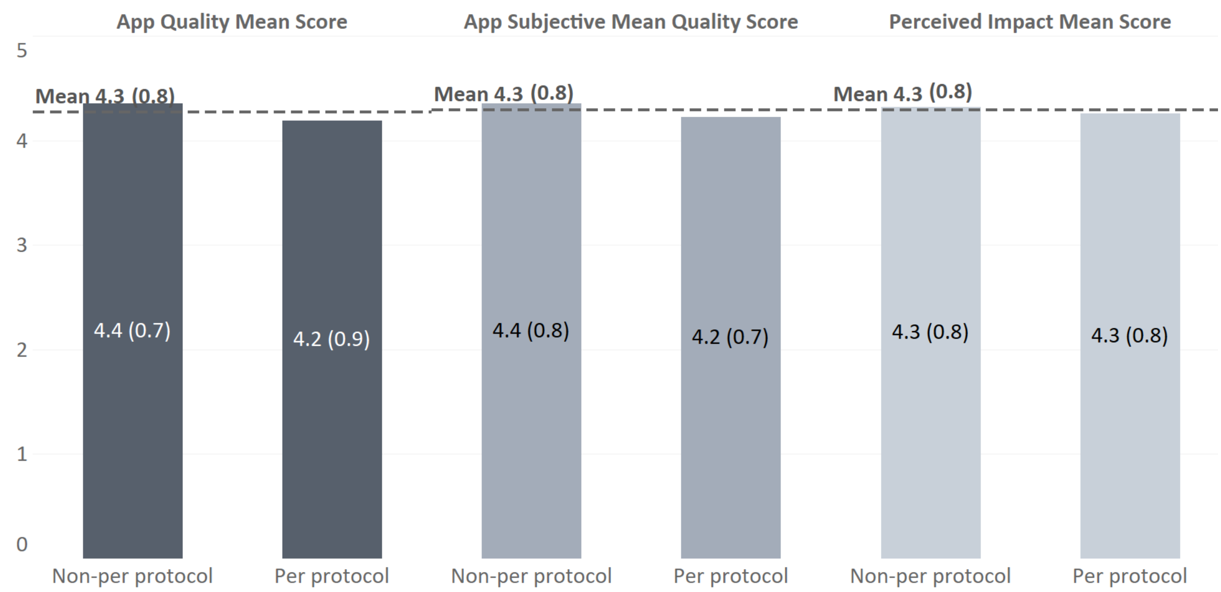

Figure 4.6: Results of the user Mobile Application Rating Scale (uMARS) in Test TRIANGLE Pilot Study
Stratified by non-per protocol (n = 13) vs. per protocol group (n = 12) and sub-score; all values as mean (± standard deviation)

The average values of the single uMARS items revealed the top five and the bottom three qualities of the *TRIANGLE* app as perceived by users (Figure 4.7).

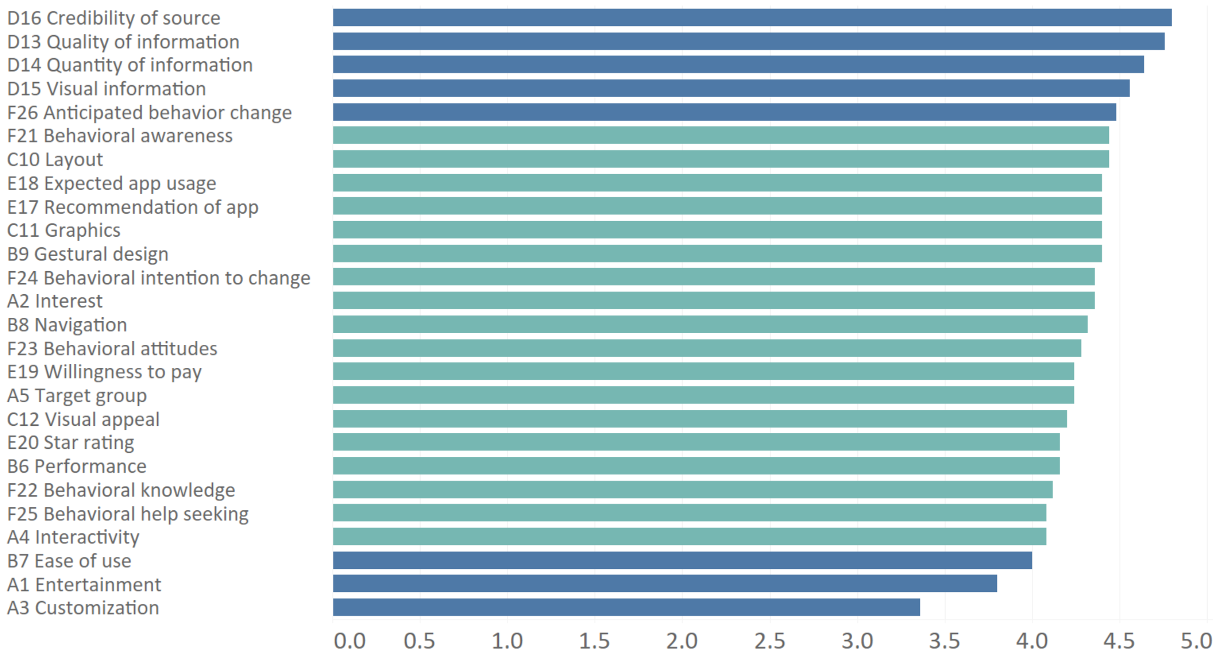

Figure 4.7: Mean values of the single items of the user Mobile Application Rating Scale (uMARS) in the Test TRIANGLE Pilot Study (n=25)

In the supplementary question on habit change at V2, significantly more women in the control group (total responses n = 27) stated that they definitely did not change health-related habits during the study compared to the intervention group (total responses n = 25, two missing) and the per protocol group (total responses n = 13, one missing) (Figure 4.8 and Supplementary Table 11).

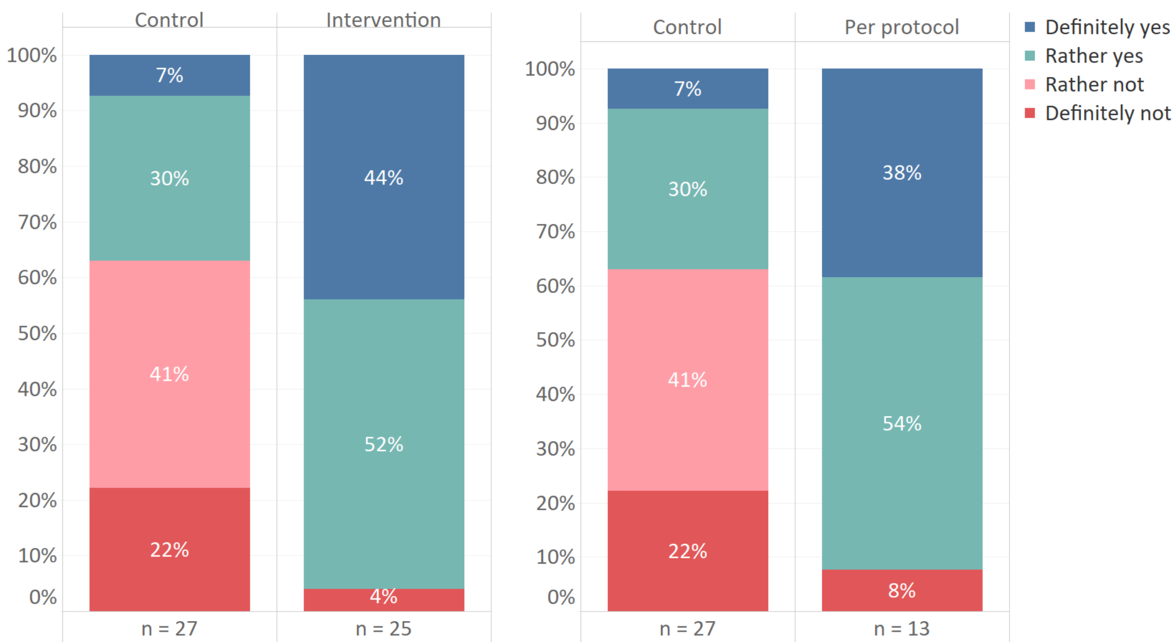

Figure 4.8: Percentage of perceived habit change in the Test TRIANGLE Pilot Study
Stratified by response item to the question “Have you changed health-related habits in the past six months?”, stratified by control, intervention, and per protocol group

The user logs (intervention group, n = 27) showed a stable functioning of the *TRIANGLE* app over the course of approximately 1.5 years with minor bugs that could be fixed during the study. A heat map of user activity (Figure 4.9) pointed to the highest number of app activities in the first month compared to the following five months, yet with individual variations.

		1	2	3	4	5	6
Non-per protocol	P1	1	7	48			
	P2	122	48	156	133	48	46
	P3	29	54	13	40	3	5
	P4	123	153	54	22	43	25
	P5	49	59	87	22	46	1
	P6	342	140	82	44	32	50
	P7	177	44	6	19	34	74
	P8	84	98	112	46	15	70
	P9	91	40	89	87	12	6
	P10	49	48	51	28	31	52
	P11	96	54	34	26	4	37
	P12	36	7	49		2	15
	P13	85	16	75	137	58	44
Per protocol	P14	237	277	212	235	171	177
	P15	273	147	130	158	125	87
	P16	246	191	85	144	118	174
	P17	193	43	62	72	28	21
	P18	205	87	123	70	46	49
	P19	256	144	78	53	15	15
	P20	105	36	125	103	91	81
	P21	119	72	66	63	21	1
	P22	111	90	90	146	102	241
	P23	266	117	247	230	210	123
	P24	283	250	161	300	137	121
	P25	279	96	63	17	76	31
	P26	336	257	194	171	161	160
	P27	246	150	159	223	166	102

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Figure 4.9: Number of app activities per participant per month in the Test TRIANGLE Pilot Study
N = 13 in the non-per protocol group (top) and n = 14 in the per protocol group (bottom); the stronger the coloring of the field, the more activities per month, P = participant

Further, about half of the participants (per protocol group, n = 14) used the app regularly, often independently of coaching activities (Figure 4.10). Some participants used the app on an almost daily basis. On average, the app was available for participants on 224 (± 27) days and used on 93 (± 48) days, corresponding to 42% of total usage. On average, participants used the app on 3.7 (± 0.5) days per week, with those in the per protocol group averaging 4.5 (± 0.7) days per week and the irregular users averaging 2.7 (± 0.6) days per week. The average number of app activities per active day was 6.9 (± 1.8) for all users, 7.5 (± 1.5) in the per protocol group and 6.3 (± 1.9) in the non-per protocol group. Responsiveness to coaching and overall app activity over time varied per participant (Figure 4.10).

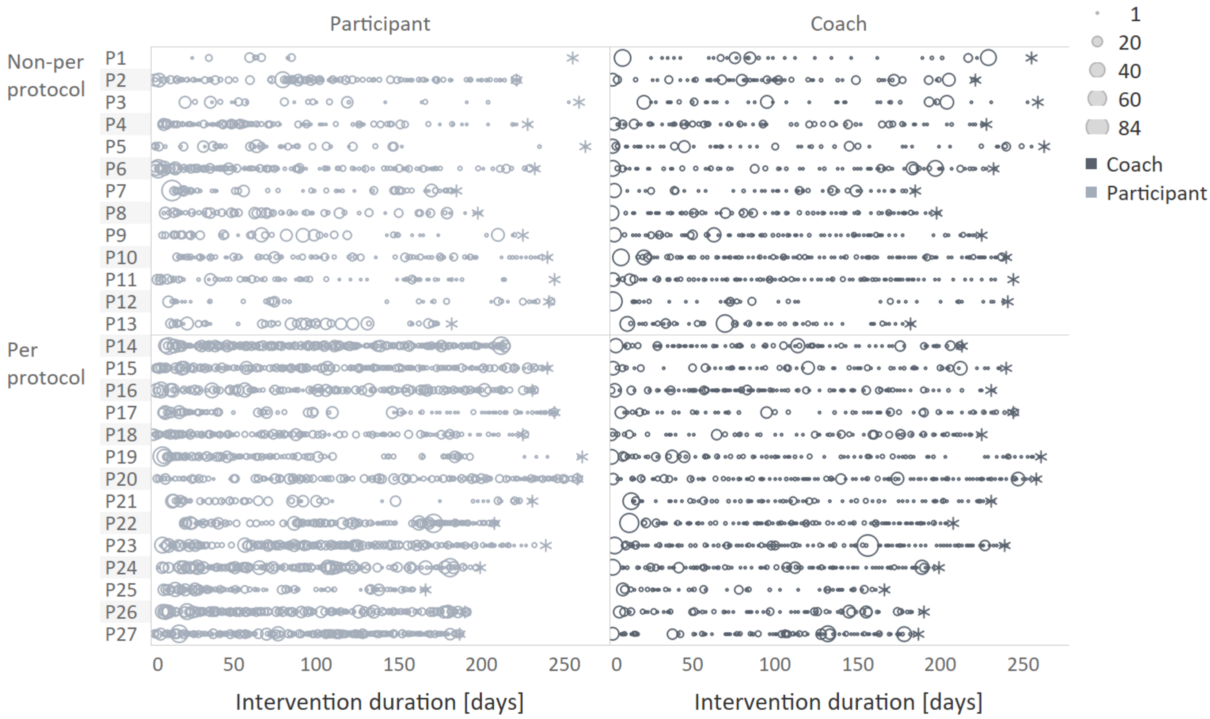

Figure 4.10: Number of app activities per participant over time in the Test TRIANGLE Pilot Study
Stratified by coach and participant activities, n = 13 in the non-per protocol group (top), n = 14 in the per protocol group (bottom); one circle per active day, circle size reflects number of activities, asterisk marks visit 2, P = participant

For most participants, app activities by the coach were low compared to app activities by a participant (Figure 4.11). Higher coaching activity was not associated with higher activity by a participant. The total number of app activities ranged between 56 and 1,523 for participants (Figure 4.11, in light grey) with a mean of 661 (± 424) activities, corresponding to a mean of 20.7 activities per week. In the non-per protocol group, the total number of app activities ranged between 56 and 742 with a mean of 349 (± 186) activities, in the per protocol group between 385 and 1,523 with a mean of 951 (± 373) activities.

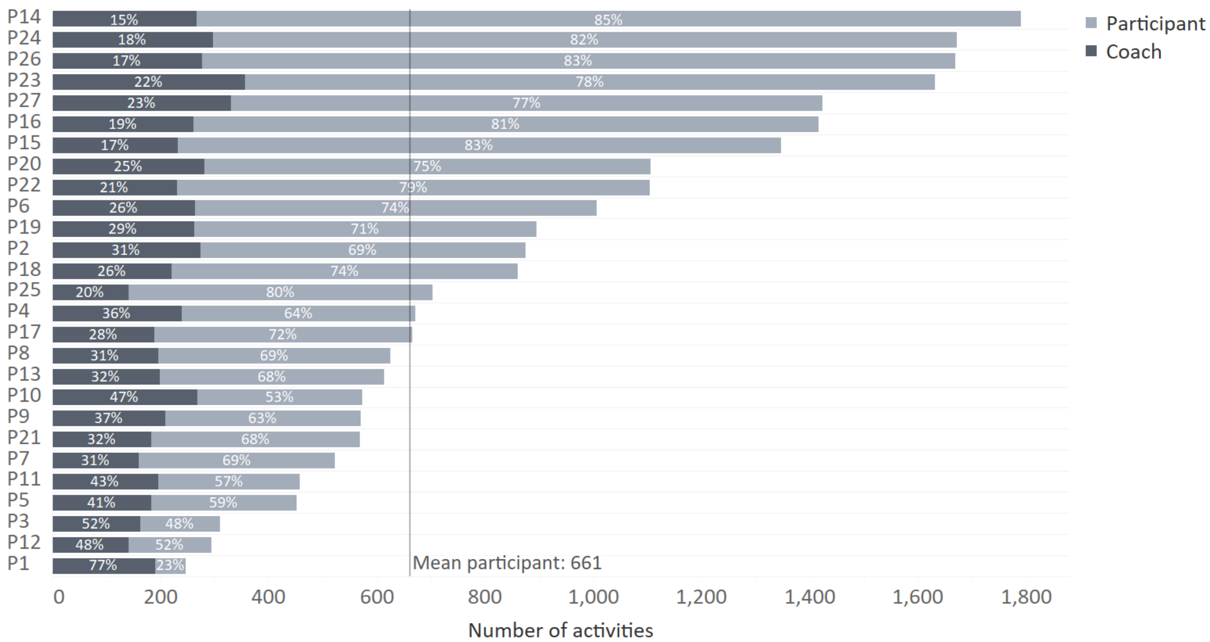

Figure 4.11: Total number and percentage of app activities per participant in the Test TRIANGLE Pilot Study
Stratified by coach and participant activities, n = 27

Participants used the app at any time of the day, independent from coaching times (Figure 4.12). Participants were most active in the app between 9 and 11 am and between 8 and 10 pm while the coach was most active between 8 am and 4 pm.

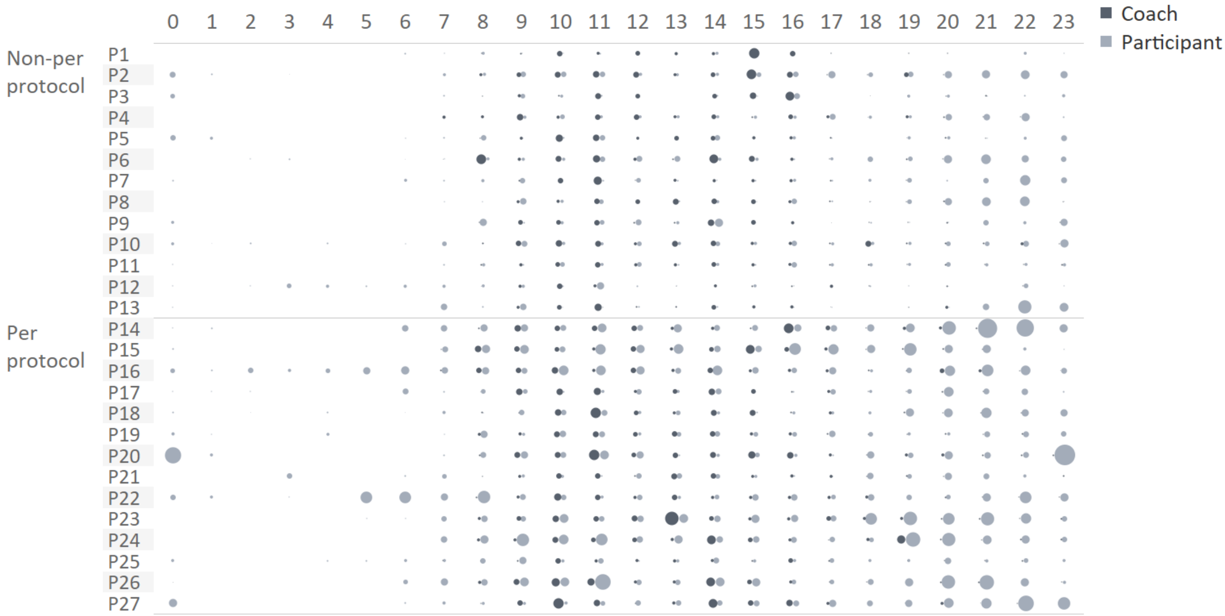

Figure 4.12: Number of app activities per participant per time of the day in the Test TRIANGLE Pilot Study
Stratified by coach and participant activities; n = 13 in the non-per protocol group (top) and n = 14 in the per protocol group (bottom); one circle per active hour, circle size reflects number of activities, P = participant

The app activities per feature confirmed the use of the interactive challenge system as core feature (76% of total activities) (Figure 4.13). Activities in coaching (15% of total activities) and in the library (9% of total activities) followed in usage frequency.

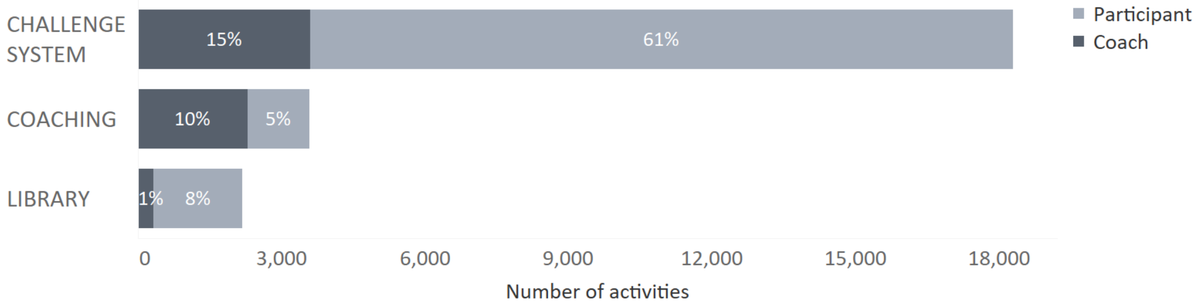

Figure 4.13: Total number and percentage of app activities per feature in the Test TRIANGLE Pilot Study
Stratified by coach and participant activities, n = 27

Regarding the sub-features, participants primarily ticked off challenges, followed by opened challenge descriptions, opened library articles, played guided practice, and sent text messages (Figure 4.14). The coach primarily sent text messages and marked challenges as suitable or recommended.

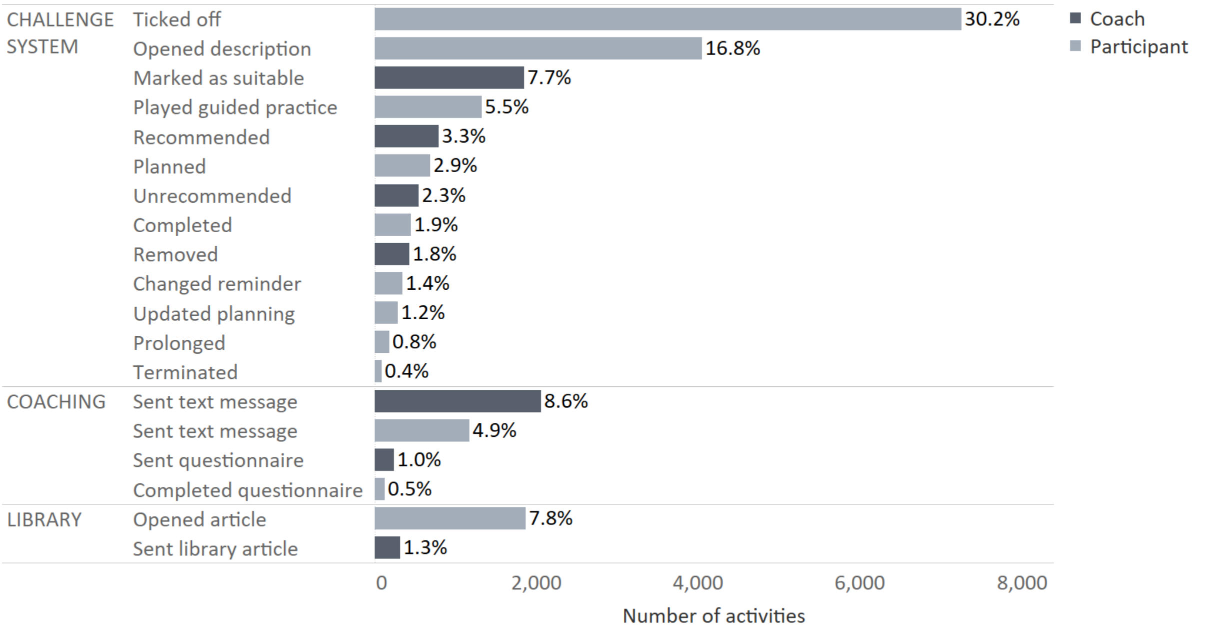

Figure 4.14: Total number and percentage of app activities per sub-feature in the Test TRIANGLE Pilot Study
Stratified by coach and participant activities, n = 27

The number of app activities over time per theme showed a usage of all three lifestyle areas per participant (Figure 4.15). Nutrition was accessed the most, followed by physical activity.

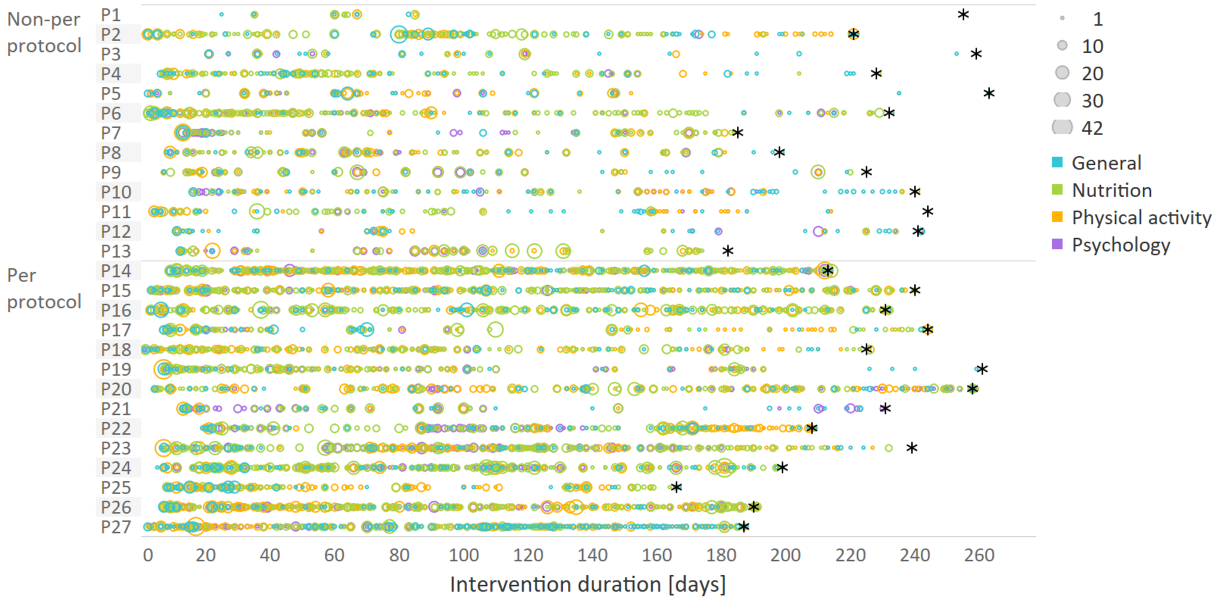

Figure 4.15: Number of app activities per participant over time in the Test TRIANGLE Pilot Study
Stratified by theme; n = 13 in the non-per protocol group (top) and n = 14 in the per protocol group (bottom); one circle per active day, circle size reflects number of activities, asterisk marks visit 2, P = participant

Similarly, the stacked line chart of participants' total app activities per theme revealed a continuous usage of the three lifestyle areas over six months of intervention, with less activities over time (Figure 4.16). Nutrition was accessed the most over time, psychology the least. App activities peaked between the second and the third week, before dropping until week eight. Weeks nine to 16 marked a plateau-like activity, before activity dropped to a lower level to reach another plateau around week 22.

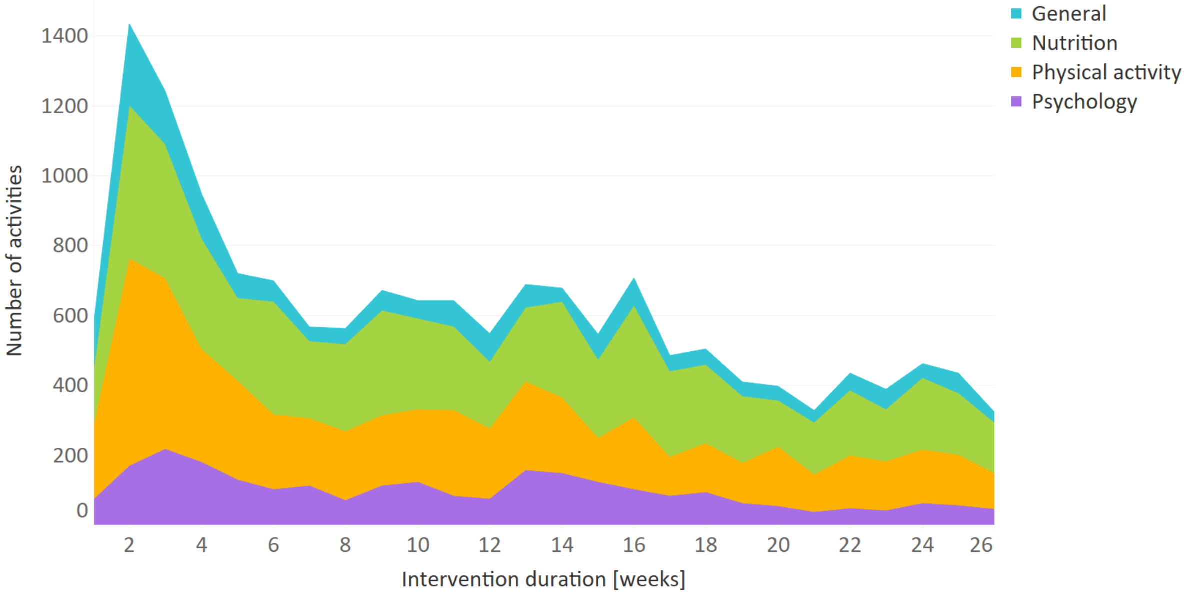

Figure 4.16: Stacked total number of app activities per theme over time in the Test TRIANGLE Pilot Study
n = 27

Participants used the assignable sub-features for all three lifestyle areas (Figure 4.17). Sent text messages were not categorized per lifestyle area by the *TRIANGLE* system. Guided practice videos were only available for physical activity while guided practice audios were only available for psychology. Participants ticked off, planned, and completed nutrition challenges more frequently and opened more nutrition library articles compared to physical activity and psychology. In contrast, participants updated challenge planning and played guided practice more frequently for physical activity compared to nutrition and psychology, respectively. Further, participants terminated similar amounts of nutrition and physical activity challenges. Psychological challenges were terminated the least and prolonged the most.

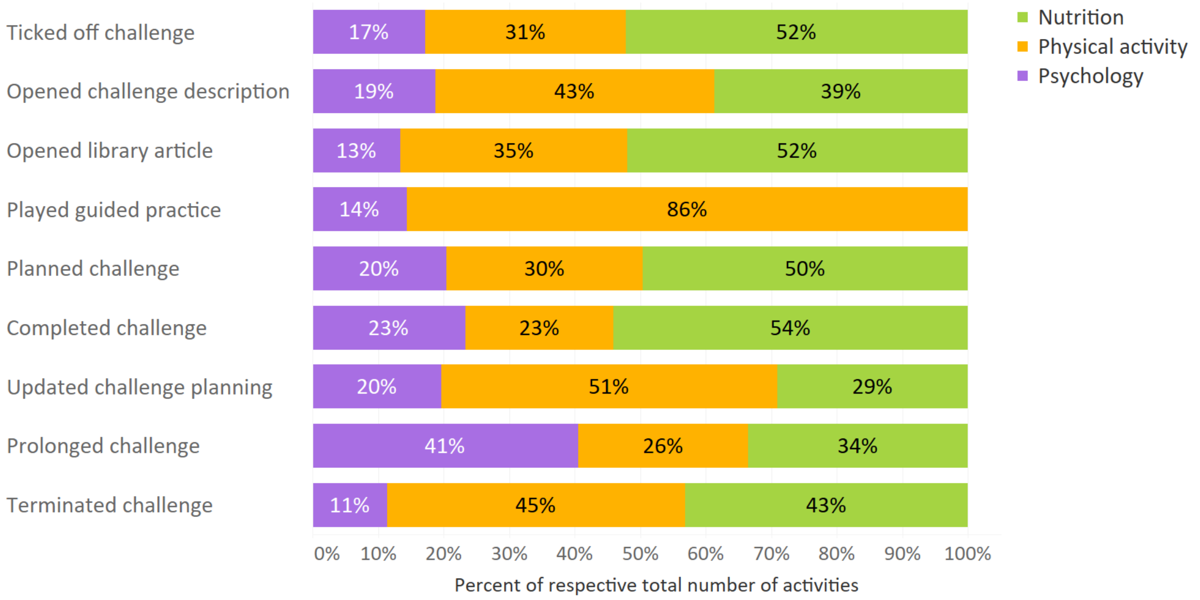

Figure 4.17: Proportion of total number of app activities per lifestyle area in the Test TRIANGLE Pilot Study
Stratified by sub-feature, n = 27

The top 15 challenges were completed by about one third or more of the participants (Figure 4.18), with some participants completing a challenge twice. Seven of the top 15 challenges were one-time actions (preparatory challenges). Regarding physical activity, none of the habitual challenges was among the top 15 completed challenges. Nutrition dominated the list with eight challenges among the top 15. The chained psychology challenge on gratitude shows that less participants leveled up in a chained challenge.

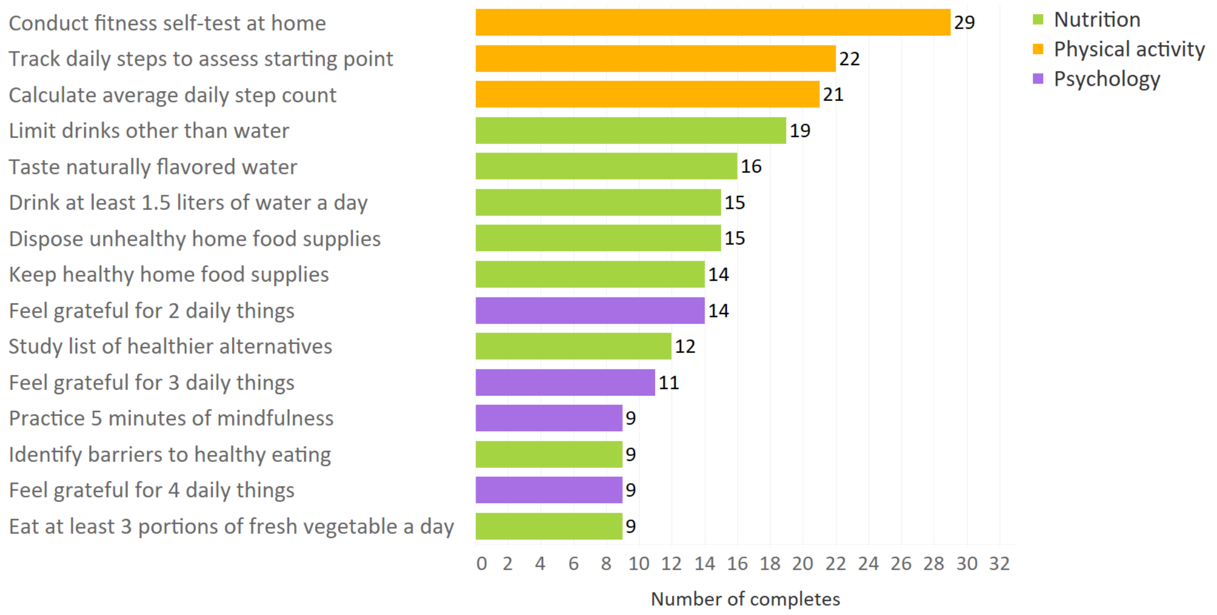

Figure 4.18: Top 15 most frequently completed challenges in the Test TRIANGLE Pilot Study
Colored per lifestyle area, n = 27, multiple completes possible per participant

Next, we addressed the question *"What does the qualitative feedback add to the understanding of app acceptance, possible improvements, and the app's suitability for similar at-risk populations?".*

We extracted the data from the following five open questions:

1. *"Further comments about the app?"* (comment section in the uMARS)
2. *"Do you miss any content for a) physical activity, b) nutrition or c) psychology?"* (additional questions for the intervention group)
3. *"Do you have any wishes or suggestions for the TRIANGLE app?"* (in-app evaluation questionnaire)
4. *"For which other at-risk groups do you consider the app suitable?"* (additional questions for the intervention group)
5. *"If you had to buy the app, how much money (in Euros) would you spend?"* (additional questions for the intervention group)

In a rapid thematic analysis, we clustered and differentiated between positive and negative statements in the following six themes: "app overall", "notifications", "content", "layout", "chat", and "progress visualization" (Table 4.6). In total, 12 participants filled in the free text in the uMARS, 23 participants answered the question on other suitable priority populations for the app, 11 participants commented perceived missing or desired content in the three lifestyle areas, 14 participants answered the in-app evaluation form after two months of intervention, and seven participants answered the in-app evaluation form after four months of intervention. Most statements were single statements by one woman.

Table 4.6: Qualitative user feedback on the TRIANGLE app in the Test TRIANGLE Pilot Study

Themes	Positive statements	Number of participants	Negative statements	Number of participants
App overall	Fantastic	3	Option for individual challenges not apparent	4
	Awareness for undesirable habits and better alternatives	2	Start at six months postpartum preferred	1
	Good	2	Too many options for postponement	1
	(A lot of) fun	2	Reporting not demanded enough	1
	Motivated to take action for health	1		
	Encouraged to reconsider habits	1		
	Changed health actions	1		
	Motivated team	1		
	Just right for people aiming at behavior change	1		
	Motivated to try something new	1		
Notifications	Helpful to see what's new in *TRIANGLE*	1		
	Keep motivation high	1		
Content	Super	1	Too little inclusion of the baby, e.g. for fitness	2
			Too much consideration of the baby	1
			Too much consideration of social support	1
			Too little consideration of pelvic floor for sports	1
			Articles on perceived barriers too long	1
			Too few vegetarian normal fat recipes	1
Layout			Too much text	1
			Link to library articles too far down at the bottom in challenge description	1
Chat			Scrolling bug	1
			No real-time message transfer	1
Progress visualization			Incomprehensible screen	1

Overall, we received 23 different suggestions for additional desirable app features or services (Table 4.7). The two most frequently desired features were “option to take notes in a challenge” and “integrated step counts”.

Table 4.7: Suggestions for additional desirable app features or services by intervention participants in the Test TRIANGLE Pilot Study

Desirable app features or services		Number of participants
General	App for Android	1
	Language setting for Spanish	1
	More individualization	1
	Optional in-person meetings	1
Challenges	Option to take notes in a challenge	4
	Integrated step count	4
	Biking tracking	2
	Tracking for beverages per unit	2
	Reminder per challenge	1
	Repeated reminders more than once per day for a challenge	1
	Integrated challenge history in progress visualization	1
	Daily calorie tracking	1
	Strict meal plan for initial one to two weeks	1
	Yoga exercises	1
	Social network feature to connect with other participants	1
Coaching	Picture upload	1
	Option to vary quantity of motivational messages	1
	Individual nutrition kick-off session	1
Library	More recipes	2
	Nutrition videos	1
	Include number of servings in recipes	1
	Option to silence library content related to overweight or obesity	1
	Separate quick and easy recipe section	1

Women post-GDM considered the *TRIANGLE* program suitable to prevent cardiometabolic disease or related complications in many other at-risk populations. The suggestions spanned the total population, including children and older people, and very specific subsets such as young working females or individuals with type 1 diabetes (Table 4.8). Some participants defined suitable groups via characteristics such as willingness to take health action or digital interest. The most frequently named populations were “everyone at high risk for T2D”, “everyone, especially those willing to take action for their health”, and “overweight individuals”.

The answers to the question *“If you had to buy the app, how much money (in Euros) would you spend?”* ranged between 3.90 Euros once to 50 Euros per month.

Table 4.8: Other suitable at-risk populations for the TRIANGLE program as perceived by participants of the intervention group of the Test TRIANGLE Pilot Study

Perceived other suitable at-risk populations for the *TRIANGLE* program	Number of participants
Everyone at high risk for T2D	6
Everyone, especially those willing to take action for their health	5
Overweight individuals	5
(Working) males	3
Everyone digitally interested	2
Young mothers	2
(Overweight) children or adolescents	2
All adults	1
Young fathers	1
Young working females	1
Females during pregnancy	1
Older people	1
Individuals with type 1 diabetes	1

4.2.5 TRIANGLE additional program material usage and acceptance

4) "How many of the participants use the additional TRIANGLE program materials and consider the materials helpful?"

As part of the questionnaires at V2, we asked intervention participants (n = 27) if they used the non-app program materials (yes/no), if they considered the materials helpful (yes/no/partly), and if they had no technical problems (yes/no/partly). The *TRIANGLE* paper note pad was used by approximately half of the participants (1 missing), of which about 40% considered it (partly) helpful (Figure 4.19). All intervention participants used the Garmin vívosmart® HR fitness tracker (1 missing), with 65% considering it helpful and about 27% indicating (partly) technical problems with the gadget.

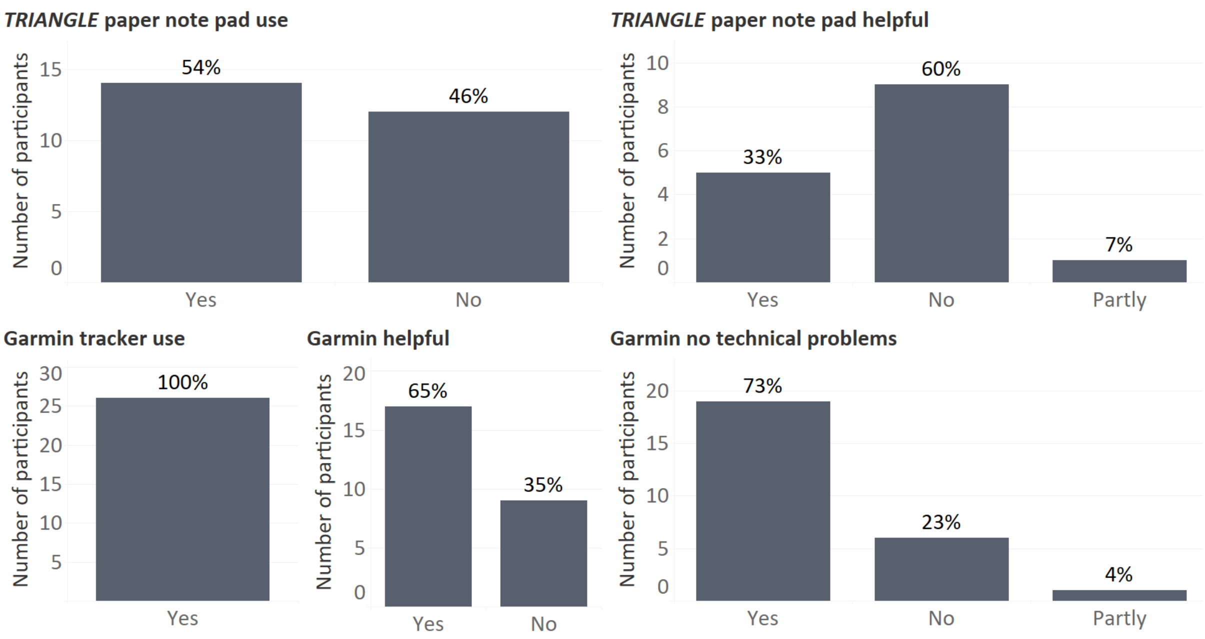

Figure 4.19: Usage and acceptance of additional program materials in the Test TRIANGLE Pilot Study
Stratified by question and response item

4.3 Discussion

The *Test TRIANGLE Pilot Study* aimed at testing the effects of the novel *TRIANGLE* mHealth intervention for cardiometabolic health behavior change in physical activity, nutrition, and psychology compared to enhanced standard care (with additional recommendations for sleep and psychosocial wellbeing) in women post-GDM. Our findings suggest that a postpartum mHealth program targeting habit change via the habit-goal interface is feasible for women post-GDM. Our results highlight the value of a mixed methods design in a pilot study with different outcome measures such as validated questionnaires on lifestyle behavior and app acceptance, clinical parameters, and app user logs. Similarly, other studies stressed the importance of mixed methods pilot testing prior to larger RCTs for mHealth interventions [917, 931, 932].

To our knowledge, this is one of the first trials testing a behavioral smartphone-based intervention for women post-GDM to prevent cardiometabolic disturbances. We found two other trials currently testing novel mHealth apps for or including women post-GDM [43, 933], yet none has published results from a clinical trial or pilot trial to this date. Hence, we compared general *TRIANGLE* intervention results with other interventions post-GDM and the *TRIANGLE* app user logs with similar smartphone-based mHealth programs for cardiometabolic health behavior change. Lifestyle intervention studies with women post-GDM are heterogenous regarding in- and exclusion criteria, intervention characteristics, outcome measures, comparison groups, lag between GDM and intervention start, and follow-up [38, 46, 76, 934, 935]. Further, the interventions differed in duration, intensity, setting, delivery mode, behavior goals, theoretical constructs, behavior change methods, and expertise of healthcare practitioners [38, 46, 76, 934]. Therefore, the comparability of results achieved by interventions post-GDM remains limited.

The dropout rate in the *Test TRIANGLE Pilot Study* was close to the 15% assumed in the power calculation, with 27 participants out of 33 completing the primary outcomes both in the intervention and the control group. The remaining 54 participants (modified intention-to-treat group) out of 66 participants indicate good retention in both the intervention and the control group. In contrast, most intervention trials with women post-GDM show a higher total attrition and a higher attrition in the control group compared to the intervention group [46]. Yet, a recent systematic review stressed the low reporting (10 out of 16) of attrition rates in intervention trials post-GDM [935]. Trials post-GDM with available attrition data ranged between 68% and 97% for complete intervention endpoints [46]. In comparison to similar mHealth trials for T2D prevention with other high-risk populations, the *TRIANGLE* attrition rate was low to comparable [808, 829, 931].

The per protocol group – the subset of intervention participants using the *TRIANGLE* app regularly – contained 100% native speakers compared to 89% in the entire intervention group. This pointed to the importance of native language and cultural aspects for program adherence, as suggested by Intervention Mapping [116], and as addressed by culturally adapted programs post-GDM [74, 936]. Further, a trend towards more working mothers in the per protocol subgroup indicated that a paid job may facilitate habit change. This may be linked to a more structured day with many stable contexts in work life [106].

The overall high proportion of women with a low DPP score of zero to two (89% in the intervention group, 92% in the control group) at baseline stresses the need for intervention in this priority population. Only 11% (intervention group) and 8% (control group), respectively, fulfilled three or four DPP criteria at baseline despite the non-plausible high self-reports of physical activity with medians around 800 minutes of moderate to vigorous physical activity per week that were responsible for one achieved DPP point in most women. The high proportion of women with a WHO-5 total score below 13 (37% in the control group, 22% in the intervention group) is in line with baseline characteristics in similar trials [70] and with previous research showing that women post-GDM are more susceptible to postpartum depression [327].

4.3.1 Primary outcome

The proportions of participants achieving at least three out of five DPP points (primary outcome) were not significantly different between groups. Yet, the proportion of participants reaching the primary outcome in the intervention group (n = 6, 22%) was double the proportion of the control group (n = 3, 11%). This indicates some intervention success in the ambitious bivariate DPP score, yet below significance. Hence, the transition from intentional behavior to regular habits may have been accomplished too recently to show behavioral effects on the larger scale of the DPP criteria or has not occurred yet. Other studies on behavioral interventions post-GDM used the DPP goals as outcomes [39, 60, 74, 937]. Yet, none of these studies seemed to have used the binary DPP score as outcome according to recent systematic reviews [76, 935].

In the single DPP components, the per protocol group showed a significantly higher fiber intake and a positive trend for a lower saturated fat intake at V2 compared to the control group. These findings are in line with most of the intervention trials post-GDM below one year of duration and below 100 participants. Such trials showed first indications, yet limited evidence for clinical efficacy of changes in cardiometabolic health behavior – as summarized in almost yearly systematic reviews with meta-analyses [38, 42, 46, 934, 935, 938]. The number of studies providing measures of health behavior at the end of an intervention post-GDM is limited compared to those on cardiometabolic outcomes such as body weight [76]. Few trials showed positive intervention effects on physical activity [68, 939, 940], fiber intake [49, 941-943], fat intake [68, 74, 944-946], and saturated fat intake [944, 946]. Other trials did not show intervention effects on physical activity [70, 941, 947], fiber intake [60], fat intake [60, 941], and saturated fat intake [60, 68]. The fifth DPP criterion of body weight change was among the most frequent measures in intervention trials post-GDM, yet with contradicting results [38, 42, 46]. If data was pooled, recent meta-analyses showed significant intervention effects on body weight reduction [42, 934, 935], with a significantly higher body weight change in studies with a duration of more than one year compared to those below one year [935]. The overall high variability in body weight change between V1 and V2 in our and other studies may reflect the high impact of natural perinatal weight fluctuations [315, 948, 949].

Overall, study designs and methods of intervention studies post-GDM were too different to compare the magnitude of behavior change, especially due to diverse measurement instruments for such endpoints [46, 76]. Some studies [68, 941, 946] indicate that smaller measures of behavior detect changes faster than the DPP criteria that require multi-behavior change per criterion. For example, after 13 weeks of intervention within five years post-GDM, a Canadian study found that fruit and vegetable intake increased by 1.5 servings per day and daily steps by 733 steps per day while consumption of convenience meals decreased by 30% and eating out by 22% [950]. Such more subtle changes lie beyond the DPP measures.

Controlling for other risk behaviors showed that two pre-pregnancy smokers (both in the intervention group) re-started smoking despite the health intervention while the active smoker in the intervention group at baseline did not quit smoking during the intervention. The *TRIANGLE* program did not directly address smoking habits, which may have prevented a relapse to pre-pregnancy smoking behavior.

Similarly, smoking was not among the 175 outcome measures in previous studies post-GDM [76]. In sum, this indicates that future interventions with women post-GDM should target smoking habits.

4.3.2 Secondary outcomes

Neither of the seven secondary outcomes differed significantly between groups, yet our data pointed towards a positive trend in the per protocol group in Δ VO_2peak compared to the control group. Similarly, another randomized controlled behavioral intervention post-GDM was not able to detect changes in metabolic parameters while detecting some changes in behavior [947]. Overall, improvements in clinical outcomes following the *TRIANGLE* intervention are likely but below significance in this short and – due to the underlying assumptions – underpowered pilot trial. In line with the findings of systematic reviews on interventions post-GDM [38, 42, 46, 934, 935, 938], our study indicates the necessity of larger, prolonged and methodologically robust trials to capture changes in clinical parameters. This is especially important considering the non-intensive intervention approaches required by women post-GDM [42].

Few intervention trials with women post-GDM reported improvements in Δ AUC glucose [951], Δ ISI [950], Δ VO_2peak [952], and Δ body fat [942] while other trials did not show intervention effects on Δ AUC glucose [953] and Δ body fat [947, 950, 952, 954]. None of the other intervention trials with women post-GDM measured Δ DI, Δ WHO-5, and Δ PSS-10 [76]. The intervention studies post-GDM were too heterogenous for sound comparisons in secondary outcomes – as discussed exemplarily for Δ VO_2peak in the following paragraph.

Only one single-arm pilot trial used the Δ VO_2peak as outcome measure in a previous behavioral intervention post-GDM [952] despite needed improvements in the lower physical fitness of women post-GDM compared to controls [225], especially in the subgroup with mild to moderate depression [224]. The home-based cardiovascular lifestyle intervention post-GDM showed increases in VO_2max after three and six months of intervention [952]. The pilot trial only included women with a pre-pregnancy BMI of at least 25 kg/m^2 and was based on four in-person visits with weekly 15-minute telephone calls, with no control group [952]. In a small more intensive intervention with older overweight/obese women with a history of GDM (n = 20) or T2D (n = 5), VO_2max increased by 16% after six months of a hypocaloric diet plus aerobic exercise [955]. The study included only weight stable and sedentary women, some were already in the premenopausal phase. The two study arms were a hypocaloric diet only versus a hypocaloric diet plus aerobic exercise, with no control group [955]. These two studies with women post-GDM or with a history of GDM confirm our findings that changes in Δ VO_2peak or Δ VO_2max may be possible even in a short time span. Yet, the trials were conducted without a control group and too different from the *Test TRIANGLE Pilot Study* for a direct comparison.

Two women in the control group developed T2D during the *Test TRIANGLE Pilot Study* while no woman in the intervention group developed T2D, similar to other intervention studies post-GDM [46, 951].

4.3.3 TRIANGLE app usage and acceptance

Due to the lack of studies on preventive smartphone app interventions for women post-GDM, we compared our results to other mHealth apps on cardiometabolic health behavior change.

TRIANGLE app users rated the app on all three uMARS scores with 4.3 out of 5.0 points. The uMARS App Quality Mean Score of 4.3 out of 5.0 points lies within the top range of health apps [913, 914]. Hence, the *TRIANGLE* app can be classified as high-quality app that was well accepted by this study sample of women post-GDM. The highest uMARS sub-score of 4.7 for the Information Mean Score of the

TRIANGLE app shows that users appreciate the current information source, and the quality, quantity, and visualization of information. Similarly, users rated the item “anticipated behavior change” with 4.5 out of 5.0 points, demonstrating that users trust the app in supporting their behavior change. Participant’s trust in the app’s support for behavior change is also mirrored in the high Perceived Impact Mean Score of 4.3 out of 5.0 points.

The lowest uMARS sub-score was the Engagement Mean Score of 4.0, showing some room for interactive improvement in content, delivery, and behavioral targets. The average values of single uMARS items revealed the bottom three evaluations for *TRIANGLE* in “ease of use” (functionality), “entertainment” (engagement), and “customization” (engagement). The “ease of use” was likely lowered by the confusion about the weekly activity screen for ticking off or unticking challenges retrospectively. Users expected this sub-feature in the progress screen, as planned in a next simplified *TRIANGLE* version. The tested *TRIANGLE* app did not contain any entertainment feature. Hence, gamification elements [956] and real-time physical activity coaching [846] could raise future entertainment scores. Further, users were restricted in customizing the app according to e.g. design preferences while the app content was highly customized to an individual user. The choice of own settings in e.g. app design could enhance perceived customization [897]. Participants further underused current customization features such as requesting an individual challenge. This indicates the need for better communication or better visibility of current customization options. Overall, the engagement domain remains underdeveloped in current habit-based health apps despite self-monitoring features [917, 932]. A recent framework conceptualized engagement in digital behavior change interventions [957]. This framework may serve as a basis to further improve engagement with the *TRIANGLE* app as an important aspect for program adherence [958].

When comparing the uMARS ratings of the per protocol group with the non-per protocol group, a more regular app activity did not seem to affect the App Quality Mean Score, the App Subjective Quality Mean Score, and the Perceived Impact Mean Score. This indicates that even though some participants did not use the *TRIANGLE* app on a regular basis, they still accepted the app and considered the app of high quality.

Significantly more women in the control group stated that they definitely did not change health-related habits during the study compared to the intervention and the per protocol group. The comparison between the intervention group and the per protocol subgroup indicates that intervention participants thought that they changed their behavior independently of regular app usage. This confirms the high ratings of the Perceived Impact Mean Score in the uMARS in both the per protocol and the non-per protocol group. In contrast, users of nutrition apps perceived an app as more effective when used regularly and long-term compared to irregular or short-term [814]. The high perceived effectiveness by irregular *TRIANGLE* users together with the trends for better behavioral and clinical outcomes in the per protocol group point towards an overestimation of behavior change by irregular users. A recent review on the perceived effectiveness of diet and physical activity apps showed that the majority of users thought the apps affected their eating and activity habits, health consciousness, and self-education about nutrition and physical activity [814]. Further, the review revealed that users of both nutrition and physical activity apps perceived app effectiveness higher compared to users of one type of app [814]. This could explain the high perceived effectiveness ratings of the *TRIANGLE* app combining three lifestyle areas in one app.

User logs allowed us to inspect usage patterns and the use of different app components. The data indicated that the intended users (women post-GDM) accept the *TRIANGLE* app features, content, and flexibility. The *TRIANGLE* app proved suitable as delivery channel for an intervention for women post-GDM with a high total app usage and usage at any time of the day. The highest number of *TRIANGLE* app activities occurred in the first month of the intervention. This usage pattern over time was confirmed by a review on studies on weight loss apps [897] and by other studies on health promotion apps [915, 916, 959, 960]. The peaks in *TRIANGLE* app usage in the late morning and late evening were similar to a vegetable tracking app that showed an additional peak around dinner time at 6 pm. [916]. The usage profile of total *TRIANGLE* app activities over time revealed peaks, plateaus, and drops that could be harnessed by adapting coaching activities to each phase.

On average, the *TRIANGLE* app was used on 42% of the days available. Therefore, the *TRIANGLE* app lies in the upper usage range compared to similar app interventions [804, 808, 917, 961, 962] – especially when considering likely attrition effects of interventions with a duration below six months. About half of the participants (per protocol group) used the *TRIANGLE* app regularly. On average, participants used the *TRIANGLE* app on 3.7 days per week, with those in the per protocol group averaging 4.5 days per week. Hence, approximately half of the participants almost reached our intended adherence of at least five out of seven days. In comparison, overweight pregnant women used a lifestyle app 1.7 days per week for about 13 weeks [963] and 60% of a subset of paid subscribers used one of the most popular meditation apps (*Calm*) five times or more per week for about 11.5 months [964]. The average number of app activities in *TRIANGLE* per active day was 6.9 for all participants, 7.5 in the per protocol group and 6.3 in the non-per protocol group. The comparable numbers in the subgroups indicate that the main difference between regular and irregular users lies in the number of active days, not in the number of activities per use day. This usage pattern was confirmed by a study testing a comparable app for T2D prevention [965]. The group difference in active *TRIANGLE* days accumulated to a large difference in the total number of *TRIANGLE* app activities, with a mean of 349 ± 186 activities in the non-per protocol group and a mean of 951 ± 373 activities in the per protocol group. The higher and more regular activity in the app with respective behavioral tracking may explain the higher total fiber intake and the trend towards a lower saturated fat intake as well as the higher Δ VO_2peak in the per protocol group compared to the control group. However, this needs to be investigated in a larger trial together with the explorative finding of improved 60 min plasma blood glucose values in the oGTT in the per protocol group compared to the control group. The much lower activity of irregular users compared to the per protocol group shows the need for further adherence strategies via behavior design since we assume that an app usage of at least five out of seven days is ideal for habit change.

For most participants, app activities by the coach were low in comparison to app activities by a participant. Higher coaching activity was not associated with higher activity by participants. These usage patterns are in line with previous studies on similar concepts [804]. The low coach to participant activity ratio indicates that coaching activities are within a realistic scope for the *TRIANGLE* app implementation in routine care. Further, some of the current coaching activities may be automated in the future to further lower staff requirements. The app usage independent from coaching activities indicates new opportunities for a fully automated *TRIANGLE* version for a subset of participants.

The interactive *TRIANGLE* challenge system was used as main feature (76% of total activities), followed by complementary use of the interactive coaching feature (15% of total activities) and the library (9% of total activities). The high percentages of user activity in the interactive core features versus the static library stress the importance of self-monitoring, communication, and counseling in mHealth apps, as shown by previous reviews [894, 966]. A similar trial confirmed the predominant use of interactive features versus library content [804]. The usage of all sub-features showed that each sub-feature was relevant for *TRIANGLE* app users. As expected, self-monitoring by ticking off challenges was the most frequently used sub-feature.

User activities per lifestyle area showed an interest in and usage of all three lifestyle areas over time. Nutrition was accessed most consistently, followed by physical activity and psychology. This order may reflect counselors' focus on nutrition during GDM, the challenging nature of engaging in physical activity postpartum [764], and the novelty of psychological habit change for most participants [150]. The use of the three lifestyle areas in our pilot trial supports a recent integrative model for interventions during and following GDM including mental and psychosocial wellbeing [71]. In contrast, previous trials post-GDM focused on nutrition and physical activity [42, 46, 935]. The predominant activities in the nutrition domain in the *TRIANGLE* app are in line with apps for weight loss targeting different lifestyle behaviors [917, 960]. *TRIANGLE* participants updated challenge planning the most for physical activity. Similarly, a recent study showed that 24% of participants changed at least one of the physical activity goals in the Fitbit app used for T2D prevention [959]. The prolonged psychological challenges with few terminations indicated that participants intuitively took their time for mental habit formation. Further, the usage pattern of repeating a challenge at a later point in time stresses that a flexible challenge system for habit formation is superior over fixed programs since interfering life circumstances may disrupt a habit and require de novo training. None of the habitual challenges in the field of physical activity was among the top 15 completed challenges. This indicates the difficulty to establish new fitness habits, as confirmed by a comparable study [917].

In the rapid qualitative thematic analysis, most statements were single statements by one woman and need to be quantified in another study. Overall, participants viewed the *TRIANGLE* app positive and supportive for habit formation. Most negative statements centered around the non-apparent option to ask the coach for an individual challenge that led to an underuse of this service within the app and may be resolved via better communication. Some participants gave contradicting feedback on certain aspects of the *TRIANGLE* app, such as "too little inclusion of the baby" versus "too much consideration of the baby" that needs further clarification – similar to the comments on comparable intervention apps [917, 931]. Similarly, the 23 suggested desirable features or services need to be quantified before taking action. In addition, women post-GDM considered the *TRIANGLE* program suitable to prevent cardiometabolic disease in many other populations with and without an elevated cardiometabolic risk, male and female, as well as young and old. The broad suggestions for other suitable priority populations indicated the great potential of the *TRIANGLE* app in health promotion.

The answers to the question *"If you had to buy the app, how much money (in Euros) would you spend?"* ranged between a one-time payment of 3.90 Euros and a paid subscription of 50 Euros per month. The wide range showed that some attribute a low monetary value to the *TRIANGLE* app while others perceive an appreciable value and are willing to pay a considerable amount of money on a regular basis.

4.3.4 TRIANGLE additional program material usage and acceptance

The usage of the *TRIANGLE* paper note pad by approximately half of the participants and even less (40% thereof) rating it as partly helpful or helpful indicated a low additional benefit of the paper note pad. Many other programs post-GDM used analog diaries [43, 68, 937, 967] or logbooks [72, 946] for self-monitoring. Yet, the user feedback to the *TRIANGLE* paper note pad showed the need of women post-GDM for digitized logbooks – including sensitive psychological exercises. Hence, future programs should work on fully digitized solutions with no analog add-ons. All participants in the intervention group (1 missing) used the Garmin vívosmart® HR fitness tracker, with 65% considering it helpful and about one third having technical problems with the gadget. This indicates that a fitness tracker is important, though a different type of tracker not attached to the wrist might be more suitable for this priority population. Usage of a gadget needs to be tested beforehand since a recent user study including women post-GDM found that women preferred a Fitbit Flex 2 wrist band over the Fitbit Zip gadget [66] – contradicting our experience with the suitability of the Garmin vívosmart® HR wrist band for women post-GDM. Many previous trials with women post-GDM used wearable devices to track physical activity with some success to increase physical activity [68-70, 940, 944-947, 954]. In different target groups, the addition of a fitness tracker enhanced retention rates [931] and proved suitable to enhance physical activity in interventions [968]. Still, physical activity increased mainly due to step counts, not due to moderate to vigorous physical activity [969].

4.3.5 Subgroups

Regarding the question *"Are there differences between subgroups, such as overweight/obese vs. normal weight?"* for any of the research questions, the *Test TRIANGLE Pilot Study* was underpowered to detect such differences between subgroups. However, some intervention trials with women post-GDM were powered to detect differences in intervention subgroups, such as a lower T2D incidence after intervention in women above 40 years of age compared to controls [970], a higher weight loss in the overweight or obese subgroup [942] or higher intervention success in the *MTNR1B* (rs10830962) genetic variant [971] and in the *CDKAL1* (rs7754840) genetic variant [972] compared to other genetic variants in the intervention group. Other trials targeted subgroups of women post-GDM with specific interventions such as overweight or obese [70, 939, 954], low physical activity [69, 940], impaired glucose tolerance (IGT) [766, 953, 970], cultural subgroups [69, 73, 936], and local or national subgroups [60, 70, 766, 942, 946, 973]. Yet, the results of these studies on subgroups of women post-GDM do not imply increased intervention success compared to those targeting women post-GDM in general [38, 42, 935].

4.3.6 Implications for a larger clinical trial

5) <u>Implications for a larger clinical trial</u>: "What can be learned from this pilot study for future clinical trials?", "Is the current binary DPP endpoint suitable to test the TRIANGLE app's clinical efficacy or does it have to be revised for a large intervention trial? Which parameters would be suitable for a power calculation?"

The *Test TRIANGLE Pilot Study* was underpowered to detect statistically significant differences between the intervention and the control group in the selected primary outcome due to some of the assumptions in the power calculation. Further, the study showed that the current combination of intervention duration, measurement tools, and primary outcome may not be suitable to detect pre- to post-intervention group differences in a larger trial.

The *Test TRIANGLE Pilot Study* of six months intervention represents the median of trial duration with women post-GDM [76]. However, both habit-based programs and programs to prevent T2D after GDM need to be prolonged [76, 917]. Trials post-GDM with a duration of six months or less failed to detect group differences in outcomes in contrast to longer trials [934]. Changing a single habit takes 66 days on average and varies between 18 and 254 days [105]. The *TRIANGLE* intervention recommends to change maximum three daily habits at once while accounting for the need of self-selected intervention pace for women post-GDM [56, 105]. Hence, not all required habits are changed from day one in the intervention, but rather one by one or with only a few in parallel [105]. In addition, the postpartum phase, living with infants, and rather unstructured days during parental leave may prolong habit formation. The varying circumstances post-GDM may lead to less stable context cues for some women, disrupt behavioral response sequences, and lower the number of behavioral repetitions – all factors required for habit change [141, 147, 155]. Lapses are particularly problematic for weekly and more complex habits such as physical exercise [105]. Therefore, the late postpartum factors may add to the required time for habit change in women post-GDM. Once a woman successfully changed a few habits, the physiological changes resulting in clinically relevant measurements require further time since habits usually accumulate small health gains over time [151, 974]. Current interventions post-GDM range from six weeks to five years in duration [76]. A recent review on the effectiveness of interventions post-GDM indicated a higher weight loss for longer interventions [935].

An extended intervention period of at least one year would likely detect not only significant changes in the chosen DPP score, but also in the chosen secondary outcomes including clinical parameters. One year also corresponds to the intervention period of the original DPP that included women post-GDM [985]. Yet, a longer intervention period requires more resources and might not be suitable to measure clinical efficacy in women post-GDM due to possible new pregnancies. Current or planned lifestyle intervention trials with longer durations will provide more information on the feasibility for women post-GDM [45, 72, 77, 971, 986-988]. The challenge with longer interventions post-GDM could be resolved by starting to intervene during GDM [75, 989-995] or in the periconceptional period for high risk groups [996, 997] – with recent recommendations to start before or during the first trimester [994, 995] and to continue postpartum [935].

An earlier intervention start would address the predicted rise of GDM due to the obesity pandemic [998], prevent excessive gestational weight gain and postpartum weight retention [999], and prevent a possibly prolonged habit formation in those having a child and family life for the first time [61]. Yet, starting an intervention before or during pregnancy requires adapted program materials for each phase, such as additional glucose monitoring during pregnancy and adapted lifestyle recommendations [989]. Still, a recent systematic review reported a trend of less intervention success for women post-GDM if started during pregnancy or less than six weeks postpartum [46]. Another meta-analysis found intervention effects for women post-GDM only in trials starting less than six months postpartum [42]. The number of interventions for the prevention of T2D starting before or during GDM until several months postpartum is increasing [75, 951, 1000]. The perfect timing for an intervention start has yet to be determined.

Further, the measurement tools for the primary outcome may have to be replaced with better suited and preferably objective alternatives. Current measures were based on the IPAQ, four days of nutrition protocols, and the scale of the bioelectrical impedance analysis. The IPAQ [921] and nutrition protocols [975-977] are prone to bias and better suited for large cohorts. The non-plausible high levels of physical activity both at V1 and V2 showed that the long version of the IPAQ was not suitable to measure physical activity in this cohort. The related DPP threshold was 150 minutes of moderate to vigorous physical activity per week while the long version of the IPAQ likely led to an overestimation wide above that target level of physical activity. This type of overreporting of the long IPAQ was shown before [921], also in a recent study post-GDM [939]. Hence, an objective measurement such as VO_2peak should be the first choice to measure clinical outcomes in physical activity. Further, the short version of the IPAQ as applied in another trial with women post-GDM [941] or data from an activity tracker may offer a better fit compared to the long version of the IPAQ. Regarding the use of a fitness tracker, a decline in usage from 100% to 16% within less than one year needs to be considered if determinants for continued use are not addressed [978].

Nutrition behaviors remain challenging to capture and evaluate [922, 979]. Regarding nutrition protocols, the traditional paper and pencil method applied in this study may have to be replaced with simpler electronical approaches such as the novel Australian *Boden Food Plate* due to a higher acceptability and better feasibility [979, 980]. Paper and pencil records are often not available during an eating event and thus filled in retrospectively. In contrast, electronic food logs via smartphone apps are accessible at all times [979].

The measurement of difference in body weight might be the most suitable measure for women post-GDM considering that postpartum weight retention [981, 982] or increases in BMI after or between pregnancies are problematic in this population [983, 984]. Weight loss and prevention of further weight gain post-GDM was beneficial for cardiometabolic outcomes [984]. A recent meta-analysis of lifestyle interventions post-GDM showed that significant differences were limited to anthropometric measures, yet with high heterogeneity between studies [935]. Still, a recent systematic review stressed the slow weight loss in women post-GDM compared to other populations [42].

Each DPP goal requires multiple habit changes in many different contexts to achieve the behavioral thresholds in nutrition, physical activity, and weight management – with three out of five DPP goals necessary to achieve the primary outcome, the number of required habit changes further increased. The DPP goals thus cover a small percentage of target behaviors of the rather holistic *TRIANGLE* intervention and do not account for psychosocial changes addressed in the intervention. Many target behaviors such as self-regulatory behaviors, optimistic thinking, processed food intake or 10,000 steps per day are not included in the DPP score. The 81 performance objectives offered in the *TRIANGLE* app represent single behaviors that support the DPP goals. With first insights from the *Test TRIANGLE Pilot Study* and considering individual differences in the starting point, we estimate that a participant will have to accomplish about 20 of the 81 performance objectives to reach a DPP score of at least three points.

A power calculation based on two complementary objective measures such as difference in body weight and body fat mass or VO_2peak pre- to post-intervention will be more reliable than the binary DPP score largely based on subjective measurement tools. With an intervention period of at least one year, the impact of natural perinatal weight fluctuations could be reduced – depending on the perinatal starting point. A high body weight or increases in body weight might be the most decisive risk factor for T2D in women post-GDM who need to lose their pregnancy weight and possibly additional weight during the first year postpartum [603, 802, 1001, 1002]. Each 1 kg/m^2 increment in BMI post-GDM was related to a 16% higher risk of T2D [603]. Body weight is the most widely used outcome to assess the health status in international trials with women post-GDM [76, 935]. Yet, other objective measures such as body fat mass or VO_2peak should be included to detect possible shifts in body composition and other preferable outcomes that the measure of body weight might fail to detect. Such complementary outcome measures to body weight are particularly important for the normal weight group.

Like many other research groups, we conducted the pilot trial to address the challenge of finding the right study duration, outcome measures, and validated measurement instruments. Next to the higher number of participants, a future trial with the *TRIANGLE* intervention must prolong study duration, use different and preferably objective measurement tools, and/or aim for a different primary outcome to capture differences between groups. A recent systematic review of diabetes after pregnancy intervention trials stressed the importance of developing a core outcome set assessed by few validated measurement tools [76]. The review of 38 studies found 172 outcomes that the authors classified into 36 groups under the three themes of health status, health behavior, and intervention processes [76]. In line with this review, we noticed the difficulty of choosing the right outcome, study duration, and measurement tools at this stage since this is a question to be resolved by a large cooperation of stakeholders [76].

Overall, the inclusion of outcomes in the three areas of health status, health behavior, and intervention processes is encouraged [76] and should be maintained for a larger trial with the *TRIANGLE* program. Regarding the study design for a large trial, alternative designs to the traditional RCT have been proposed to measure mHealth intervention success and should be considered [54, 1003].

4.4 Strengths and limitations

The *Test TRIANGLE Pilot Study* has several strengths. First, the multicentric randomized controlled design with 1:1 randomization stratified by study site ensured equal group comparisons. Second, the trial showed a good retention of participants. Third, the mixed methods approach allowed to assess different feasibility aspects via both objective (user logs, clinical parameters) and subjective (questionnaires, nutrition protocols) data. Therefore, we were able to show the suitability of an mHealth intervention for women post-GDM. Fourth, the mixed methods approach accounted for limitations of each method. Fifth, the *Test TRIANGLE Pilot Study* provides insights into behavior change, clinical efficacy, user acceptance, usage, and user experience of the *TRIANGLE* intervention. Hence, the study allows for further user-driven adaptations and the selection of appropriate outcomes for a large RCT. Sixth, user logs in the intervention arm enabled in-depth analyses of user participation and the use of individual program components. Seventh, the software support and online coaching for all participants was based in Munich and thus excluded variations in the mHealth program between study sites. This was particularly important for consistent coaching. Eighth, we did not impute missing data, but limited our analyses to complete data sets (modified intention-to-treat analysis).

The *Test TRIANGLE Pilot Study* has several limitations. First, the study cohort was rather homogenous and may induce a socioeconomic bias and limited socioeconomic variability. The study cohort included iPhone users only, most of which were highly educated, living with a partner, native speakers, non-smokers, and non-working. Participation was on a voluntary basis, possibly pre-selecting those with a higher motivation to participate in an mHealth intervention. Hence, the sample may not be representative for the entire population of women post-GDM. Second, the study was underpowered due to some of the assumptions in the power calculation so that the cohort was too small to detect statistically significant group differences for the measured outcomes given the intervention intensity and duration. Third, all but one component of the primary outcome and some secondary outcomes were based on subjective measurement tools (nutrition protocols, IPAQ, WHO-5, PSS-10) that are prone to bias and better suited for large cohorts. Fourth, the intervention period was too short for the expected outcome considering the non-intensive approach with small habit changes at an individual pace, as required by the priority population [56, 802]. Similarly, a study duration of six months was too short to measure changes in clinical parameters. Fifth, the study included women from different cultures without a cultural adaptation of intervention content or different language settings. This opposed the recommendations given in Intervention Mapping and is reflected in the low participation of non-native speakers that may have lowered intervention success in some women. Sixth, the German version of the uMARS has not been validated in earlier studies. We therefore had to rely on the suitability of the translated and back-translated version in cooperation with the Department of Clinical

Psychology and Psychotherapy in Goettingen. Seventh, the user logs did neither track usage duration per app activity nor activities in the progress screen, unlike other apps [932]. Hence, users accidentally opening a library article or challenge description could not be distinguished from those staying longer on a page and the usage of the progress feature could not be analyzed. Eighth, the results on app usage of the iOS system cannot be transferred to the Android system. Lastly, the study was limited to the clinical setting and does not translate to possible effects in routine care.

4.5 Conclusions

A German multicenter randomized controlled pilot trial of the smartphone-based *TRIANGLE* program indicated first clinical effects for behavior change to prevent cardiometabolic disease in women post-GDM after six months of intervention – despite not reaching the primary outcome. The mixed methods trial with a retention of 85% demonstrated that the *TRIANGLE* program was feasible, accepted, and used by women post-GDM. However, the trial also showed the challenge of choosing the right study duration, measurement tools, and outcomes suitable to detect group differences in a controlled trial. The higher fiber intake and other positive trends for regular app users indicated first behavioral and clinical benefits with a higher app usage. Overall, about half of the participants used the app regularly and on average, participants rated the app quality amongst the top health apps with a high perceived impact on behavior. Still, participant engagement beyond one month remains a challenge in a subpopulation of this priority population that views family life as priority over self-care – especially regarding exercise. The combination of the three core features "challenge system", "coaching", and "library" seems feasible for large scale implementation considering the limited coaching needs and the potential for further automation. While the overall feedback to the *TRIANGLE* app was positive, some additional user needs will have to be quantified and addressed in future app versions.

Our findings suggest that a smartphone app based on the habit-goal interface and three lifestyle areas including psychology/sleep is a promising approach with a great potential for health promotion post-GDM and possibly in other at-risk populations. A large clinical trial needs to assess the program's capacity for changes in behavioral and clinical outcomes in a more representative sample. Further, a large trial is required to detect differences between subgroups and implementation aspects such as the right timing for the start of the intervention, integration into existing healthcare systems, and *TRIANGLE* app usage on Android systems.

5. Discussion

This thesis aimed at planning, developing, and pilot testing one of the first smartphone-based mHealth programs to prevent T2D and related cardiometabolic disturbances post-GDM with the Intervention Mapping approach [116]. Our findings highlight the value of a systematic and iterative development process since the resulting *TRIANGLE* program offers a unique intervention model for women post-GDM and showed first clinical effects compared to enhanced standard care (with additional recommendations for sleep and psychosocial wellbeing) in a multicenter pilot RCT. The related *TRIANGLE* app further showed a high usability and user acceptance. The next steps will include further improvements in the *TRIANGLE* intervention model and the practical applications, further evaluation comprising cost-effectiveness, and implementation in routine care.

We chose Intervention Mapping as blueprint to enhance the likelihood for effective intervention, program uptake, engagement, and feasibility [134, 1004]. Intervention Mapping covers the most common actions in the development of complex interventions identified by a recent review [1005]. To our knowledge, the novel *TRIANGLE* program is the first behavioral intervention for women post-GDM using the Intervention Mapping approach. The *TRIANGLE* program aimed at tackling some of the limitations from earlier prevention programs post-GDM, including required in-person contact [60] or the lack of addressing psychosocial wellbeing [71]. As one of the first programs for women post-GDM in German-speaking countries [42], the *TRIANGLE* program adds to the international landscape. Other novelties comprise the multi-theory approach at the habit-goal interface for the interactive smartphone app including 39 behavior change methods while complying with industrial app standards. The multi-theory approach involved theories of automatic behavior and habits, goal-setting theory, theories of information processing and persuasive communication, process models of health behavior change, and social cognitive models. Further, *TRIANGLE* is one of the first attempts to address psychosocial wellbeing and sleep beyond the traditional lifestyle areas of physical activity and nutrition. The *TRIANGLE* program offers a practical tool for healthcare practitioners and women post-GDM. It has the potential to close the gaps of insufficient lifestyle follow-up post-GDM, international upscaling, low-cost program delivery, and human coaching support independent from an expert's location.

In addition to the prospective planning, we applied Intervention Mapping as a descriptive and analytic tool [116] for the first steps since we were unfamiliar with the Intervention Mapping approach in the beginning of this project. Similarly, health promoters targeting young mothers within the *Mamma Mia* program applied the Intervention Mapping protocol in a post-hoc manner to describe the development process and to uncover weaknesses during program planning and in the intervention [1006]. Further, two other trials applied Intervention Mapping retrospectively for a comprehensive description of the interventions – one for smoking cessation and one for at-risk drinking [1007, 1008]. The retrospective approach in the first steps added transparency and comparability. Both are important for mHealth interventions based on information and communication technology to create replicable programs that can be compared to one another [1008, 1009]. We integrated original findings and methods into the protocol since most of the methods and decisions fit the Intervention Mapping approach and to secure better readability.

The project provides one of the few transparent descriptions of underlying steps, tasks, and processes when planning a health promotion program under given time, staff, and budget restrictions [1010]. Transparency is particularly important for complex behavioral interventions such as *TRIANGLE* with many cross-linked components that are difficult to comprehend or reproduce without a written record of how it had been developed. The problem-driven Intervention Mapping approach was feasible for this project and helped us ground the *TRIANGLE* program in multiple theories, empirical evidence, and the practical context [1011]. This resulted in a theory of how the *TRIANGLE* program operates. The first positive results in *TRIANGLE* pilot testing compared to standard care and the provided blueprint in Intervention Mapping Steps 1 to 4 paved the way for further improvement, implementation, and evaluation in Steps 5 and 6.

The Intervention Mapping Steps 1 to 4 for the development of the *TRIANGLE* program will be discussed in light of the current literature on other intervention studies post-GDM. For some methodological aspects, we will refer to other programs applying Intervention Mapping. Intervention Mapping Steps 5 and 6 will be discussed briefly as outlook.

5.1 Cardiometabolic risk behavior model post-gestational diabetes mellitus (Intervention Mapping Step 1)

The initial planning, systematic needs assessment, and analysis of the practical problem were informed by our experience with women post-GDM, empirical evidence, and theoretical additions. According to a recent review, 98% of Intervention Mapping users reviewed the literature, albeit most of them with additional assessments [114]. Both qualitative and quantitative empirical data disclosed relevant factors for the logic model of the problem. The resulting *cardiometabolic risk behavior model post-GDM* helped us map the complexity of the health problem and of the priority population. The first Intervention Mapping Step further allowed to clearly describe the context for intervention despite our focus on individual factors.

5.1.1 Planning group

Our planning group consisted of a small core team (n = 2) with further internal expertise from the Diabetes Research Group in Munich (n = 9), external experts (n = 8), and commercial partners (n = 8). Thereby, the planning group met the needs of expertise in the health problem and its causes, responsibility and authority, influence, and commitment according to the Intervention Mapping protocol [116]. Having worked with women post-GDM for several years confirmed the conclusion of a previous program that it takes time to get to know the priority population [1012]. We actively involved women post-GDM in the development of the *TRIANGLE* program starting with Intervention Mapping Step 4. Similar to the *TRIANGLE* development, other Intervention Mapping projects included the priority population during pre-testing [1013, 1014]. This approach was in line with our feedback from women post-GDM stating that without a product at hand, it was difficult to judge what worked for them and what differed from their needs.

We retrospectively identified some more stakeholders to be included in the planning group once the Intervention Mapping approach was integrated in the project. These will be of particular interest for the remaining two Intervention Mapping steps that often demand new team members [1011, 1015]. Gynecologists, diabetologists, and general practitioners as well as diabetes counselors should be involved as potential program adopters and health insurers as potential program implementers. In addition, the socioecological model pointed towards a future inclusion of:

1) Family members of women post-GDM (interpersonal level)
2) Additional healthcare practitioners such as diabetes counselors, midwives and leisure time influencers such as in postnatal courses or mother-child courses (organizational level)
3) Local reporters (community level)

4) Societal and cultural influencers (societal level)

In line with these findings, one of the new trials targeting behavior change post-GDM in Denmark involved multiple stakeholders in the planning process, including women post-GDM and their partners, healthcare professionals such as nurses specialized in postnatal health, obstetricians, endocrinologists, and dieticians [45]. Additional sources of meaningful contributors may comprise behavioral scientists, medical doctors working in the prevention of behavior-related noncommunicable diseases, and scientists having applied the Intervention Mapping protocol – especially steps 5 and 6 – to similar projects.

5.1.2 Priority population and subgroups

We defined the priority population in line with most programs for women post-GDM [935]. However, a recent meta-analysis showed that many trials with women post-GDM narrowed the definition from women post-GDM in general to certain subgroups with an elevated diabetes risk, such as those with IGT postpartum, overweight/obesity, high waist circumference, altered lipid profile, hypertension, use of insulin during GDM, and family history of diabetes [42]. Such a narrower definition of the intervention group may enhance program specificity to reach the desired outcomes in a distinct subgroup and drive engagement [60]. Yet, this approach excludes other high-risk subgroups among women post-GDM in need for intervention. Women post-GDM already represent a subgroup of high-risk individuals for cardiometabolic disease. Thus, a focus on subgroups within the population of women post-GDM for an entire program may be too limiting since subgroups can be addressed by tailoring program materials.

The participants' feedback in the *Test TRIANGLE Pilot Study* and in a recent user study with postpartum women at risk for cardiometabolic disease confirmed the importance of tackling postpartum issues in women post-GDM [66]. Finding the right balance between involving the family and allowing for self-care seems key for a program post-GDM. On the one hand, the family context such as being married, living with a partner and at least one infant, and the double challenge of being a working mother played a big role. On the other hand, *TRIANGLE* participants appreciated the focus on self-care and their own needs next to being a mother.

Given the scope of this project, we focused on behavior change in women post-GDM while the ideal Intervention Mapping adds behavior change modules for the most relevant environmental agents [1011]. In line with Intervention Mapping, recent research urges health promoters to consider the fathers of GDM-infants as second priority population in this context [1016]. A recent review even called for the inclusion of the families and communities in behavioral interventions post-GDM [44]. Some of the participants in the *Test TRIANGLE Pilot Study* expressed the need to involve their partners. So far, few programs allowed women post-GDM to bring a friend or family member to group sessions [72] or contained family home visits [45]. One program post-GDM involved the fathers and showed improved physical activity, sleep, and dietary quality in both mothers and fathers after 13 weeks of intervention [59]. A current trial goes one step further and adds the entire family and healthcare professionals [45]. Similarly, we plan to involve both families via group accounts and healthcare professionals as health coaches in future *TRIANGLE* versions.

We tailored content to the most pronounced high-risk subgroup of overweight or obese women next to the normal weight group since body weight is the most consistent risk factor for cardiometabolic disturbances [6, 307, 308]. A novel Asian app-based program post-GDM chose the same subgroup starting at a BMI of 23 kg/m^2 or higher based on the baseline weight for tailoring [933]. In line with a recent call for more detailed subgroup analyses [1004], we identified other subgroups for possible tailoring in the *TRIANGLE* program, such as mothers with low socioeconomic status, high risk ethnicity, and women with polycystic ovary syndrome (Chapter 2.1.2.1.3). The project resources did not allow to address each subgroup with specific content, but via individual human coaching. Specific needs of these small subgroups will be addressed in future extended versions of the *TRIANGLE* program. The *Test TRIANGLE Pilot Study* indicated that the lack of language settings and culture-adapted content for subgroups may determine their non-adherence – despite the efforts of a human coach to deliver respective information. To date, few programs post-GDM adapted program materials for cultural subgroups [73, 936, 1017] – mostly by matching the entire program, not by tailoring to cultural subgroups within a program. Hence, the challenge of engaging a wide range of minority groups within one program remains [780].

5.1.3 Health problem and quality of life

We defined the health problem as T2D and related cardiometabolic disturbances, like other recent programs including women post-GDM [66, 933]. In contrast, most programs for women post-GDM limit the description of the health problem to T2D despite measuring additional cardiometabolic outcomes as proxies in clinical trials [46, 76]. We included the more traditional cardiometabolic disturbances of overweight/obesity, hypertension, dysglycemia, dyslipidemia, and combinations thereof in the description of the health problem. Further, we and some other behavioral interventions post-GDM included other cardiometabolic risk factors such as pro-inflammatory factors as exploratory measures, possible confounders or outcomes [76]. A recent review called for a consensus-driven minimum set of outcomes for clinical intervention studies on women post-GDM [76]. Once available, the set of outcomes related to the health status post-GDM could also be used to further refine clinical aspects of the health problem in an Intervention Mapping approach.

Compared to other Intervention Mapping projects providing details on their logic model of the problem [116, 1018], our analysis of the health problem and quality of life implications was extensive. On the one hand, this indicates the complexity of T2D and related cardiometabolic disturbances. On the other hand, participants in the *Test TRIANGLE Pilot Study* confirmed the need of such an extensive approach and demanded even more aspects of our in-depth analysis in future *TRIANGLE* versions. Such aspects included the diabetic complications and comorbidities that start to develop in a pre-diabetic state [279] and the high vulnerability of women for impaired physical and psychosocial functioning with T2D [344].

5.1.4 Cardiometabolic risk behaviors

Unlike most other post-GDM interventions [42], we searched the empirical literature for risk behaviors beyond nutrition and physical activity. Our search contained cardiometabolic risk behavior in women post-GDM and other adult at-risk groups. The result was an extensive list of potential target behaviors. While current global analyses on cardiometabolic risk behaviors still favor nutrition behaviors as predominant lifestyle factor [21, 1019, 1020], accumulating evidence suggests the important role of physical activity [22, 1021], sleep [23, 725], and mental health behaviors [676, 677, 1022]. In line with these studies, we added stress management [683], emotional processing [677], sleep hygiene [736], breastfeeding [742], smoking [1023], and shift work [687] to our list of risk behaviors in the *cardiometabolic risk behavior model post-GDM*.

Our approach to include three main lifestyle areas (physical activity, nutrition, psychology/sleep) was recently addressed by an integrative review describing how mental and psychosocial wellbeing interact with dietary and physical activity behaviors in women during and following GDM [71]. Similarly, previous studies in other adult populations showed that the three behavioral risk domains interacted [28, 30, 31, 35]. Healthy and unhealthy behavioral clusters have been established across lifestyle areas, starting in childhood [1024] or adolescence [1025-1027] and continuing in adulthood [36, 1028, 1029]. Our *cardiometabolic risk behavior model post-GDM* takes the influence of diverse behaviors on cardiometabolic risk into account and allows to be extended with new scientific insights.

5.1.5 Determinants for behavior

We selected 11 behavioral determinants based on several theories and matched them with empirical evidence from our priority population. Our inclusion of various behavioral determinants is in line with the Intervention Mapping approach [116] and a recent study that shows distinct activation patterns for behavioral clusters [1030]. In contrast, many programs post-GDM were not based on behavior theory and few mentioned a limited number of behavioral determinants in the description of the health problem [38, 44, 934]. Yet, no previous publication of a behavioral program post-GDM disclosed a full logic model of the problem which makes it difficult to trace back which of the determinants were considered at this stage. Some trials revealed target determinants in the intervention description that will be discussed in Chapter 5.2.3.

In line with our focus on habits as a major behavioral determinant, a recent study called for the consideration of contextual cues for behavioral differences in young adulthood [1031]. In contrast, behavioral programs post-GDM using at least one behavioral theory were limited to cognitive theories – mostly the Social Cognitive Theory [69, 70, 73, 74, 77, 937, 939, 940, 945, 947, 1032, 1033]. Hence, behavioral determinants were bound to cognitive theoretical constructs although most authors mentioned the habitual nature of nutrition and physical activity [936, 942, 946, 950, 952, 1000]. Few programs post-GDM mentioned social and environmental cues [74, 952] or daily routines [45] according to habit theory. The *TRIANGLE cardiometabolic risk behavior model post-GDM* was the first model to combine cognitive theories with theories of automatic behaviors and habits in this context.

In a narrative review, the authors from the Danish Diabetes Academy symposium concluded that health literacy and perceived disease risk may influence major barriers to behavior change in women post-GDM [1016]. In line with this review, the *TRIANGLE* program contains the determinants “behavioral knowledge/health literacy” and “perceived risk” in the *cardiometabolic risk behavior model post-GDM*.

Two recent reviews called for the inclusion of social-ecological determinants in behavioral programs post-GDM [44, 1016]. This would require additional factors of the physical environment and personal determinants for behaviors of family members, friends, and communities in the *cardiometabolic risk behavior model post-GDM*. While this approach was not feasible within the scope of this project, some social-ecological determinants may be added to future versions of the *TRIANGLE cardiometabolic risk behavior model post-GDM*. Still, environmental agents on the organization, community or society level remain difficult to address for this rather small and scattered niche priority population. In the current *TRIANGLE* version, we focused on the changeable home environment, including food supplies, physical activity options, and sleeping conditions since many mothers with infants spend a lot of their time at home. Further, we addressed strategies on how to limit exposures to unhealthy lifestyle factors outside the home. The *TRIANGLE* approach thus corresponds to novel research indicating the power of situational self-control that involves avoiding or modifying environmental stimuli for unwanted behavior and choosing environments that reinforce wanted behaviors [1034-1038].

5.1.6 Context for intervention

The habitual character of lifestyle needs to be addressed in daily life outside the clinical setting. Some other behavioral programs post-GDM considered the home as main context for intervention [43, 44, 58, 933, 952, 1039] or acknowledged the home as an important factor for T2D prevention post-GDM [766]. Yet, few programs applied a full or partial home-based approach [45, 77, 933, 946] or promoted home practices and participation of family or friends [45, 73]. In contrast, the *TRIANGLE* program prioritized behavioral contexts in daily life that provide repeated environmental cues for behavior.

5.2 Logic model of change for cardiometabolic health post-gestational diabetes mellitus (Intervention Mapping Step 2)

Intervention Mapping helped us define and delineate desirable behavioral outcomes into concrete health actions and changeable behavioral determinants.

5.2.1 Expected behavioral outcomes

Similar to the *TRANGLE* program, many other interventions for women post-GDM focused on the DPP goals as behavioral outcomes [39, 48, 58, 60, 70, 73, 74, 937, 939, 945, 1039, 1040]. Yet, most programs missed to either specify or report other behavioral outcomes beyond the DPP goals. A recent systematic review showed that some trials post-GDM measured sleep quality and secondary outcomes in psychology such as depression, quality of life, anxiety, stress, and wellbeing [76]. However, few interventions [60, 73, 986] were similar to the *TRIANGLE* approach of combining nutrition, physical activity, sleep, and psychosocial wellbeing with behavioral psychology. Meta-analyses with pooled data from behavioral interventions post-GDM are still debating whether a healthy nutrition or enhanced physical activity was more effective, with inconclusive results [38, 46, 76, 934, 935, 1041]. The inconclusive results might be related to the interplay of lifestyle areas that influences health outcomes post-GDM [71]. Further, only eight out of 38 studies post-GDM included engagement measures [76], reflecting the low focus of programs on behavioral adherence outcomes.

Some participants in the *Test TRIANGLE Pilot Study* showed low WHO-5 total scores at baseline stressing the need for psychosocial intervention. This is in line with baseline values in other trials with women post-GDM [939, 950] and with previous observational studies showing that women post-GDM are susceptible to postpartum depression [327]. A recent Cochrane review suggested that lifestyle interventions decreased the risk for postpartum depression in women post-GDM [1042]. Similarly, a few trials detected a decrease in depressive symptoms [73], a decrease in perceived stress [73, 766], and a higher quality of life after intervention post-GDM [766]. Hence, increasing evidence shows first improved psychosocial outcomes after intervention post-GDM, yet calls for more targeted and effective strategies.

We excluded temporal, addictive, and rather unchangeable behaviors from our *logic model of change for cardiometabolic health* due to our selected focus on long-term habit change. However, the exclusion of breastfeeding as temporal and smoking as addictive behavior proved premature according to the explorative findings in the *Test TRIANGLE Pilot Study* and another recent user study on a similar app [66]. Further, breastfeeding [1043] and smoking [1044, 1045] fulfill some of the criteria of habitual behavior [141] and may be tackled with the same behavior change methods.

Our findings indicated the need to address smoking in this priority population despite the small numbers of active smokers in our and other cohorts with women post-GDM [60, 304, 939, 942]. After having stopped breastfeeding, women are at higher risk of relapse to old smoking habits [1046]. Another challenging subgroup continues smoking during a pregnancy with GDM [982] and might be even harder to get to stop post-GDM. However, few programs post-GDM addressed smoking cessation [50, 946] or measured smoking as behavioral outcome [76]. Some interventions post-GDM even excluded active smokers [950]. Smoking cessation may lead to a higher postpartum weight retention [981] and thus interfere with postpartum weight loss in interventions. A recent review showed that the prevention of a return to smoking habits postpartum remains challenging and requires an own set of behavior change methods [1047]. Yet, the review did not address the habitual aspects of smoking and respective behavior change methods such as response inhibition via changes in specific cues [1044].

Current trials such as the *electronic Monitoring Of Mom's Schedule (eMOMS^TM)* study with overweight women post-GDM test an expansion of the DPP criteria with breastfeeding versus DPP only and standard care [1048]. Similarly, an increasing number of trials post-GDM include breastfeeding as part of the program [45, 48, 58, 70, 74, 939, 945, 951, 1039, 1049]. Several reviews call for programs to encourage breastfeeding in women post-GDM [935, 938, 1016, 1050-1053] since the low numbers of breastfeeding women in some cohorts were alarming [943]. Further, women post-GDM/other pregnancy complications requested more content on breastfeeding in a recent mHealth user study [66].

5.2.2 Performance objectives for behavioral outcomes

The *TRIANGLE logic model of change for cardiometabolic health* comprised an extensive list of 81 performance objectives. Previous publications on interventions post-GDM did not fully reveal the specific health actions or action sequences to achieve the desired behavioral outcomes. Of those providing some detail, none seemed to address main health decisions or communication thereof as a distinct preparatory health action. Further, we have not encountered the clear distinction between one time preparatory and habitual health actions in other programs post-GDM. In the following paragraphs, we will describe how the performance objectives used in the *TRIANGLE logic model of change for cardiometabolic health* compare to other interventions post-GDM. We grouped the performance objectives per behavioral objective, i.e. enhanced physical activity/exercise, enhanced fiber intake, reduced total fat intake, reduced saturated fat intake, weight management, enhanced psychosocial wellbeing, and enhanced program adherence.

Like *TRIANGLE*, some interventions post-GDM broke down physical activity goals into sub-behaviors. Given that many previous trials post-GDM used wearable devices to track physical activity [68-70, 940, 944-947, 954], we assume that wearing those devices was one of the required health actions. Similarly, other interventions post-GDM gradually increased step goals with the ultimate goal of 10,000 steps per day [69, 940, 950, 954]. Unlike *TRIANGLE*, some of these interventions adapted step goals every week based on the performance of the previous week [69, 954]. Although many studies measured sedentary time as outcome and aimed at a decrease in duration [38, 934, 944], none mentioned specific actions to disrupt unavoidable sedentary stretches – including those trials that involved sedentary women only [69, 940]. Similarly, no other intervention than *TRIANGLE* seemed to apply the concepts of active regeneration on non-exercise days or active transportation such as biking in addition to exercise.

While most trials post-GDM used the DPP goal of 150 minutes of moderate to vigorous exercise per week, few mentioned exercise planning as distinct action [43, 58, 60, 939, 947, 952, 1032] despite evidence that planning was useful [769]. Further, no other trial seemed to comprise a fitness self-test at home. Conducting the fitness self-test at home was the most completed challenge in the *TRIANGLE* program and proofed valuable to start individual coaching for both endurance and resistance training. One intervention post-GDM advised heart rate monitoring before and after exercise units [946] while the *TRIANGLE* program explored promising novel options such as high intensity interval training with heart rate monitoring during exercise. Previous programs based on high intensity interval training were accepted by sedentary individuals and showed lower dropout rates than continuous training programs [1054]. Further, a meta-analysis showed a significantly higher increase in VO_2peak after high intensity interval training compared to moderate intensity continuous training in patients with cardiometabolic disturbances [672]. Hence, high intensity interval training should be encouraged in future programs for women post-GDM considering their lack of time for exercise. Overall, *TRIANGLE* seems unique in breaking down the DPP physical activity goal into small preparatory actions and daily habits that guide a woman on how to achieve the goal.

In line with the *TRIANGLE logic model of change for cardiometabolic health*, a recent systematic review on the role of diet in the prevention of T2D post-GDM stressed the importance of a partial shift from animal-based to plant-based products [1041]. So far, no intervention post-GDM advised a predominantly plant-based nutrition with non- to minimally processed food and clear action plans. To increase fiber intake, most trials focused on an increased intake of fruits and vegetables [50, 58, 74, 936, 941, 942, 946, 951, 1033], some on whole grains [74, 942, 951, 953] and/or the glycemic index [70, 941, 945, 946, 953, 1039], and one on legumes and nuts [946]. In addition, some programs advised actions to reduce highly processed food for example by minimizing salt, sugar, and oil [941] or by limiting intake of high-energy products [951]. This partly corresponds to the *TRIANGLE* performance objective to first remove unhealthy and ultra-processed food products from home food supplies and then habitually keep predominantly plant-based non- to minimally processed home food supplies. Yet, the *TRIANGLE* shift in nutrition post-GDM is among the first fostering mainly non- to minimally processed whole grains, legumes, nuts, seeds, fruits, and vegetables.

Similar to *TRIANGLE*, other programs provided helpful models or tips to improve nutrition, including recipe ideas [58, 950, 1033], a healthy meal model [950], a hand model [950] or education on different measures for portion sizes [943]. Many interventions included meal planning [49, 60, 70, 941, 950, 967, 1032], which was previously identified as strategy for women post-GDM to save time [764]. Tips for grocery shopping varied between programs and comprised the opportunity for a guided grocery store visit [73, 950], a healthy grocery shopping list [70], education on healthier food shopping [60] or advice to carefully read food labels for better buying or consumption decisions [58, 73, 945]. All approaches addressed the demand for tutorials and lists for grocery shopping by women post-GDM [57]. Overall, the *TRIANGLE* program seemed to be the first program providing several useful models and allowing to self-monitor habits of meal planning, grocery shopping, and daily cooking in line with a healthy meal model.

Most trials focused on the DPP goals to reduce total and saturated fat intake, yet few programs specified their approach how women post-GDM can achieve these goals. Some programs post-GDM focused on reducing high-fat food [58], on increasing low-fat alternatives [936, 945, 951] or both [50, 941, 942, 946]. Other programs post-GDM detailed how to prepare balanced low-fat meals [58, 60, 73, 936, 950] while none mentioned the habitual use of herbs and spices. Former strategies to reduce saturated fat intake comprised limited animal fat intake [942, 951], family-focused activities on a diet reduced in saturated fat [60], and limited intake of dairy products, bread, cookies, sausages or other processed meat [946]. The positive feedback on the *TRIANGLE* challenges showed how important different approaches are to offer individual choice on how to reduce total fat and saturated fat intake.

While many trials post-GDM used food journaling to assess trial outcomes [939, 941, 943, 970, 1039], few reported food journaling for self-monitoring in weight management [66, 942, 944]. However, women post-GDM felt an unmet need of individual diet suggestions based on food records [43]. One program limited dietary tracking to several days with different dietary themes (e.g. saturated fat) to enhance engagement [66]. Further, programs post-GDM improved eating situations for weight control by mindful eating [60, 950], healthy eating out [58, 74, 937], recognizing emotional eating and food cravings [58], and minimizing distractions to notice satiety signals [950]. This is in line with a recent link between intuitive eating during and after GDM with lower BMI, weight retention, fasting glucose, and HbA1c at one year postpartum [982]. Other weight control strategies included minimizing refined sugar intake [58, 941, 942] or healthy snacking [58], such as choosing a low glycaemic index snack [1039], having healthy snacks visible at home and at work [950], eating a fruit first [950], and taking time for a snack [950]. Few other trials aimed at regular meal intervals to avoid overeating when starving [950] or controlled portion size in general [58, 70, 73, 74]. Moreover, some programs contained substitute lists with healthier alternatives especially for high fat/sugar foods [70, 941], practices for food substitution [58, 73, 1032], tips to deal with unhealthy food at social events [73], and advice to eat as a family [950]. Only one other trial advised to monitor drinks, to consume more water and less other drinks [58] – albeit one of the simplest methods for reducing calories and simple sugars. In addition to the solutions for weight management mentioned above, the *TRIANGLE* program offered performance objectives on self-monitoring of eating contexts, limited snacking frequency (maximum two healthy snacks per day), an extended overnight fast, flexible eating control, and a slow pace of losing one to two kilos of body weight per month.

In the psychosocial area, many of the programs post-GDM mentioned a stress management component [58, 60, 73, 937, 950] without specific performance objectives. While the *TRIANGLE* program includes mindfulness exercises in all three lifestyle areas, the *MoMM (Mindful mOvement, Mindful eating, Mindful living)* program is entirely based on mindfulness [950]. Few programs post-GDM addressed negative thoughts [937], coping with negative thoughts [74] or negative emotions [58, 73]. Some trials contained problem solving [72-74, 937] including lapses, barriers, and other factors related to goal achievement [1032]. In contrast, only one program encouraged women post-GDM to build on their strengths [58]. Although competing priorities post-GDM are known [43] that often result into a woman not prioritizing her own health [766], no other program seemed to teach how to prioritize health behaviors. Similarly, no other program trained to engage into regular enjoyable leisure activities, progressive muscle relaxation or positive thoughts and emotions.

Sleep often occurred as measure in behavioral interventions post-GDM [76], yet few programs addressed performance objectives related to a good sleep hygiene [59, 60, 1039]. One trial required participants to use a gadget to measure sleep quantity and quality temporarily, rather as outcome than for continued self-monitoring [72]. *TRIANGLE* participants received the Garmin vívosmart® HR fitness tracker that allows for sleep monitoring. Some participants tracked their sleep with the gadget in addition to the *TRIANGLE* habit tracking. This interest for self-monitoring of sleep quantity and quality indicates the need for an additional performance objective in future programs post-GDM. In addition, only one program addressed infant sleep [58] next to the *TRIANGLE* program.

Performance objectives on program adherence and self-management differed widely between programs, with few programs providing details. These differences mainly arise from the chosen behavior change methods and the respective practical applications. Hence, related performance objectives will be compared to other programs post-GDM in Chapter 5.3.1.

Overall, many behavioral interventions post-GDM comprised some of the performance objectives that are part of the *TRIANGLE logic model of change for cardiometabolic health*. Yet, the *TRIANGLE* model was the first to include the high number of 81 performance objectives across different lifestyle domains. The high number of *TRIANGLE* performance objectives forms the basis for individualization versus "one size fits all" approaches.

5.2.3 Determinants for behavioral outcomes

The *TRIANGLE logic model of change for cardiometabolic health* spanned 11 personal determinants for behavior. Previous publications of interventions post-GDM did not seem to fully describe the determinants for cardiometabolic risk behaviors. Those providing some details covered less determinants than the *TRIANGLE logic model of change*. A recent systematic review identified 12 trials measuring a few similar determinants to *TRIANGLE*, yet not the key determinant of habits [76]. This is in line with our findings. In the following paragraphs, we will describe how each of the determinants (highlighted as underlined words) used in the *TRIANGLE logic model of change for cardiometabolic health* compares to their use in other interventions post-GDM.

Although many trials noted the <u>habitual</u> character of dietary and physical activity behavior [50, 58, 74, 766, 937, 950, 1039], few seemed to consider habits as personal determinant for behavior change. Single programs integrated individual exercise habits into the exercise schedule [952] provided resources to balance desired personal and familial postpartum eating habits [58] or addressed daily routines [45]. The *TRIANGLE logic model of change for cardiometabolic health* extends these first attempts by prioritizing automatic behavior in repeated contexts. Habits determine behavior particularly in stressful life situations and under mental exhaustion [107-109], such as in the postpartum phase.

In line with the general focus on cognitive theories, all former interventions post-GDM covered <u>commitment</u> or motivation – including intention formation [60]. Still, several interventions post-GDM discussed the need to further explore and enhance the motivational determinant in future trials [50, 954, 970]. One program post-GDM included only those women with an intention to enhance their physical activity or diet [944] while another measured intention to change as outcome [766]. The high focus on motivation in previous trials reflects the overestimation of the cognitive versus the habitual self [144, 154] that the *TRIANGLE* model aims to counterbalance.

Behavioral or health-related behavioral <u>knowledge</u> was the main determinant addressed in all previous programs post-GDM. Further, a few trials measured knowledge as outcome [937, 973] or as compliance measure [943]. One program explicitly targeted women post-GDM with a low health literacy [1032]. In a ranking of different intervention components by women post-GDM, knowledge ranked first [1039]. In line with this finding, the *TRIANGLE logic model of change for cardiometabolic health* placed knowledge transfer at the same level with behavioral practice.

Some interventions acknowledged the high vulnerability and susceptibility for cardiometabolic disturbances [58, 70, 952] or unhealthy habits post-GDM [1039]. One novel intervention comprised a personal T2D risk assessment tool [43]. However, few programs treated <u>perceived risk</u> by women post-GDM as changeable determinant [69, 973, 1032]. In contrast to the *TRIANGLE* program, other programs addressed perceived risk for T2D in general instead of in relation to a particular risk behavior.

Many programs post-GDM did not distinguish between barriers and <u>perceived barriers</u>, yet mentioned one of the two as determinant for behavior [68, 73, 941, 973] or as outcome measure [73, 76, 766].

Some trials discussed the need to address barriers to health behavior specific for women post-GDM [944] – in particular barriers to physical activity post-GDM such as illness of the mother or child, being a working mother, and bad weather [937, 945]; time and family constraints [936, 1055] or lack of interest [950]. The number of programs addressing barriers to behavior change to enhance engagement is increasing [43, 60, 69, 70, 74, 952, 954, 973, 1032, 1039, 1055]. Single trials included barriers specific for cultural subgroups [58, 936] or specific for physical activity [947]. The *TRIANGLE* program does not yet address barriers for cultural subgroups, but covers such aspects at the individual level – similar to another program post-GDM [939]. Further, the *TRIANGLE* program adds behavior-specific perceived barriers.

Some former programs post-GDM contained behavioral skill building for lifestyle self-management [58, 60, 72-74, 766, 937]. Women post-GDM were taught how to cope with stress and negative emotions [73], get social support for lifestyle changes [73, 74], set goals, and self-monitor [60, 74]. One trial specified skill building for reducing total and saturated fat intake, increasing fiber intake, healthy grocery shopping, healthy meal planning, negotiating stressful eating decisions, sleep hygiene, postnatal depression, and stress management [60]. Similarly, the *TRIANGLE* program applies skill building to a wide range of behaviors since health self-management remains challenging in women post-GDM [766].

Several interventions post-GDM comprised self-efficacy as behavioral determinant [43, 73, 74, 933, 937, 954, 973, 1032], some specific for physical activity [60, 69, 72, 766, 939], weight management [69, 950] or diet [60, 766]. Other programs discussed the importance of behavioral self-efficacy for future trials [1056] or built the intervention during GDM around self-efficacy [1057]. The *TRIANGLE logic model of change for cardiometabolic health* adds the layer of perceived self-efficacy for diverse health behaviors.

Perceived or weighted outcome expectations [68, 69, 1032], weighted perceived benefits [973] or measures of attitudes [766, 954] were part of few programs post-GDM. Single programs addressed beliefs according to the Health Belief Model [973] or aimed at reversing the belief that diabetes is determined by fate [74]. Overall, outcome expectations, attitudes, and beliefs were rather addressed at the general level of diabetes prevention in other programs. In contrast, the *TRIANGLE logic model of change for cardiometabolic health* targets weighted outcome expectations and attitudes at the behavioral level.

Few programs covered perceived social norms [936], social cues [74], social and cultural needs [72] or influences by the family, friends, and the social network [45]. One trial focused on cultural aspects such as how to keep up dietary health behaviors without violating social norms during fasting holidays, and how to balance personal needs, familial and social expectations [936]. In contrast, the *TRIANGLE* model comprises a wide range of possible perceived social norms specific to the desired health actions.

Other programs post-GDM did not mention the determinant of self-image, including personal or subjective norms, personal standards, and identity. Hence, self-image can be seen as a novel component applied in the *TRIANGLE* program – despite the assumption that individual in-person or remote sessions in former programs post-GDM [58, 60, 74, 766, 941-943, 946, 967, 970, 1058] covered some aspects of this determinant.

Few studies measured baseline or post-intervention emotions [939, 954] or moods [58, 766, 950, 954] while some included emotional control [58, 73, 74] or self-regulation [60, 69] during the intervention. Yet, no former program post-GDM directly addressed emotional reaction to behavior as behavioral determinant as in the *TRIANGLE logic model of change for cardiometabolic health*.

In sum, many programs post-GDM comprised one or more of the determinants of the *TRIANGLE logic model of change for cardiometabolic health*. However, the *TRIANGLE logic model* was the first to cover 11 determinants. Each of these 11 factors determines behavior to some extent, but none sufficiently explains behavior on its own. Hence, a combination of determinants such as applied in the *TRIANGLE logic model* seems promising to target the cardiovascular performance objectives described above.

Since no other program post-GDM has applied the Intervention Mapping approach so far, none of the publications provided matrices of change or corresponding details. Therefore, direct comparisons were not possible at this level.

5.3 TRIANGLE program design (Intervention Mapping Step 3)

Intervention Mapping helped us design the *TRIANGLE* program with theory- and evidence-based methods. In addition, we cooperated with industry to guarantee the current technical state of the art in software development. In the following paragraphs, we compare the *TRIANGLE* themes, components, scope, sequence, behavior change methods, and practical applications to other programs.

5.3.1 Theory- and evidence-based change methods and practical applications

Intervention Mapping offered a systematic approach to select behavior change methods and their practical applications in parallel. We chose the high number of 39 behavior change methods to target all change objectives and to allow for personal choice how to change a certain behavior. This is in line with the literature showing that mHealth programs for physical activity tended to be more effective if applying several behavior change methods [1059]. Further, recent reviews called for more behavior change methods in mHealth programs [1060-1062]. The more behavior change methods are applied, the more likely is intervention effectiveness [1063]. Still, most programs for women post-GDM provided few and differing behavior change methods [42]. This makes it particularly challenging to identify the most successful methods for women post-GDM. Some authors only used general terms when describing behavior change approaches in programs post-GDM [1039], such as learning techniques [939], methods to overcome barriers [973] or group facilitation methods [74] – without specifying details. In the following paragraphs, we compare each of the applied behavior change method (highlighted as underlined words) in the *TRIANGLE* program to other programs post-GDM.

When speaking about <u>tailoring</u>, most trials post-GDM referred to the tailoring of the program to the needs of women post-GDM in general [43, 45, 60, 70, 950, 954] or to a specific cultural group thereof [58, 73, 74, 936]. In addition, some programs used the term “tailoring” to describe “individualization” to personal needs based on dietary and physical activity assessments [58, 937, 944, 945, 1033]. Yet, the behavior change method refers to the tailoring of program components to several subgroups such as BMI category or stage of change [116]. Although using different weight goals for normal weight and overweight/obese women, few other programs mentioned respective tailoring, such as goals for gestational weight gain depending on pre-pregnancy BMI [937] or goals for dietary fat intake depending on the baseline weight [1064]. The current *TRIANGLE* program only tailors content according to normal weight and overweight/obesity while the underlying *logic model of change for cardiometabolic health* contains more potential subgroups for tailoring.

Former programs offered <u>discussion</u> during phone contacts or callbacks [58, 945], group sessions [60, 73, 74, 936, 950, 1032], individual sessions [936], grocery store tours [950], and in web-based forums [69, 950]. The program *STAR MAMA*, however, seemed to foster discussion the most with individual health coaching callbacks on diverse topics [58]. Overall, discussion partners and topics varied in programs post-GDM including healthcare professionals and/or program participants and/or their partners and/or friends. Yet, some discussion partners may not be sufficiently trained to listen and to activate correct schemas – as specified in the parameters of this method [116]. Therefore, the *TRIANGLE* program encourages discussions on various topics and concerns between a trained personal coach and a participant only.

All former programs post-GDM delivered credible information and educated based on the scientific background in research teams. Few programs also provided external links to other credible sources [58, 950] or information on local health promotion events [45]. Some interventions post-GDM were based on information only [941, 973]. Information varied in topics, details, practicality, and delivery, as discussed in the scope of the performance objectives (Chapter 5.2.2). So far, *TRIANGLE* did not contain direct links to useful external sources, yet the coach sent respective links in case of personal need by a participant. A recent user study with a novel app confirmed that women view a health app post-GDM as "comprehensive source of relevant, credible, and reliable information" that is up-to-date [43]. Further, women post-GDM considered information by experts important to be able to explain their condition to others [43].

Most other programs post-GDM covered individualization in different ways, mainly in one-on-one sessions. Some authors mentioned individual training [947, 953], individual counseling or coaching [933, 936, 945, 947, 950-952], individual reinforcement [946], individualized goals [60, 69, 766, 939, 941, 947, 970, 1032], individual user accounts [69], individualized five-day cycle menus [942], individualized behavior change methods according to personal preferences, resources, and culture [48, 937], individual action plans [1032], and an individual health library [66]. Like the *TRIANGLE* program, most of these programs individualized components based on prior assessments and some allowed for individual adaptations [69, 944]. Yet, the number of web-based programs with optional adaptations is not enough considering that flexibility is one of the main issues for women post-GDM [766]. The *TRIANGLE* program added individualizable components – for example, a feature that the personal coach may adapt an existing challenge or create a new challenge in the app according to a participant's needs.

Few programs reported methods to enhance participation such as mutual goal setting [58], reflective questions [72], decreasing barriers to participation through web-based delivery [70], remote lifestyle coaching [70, 952] or high program flexibility [952]. Most programs post-GDM aimed at a participation in all or most scheduled one-on-one or group sessions while the objectives for minimum attendance varied [48, 60, 73, 766, 939, 951, 954]. Previous web-based programs post-GDM encouraged interaction at least once per week [69, 70]. However, most programs reported participatory problems [60, 950]. Further, few interventions fostered participatory communication between healthcare practitioners or health coaches and women post-GDM by phone or email [58, 69, 70, 952]. Two programs encouraged women post-GDM to communicate with their health coach weekly during week 1-12, every other week during week 13-24, and monthly afterwards [45, 70]. Another program reduced the weekly frequency and intensity of phone sessions after three months [952]. Overall, this frequency of participation and/or communication on a weekly or monthly basis was not comparable to the daily participation goal in the *TRIANGLE* program, with at least five out of seven days per week.

The level of technical assistance in the *TRIANGLE* program was unique among programs post-GDM. Technical assistance in the *TRIANGLE* program comprised features such as the interactive challenge system with reminders and individual progress streaks, keyword searches, and offline use of multimedia files for guided practice. Few other programs post-GDM mentioned similar technical assistance such as progress graphs [69], fields to create own challenges [72], selection of call times for automated calls/requests for individual coaching callbacks [58] or online tracking tools for step counts and nutrition [950]. Yet, one study reported an underuse of tools and frustrations or problems with the websites [950]. Many programs aimed at reminding participants of health check-ups [58, 937, 1053, 1065, 1066], coaching sessions [43, 60, 946] or on concepts of healthy living [943]. However, no previous technology-based program seemed to allow participants to set reminders for their health actions on a daily basis. A novel app post-GDM sends prompts if a participant exceeded her calorie limit for the meal or for the day [933]. Novel approaches that integrate artificial intelligence such as the *Lark Weight Loss Health Coach AI* [1067] offer promising cost-efficient technical assistance for behavior change.

Only one program post-GDM mentioned to raise consciousness – limited to stress-related behaviors [60]. In contrast, the *TRIANGLE* challenge system and the personal coach raise awareness on the habitual character of many individual behaviors and related environmental cues by showing causes, effects, and by training alternative behaviors. Thereby, the *TRIANGLE* program addresses the parameters of confrontation followed by increasing problem-solving and self-efficacy in a participant [116].

Few programs post-GDM mentioned strategies for problem solving [73, 74, 937], problem-solving activities [72, 1032], shared problem-solving [933, 1048], and/or encouraged active problem solving after the coaching has ended [937]. Similarly, the *TRIANGLE* program encourages participatory problem solving. The *TRIANGLE* system informs and contains challenges to detect perceived personal barriers for a behavior and to train a participant's problem-solving skills. Further, the personal coach fosters joint problem solving with action planning and regular feedback.

Similar to the *TRIANGLE* program, other programs post-GDM helped to mobilize social support by different means, e.g. in group sessions [73, 954], peer-led coaching [73, 74], virtual support groups [45, 1048], a group chat [66, 72], via the Facebook website [1048], and/or informed about social support strategies [43, 58, 73, 937]. One program post-GDM specified how to engage a partner in child care and self-care, ask for help, and demand family support [58]. Regarding social media, women post-GDM viewed social support through a Facebook community page as a positive feature [43]. Facebook also proved useful for the recruitment and retention of participants in a social network-based physical activity program for women with infants [834]. Further, a novel program post-GDM stressed the possible role of social networks or messaging apps to maintain social support after a program has stopped [936]. Hence, the current literature points to potential benefits of integrating social media into future programs that need further investigation. Similarly, social app features in health apps are promising [834, 1068], yet warrant further investigation [833]. In a recent user study on a similar mHealth app to *TRIANGLE*, postpartum women at risk for cardiometabolic disease showed interest in sharing information with program peers [66]. In contrast, competitive elements or working towards a common goal led to mixed opinions [66]. The *TRIANGLE* program adds tips on finding supportive partners or role models for a particular health behavior in the own social network, provides social support via personal coaching, and prompts a participant to strengthen trusting and caring relationships in the social network.

Guided practice in former programs post-GDM comprised in-person physical activity group sessions [936] such as floor exercises [950], walking or high-energy dance [73]; instructional photos using body weight and/or resistance bands for major muscle groups with or without the baby [66, 1039], a yoga curriculum with two new poses per week [66] or instructions on how to correctly place and use a pedometer [72, 950]. For nutrition, guided practice included the Handy Portion Guide or a plate model [66, 950, 1039]. Few programs post-GDM used multimedia options such as audio [58] or video [70, 1048] to guide practice. The *TRIANGLE* challenge system provides step-by-step text, audio or video instructions for a health behavior by a healthcare professional. Yet, *TRIANGLE* does not provide the parameters of supervision and feedback by an experienced person during performance [116]. Approaches combining digital and in-person guided practice may be most effective for behavior change post-GDM.

Only one other program post-GDM fostered enactive mastery experiences in healthy eating, physical activity, and breastfeeding [1048] while another program suggested that experiential exercises may enhance dietary behavior change [73]. The precondition for this method is that participants are willing to accept feedback when facing increasingly challenging tasks [116]. The *TRIANGLE* program promotes enactive mastery experiences through free choice of chained challenges of increasing difficulty with regular questions and feedback by the coach.

So far, emotional states post-GDM were addressed via human coaching in emotional eating [58], cravings [58], negative feelings [58], emotional support [58], and coping with negative emotions [73]. Further, all programs post-GDM except for the nutrition only programs [953] aimed at increasing physical states via exercise. The *TRIANGLE* program focused on both improving physical and emotional states with effective physical and psychosocial exercises. It is the first program post-GDM to apply positive psychology to foster careful interpretation and management of emotional states, reduce stress and build positive emotions, as required for this behavior change method [116].

Some of the digital programs post-GDM provided daily self-monitoring for some behaviors such as step count logs [69, 950], the *eaTracker* to log dietary intake [950] or an app for diet, physical activity, and weight tracking [45, 933]. Yet, self-monitoring post-GDM was mostly covered by paper diaries or logbooks to track diet, physical activity, and weight [43, 68, 72, 937, 946, 967]. Other programs post-GDM mentioned education on self-monitoring [73, 937] or skill training on self-monitoring [74, 954]. Still, most authors did not provide details on the method's required parameters such as interpretation of monitored data and rewards that need to be reinforcing for an individual [116]. The *TRIANGLE* program extends self-monitoring to psychosocial and sleep behaviors since the *TRIANGLE* app may track most behaviors at any time due to the simple nature of the challenge system and smartphones usually being at hand. A recent app for women post-GDM further supported self-monitoring for diabetes screening test results [43] – a useful component for future mHealth programs post-GDM.

In a few programs post-GDM, participants were able to use a goal setting tool [43, 70]. Goal setting was encouraged in general [43, 48, 58, 60, 72, 73, 766, 933, 944, 1032], for exercise [947, 952, 954], for daily fat and energy intake [48], and on a weekly basis [74, 939]. Some programs involved family members [74] or intervention groups [60] in goal setting. The *TRIANGLE* program integrated goal setting for challenging yet attainable individual goals via the challenge system. Support for realistic goal setting was highly requested by women post-GDM [43]. Few other programs post-GDM mentioned smaller step action planning [58, 77, 1032, 1039].

In practice, the behavior change method of setting graded tasks seemed to be limited to increasing daily steps post-GDM [69, 940, 950, 954]. In contrast, the *TRIANGLE* program anchored graded tasks in the challenge system with versions of varying difficulty for most health behaviors. The personal coach first recommends an easy version of a challenge according to a participant's starting point and increases difficulty over time.

Few programs post-GDM contained sessions on how to handle behavioral triggers in general [74, 937] or specific to food [939]. Yet, the authors did not provide details on required parameters such as insights into individual automatisms, substitute behaviors or an existing positive intention to alter cues [116]. In line with the focus on habit theory and these parameters, the *TRIANGLE* program includes the three behavior change methods cue altering, stimulus control, and counterconditioning. The *TRIANGLE* challenge system and library provide tips on how to create environmental cues that trigger a health behavior and suppress an unhealthy behavior. The *TRIANGLE* coach advises on how to notice automaticity or cues to action and how to interfere. New practical applications such as context-sensing [1069] or Ecological Momentary Assessment [1070] are promising in the field of habit change and should be considered in future programs post-GDM.

Few programs aimed at changing beliefs according to the Health Belief Model [973], discussed cultural beliefs about T2D [73, 74], socioeconomic barriers to healthy living [74], and fatalistic beliefs about the controllability of diabetes [74]. Yet, the authors did not specify required parameters for belief selection as a behavior change method, such as the investigation of individual attitudes or norms [116]. The *TRIANGLE* coach addresses belief selection by asking questions on personal beliefs, attitudes, and outcome expectations for a certain health behavior and selects those beliefs to be strengthened, weakened, or introduced.

Few trials including women post-GDM mentioned several contingent rewards. One program gave rewards upon completed program components, starting with a pack of diapers at e-consent, a 50 USD Amazon gift card for surveys, a scale and pedometer after phase one, a 10 USD engagement gift card before delivery, and a 75 USD Amazon gift card at study closure [1048]. In a program at the healthcare system level, women received gift cards between 40 and 70 USD for several completed surveys and checks for 40 USD for weight and blood pressure assessments at six and 12 months postpartum [937]. Another program based contingent rewards on a health warrior badge with four levels (bronze, silver, gold, and platinum) to earn gift cards [66]. Participants in the *Test TRIANGLE Pilot Study* received a fitness tracker as reward for successful program participation. Further, the features of habit streaks, successful weeks, and leveling up after the successful completion of a chained *TRIANGLE* challenge also served as contingent rewards.

Strategies to increase participant commitment comprised biweekly motivational messages [943], cultural integration [74], and strengthening of internal and external motivations [933] in programs post-GDM. Further, commitment was addressed in audio narratives [58] and group sessions [60]. In contrast, the *TRIANGLE* program distinguished between the two behavior change methods of early commitment and public commitment. Early commitment requires the voluntary choice of a delayed reward for a behavior, while public commitment requires a public announcement of a planned health behavior change that may include a contract with others [116]. On the one hand, the *TRIANGLE* challenge system prompts a participant to voluntarily commit early to a certain behavior for long-term health benefits. On the other hand, the *TRIANGLE* coach motivates a participant to go public and involve the social network in their health behavior change.

Most programs viewed reinforcement as repetition of behavioral information in person [946, 970, 1071], as postcards [940] or during phone contacts following positive behavioral changes [58, 945]. In contrast, the *TRIANGLE* program and a novel mHealth program for postpartum women at risk for cardiometabolic disease [66] addressed the method's parameters of direct reinforcement following a behavior that can be seen as a consequence of an action [116]. The *TRIANGLE* challenge system allows a participant to tick off a completed challenge and to directly view the individual progress both on the home screen and in the habit streak. Further, the personal coach provides individual reinforcement on a participant's activity and progress. In the *Fit After Baby* program, reinforcement was applied via points and badges [66]. In all these solutions, the participant needs to take action in the apps first since fully automated forms of direct reinforcement following a behavior remain challenging from a technology and data protection perspective.

Some programs offered behavioral feedback, such as individualized pedometer feedback [69, 72, 954], feedback on healthy eating and physical activity [43], progress reports [933] or visualized progress toward daily step goals [69, 72], emails/text messages [69, 70], feedback per phone by a health coach [58, 70] or information on the accomplished percentage and frequency of target behaviors [72]. The *TRIANGLE* challenge system provides a participant automated positive feedback after several actions in the app while the *TRIANGLE* coach gives a participant irregular but timely positive feedback on achievements. Wearable gadget interfaces may allow for additional real-time feedback to specific behaviors in future programs post-GDM.

Some programs post-GDM covered additional behavior change methods such as modeling from peer educators and other group members [74] or social modeling of healthy behaviors [73]. Modeling may be used in future digital solutions if fulfilling the parameters of self-efficacy, skills, and reinforcement of a model; identification with a model, and using a coping model instead of a mastery model [116]. Motivational interviewing was among the predominant behavior change methods in interventions post-GDM [48, 58, 68, 77, 766, 937, 939, 952, 1039] and may be promising for mHealth programs according to a recent digitization attempt in *MyLifestyleCoach* [1072]. Yet, details on required parameters were not specified by the authors, such as a supportive relationship between a client and a professional that involves collaboration, evocation, autonomy, and exploration [116]. Further, programs post-GDM provided active learning via quizzes [43, 72], group learning activities [60], interactive games [72], and gamification through points and badges [66]. Gamification is becoming increasingly popular in health promotion apps, including rewards, prizes, avatars, badges, leaderboards, competitions, levelling-up or health-related challenges [956]. However, gamification elements for women post-GDM need to be kept simple and designed carefully to avoid any confusion [66]. Further, active learning must be goal-driven and address the parameters of time, information, and skills [116]. Women in the *Test TRIANGLE Pilot Study* expressed the need to personalize risk, as applied in few other programs post-GDM [43, 77]. However, risk messages need to be presented as individual, undeniable, and in perspective with absolute and normative values [116]. Lastly, programs post-GDM for cultural minorities used cultural similarity via bilingual coaches [937] and/or coaches with a bicultural background [58, 73].

In sum, programs post-GDM used many different behavior change methods in diverse practical applications, yet none combined such a high number of behavior change methods in one program compared to *TRIANGLE.* Further, some of the programs did not fulfill the required parameters for an adequate use of a behavior change method. Many behavior change methods addressed in Intervention Mapping [116] or in the behavior change taxonomy [1073] remained untapped by programs post-GDM. None of the other programs post-GDM mentioned 17 of the methods applied in the *TRIANGLE* program, including chunking, advance organizers, imagery, framing, environmental reevaluation, persuasive communication, verbal persuasion, arguments, elaboration, implementation intentions, resistance to social pressure, information about other's approval, direct experience, counterconditioning, cue altering, planning coping responses, and self-evaluation. Still, we assume that some of these methods might have been applied to some extent either without awareness or without being mentioned. Each of these methods adds to the possibility that an individual will change a specific behavior – with some being more effective than others. Our focus on habit formation may require additional methods, such as facilitation, nudging or providing cues. However, some behavior change methods may not be suitable for digitization and/or require excessive training of the coaches.

Similar to the *TRIANGLE* program, some other programs post-GDM applied coaching techniques [58, 788, 952] or involved lifestyle coaches [48, 58, 70, 937, 1039, 1055, 1064]. The educational background and training of health coaches varied depending on the program or even within a program [45, 933]. Most coaches were dieticians with additional training in behavior change methods and program curricula [58, 66, 70, 937, 954]. Others included exercise specialists [952] or DPP lifestyle coaches [1048]. A rather novel approach was to train certified diabetes educators in program-specific content for phone coaching, with continuous support by a registered dietician and a registered kinesiologist [1039]. If possible, programs assigned women post-GDM to one coach only to guarantee coaching continuity [58, 937] as in *TRIANGLE*. In the scope of the pilot study, the *TRIANGLE* program had one lifestyle coach for all participants. The coach holds a master's degree in nutritional science and additional training in behavior change methods and habit formation, patient-centered counselling, positive psychology, and physical activity. Further, qualified staff was trained for *TRIANGLE* coaching in case the coach was absent. Similar to other programs post-GDM, *TRIANGLE* coaching cases were discussed at staff meetings [58] or with the principal investigator [66] if needed. An in-person visit to get to know the personal health coach may be beneficial at the beginning of a program [1039] to foster a personal relationship. The most suitable profession and training of lifestyle coaches in this setting have yet to be identified, with first attempts to look into this issue [1039]. Overall, coaching approaches varied in profession and training of coaches, cultural background requirements, coaching support by interdisciplinary teams, frequency and type of contact with coachees, and coaching curricula. Still, participant feedback indicated how important coaching was for engagement [952].

Overall, Intervention Mapping Step 3 helped refine the three main *TRIANGLE* app features "challenge system", "library", and "human coaching" as basis for Step 4.

5.3.2 Program themes, components, scope, and sequence

We first specified 16 requirements by women post-GDM to address the question *"How will women post-GDM receive program materials?"*. Former programs post-GDM did not reveal such an in-depth analysis. The scope and components of programs post-GDM varied in type and form of program delivery (in-person vs. technology-based; individual sessions vs. group sessions), lifestyle areas (mostly diet, physical activity or both), modules and submodules, duration, additional program material, intensity/pace, perinatal phases, and areas for behavior change [38] – most of which have already been discussed in the previous chapters on the *cardiometabolic risk behavior model post-GDM* (Chapter 5.1), *the logic model for cardiometabolic health* (Chapter 5.2), and the theory- and evidence-based behavior change methods with practical applications (Chapter 5.3.1). Hence, only the most important differences will be discussed in the following paragraphs.

The key *TRIANGLE* components of knowledge transfer, skill training, and behavior change support with personal coaching were integrated into app features. Additional program materials included a fitness tracker, a step tread, and a paper note pad for psychological exercises to cover specific needs in the lifestyle areas (physical activity, nutrition, and psychology/sleep). In contrast, most programs post-GDM contained print material or verbal information in face-to-face individual or group sessions combined with phone calls, postcards, SMS, and/or email [49, 60, 766, 936, 940, 941, 945-947, 970]. Others chose remote delivery only [58, 68-70], the use of websites [69, 70, 72, 937, 950, 954], web forums [69, 72, 950], automated telephone self-management support [58], or – only recently – apps [43, 45, 72, 933]. Yet, some of these technologies may already be outdated since the feedback by participants in the *Test TRIANGLE Pilot Study* showed the need for full digitalization and data import into a single smartphone app. This is in line with the findings of a recent user study showing that women did not want to switch between apps and that they did not use an adjunctive website if a smartphone app was available [66]. Some form of interpersonal contact paired with new web-based technologies may be key for program delivery post-GDM [43, 58, 69, 72, 73]. Overall, the best scope and components for program materials post-GDM have yet to be found and programs need to learn from one another and cooperate to shorten this process.

Many mHealth apps similar to *TRIANGLE* were developed in parallel, such as the *JOOL Health* app for adults with prediabetes [931, 1074], the culture-sensitive *Pregnant+* app for women with GDM [1075], and the fully automated *Sweetch* app for adults with prediabetes [829]. Some new or adapted apps for women post-GDM are currently tested in clinical studies, including the *Health-e mums* app [43], the *Baby Steps* app [72], the *nBuddy* app [933], and the *Liva* app [45]. Hence, these apps were not part of our market analysis in the early stages of the *TRIANGLE* app design, yet provided new insights. Still, knowledge on app features responsible for behavior change remains limited. In contrast, evidence for both clinical efficacy and effectiveness of apps is increasing on apps for stress reduction [1076], nutrition [966], fluid consumption [1077], physical activity and sedentary behavior [833, 1062], combined mental and physical health [813, 1060], and combined sleep, nutrition and physical activity [90]. Our quick review of related mHealth apps further showed a recent focus on habit change. Novel habit-based apps include the *Top Tips Habit-Based Weight Loss App* [917], the *Habit App for Weight Loss Problem Solving* [1078], and the *VegEze* app to increase vegetable consumption in adults [932].

Like the *TRIANGLE* program, other interventions post-GDM chose names or acronyms related to program themes. Program names were based on acronyms standing for female names such as *WENDY (walking for exercise and nutrition to prevent diabetes for you)* [954] or *MAGDA (Mothers after Gestational Diabetes in Australia)* [60]; referred to motherhood such as *Dulce Mothers [Sweet Mothers]* [74], *Balance after Baby* [70], *STAR MAMA (support via Telephone Advice and Resources/Sistema Teléfonico de Apoyo y Recursos MAMA)* [58], *Baby Steps* [72], *Health-e Mums* [43], *Fit After Baby* [66], or *Electronic Monitoring Of Mom's Schedule (eMOMS™)* [1048]; or indicated program themes such as *Diet, Exercise and Breastfeeding Intervention (DEBI)* [945], *MoMM (Mindful mOvement, Mindful eating, Mindful living)* [950], *Avoid Diabetes After Pregnancy Trial in Moms (ADAPT-M)* [1039], or *Smart Phone APP to Restore Optimal Weight (SPAROW)* [933]. So far, women seemed to accept these program names. However, comparative user analyses are pending on which approach for program names works best.

The *TRIANGLE* program is the first one branding a program for women post-GDM with an interactive challenge system to directly address the challenge of behavior change in this target group. Still, one other program post-GDM allowed participants to set new challenges [72] and others acknowledged the challenge of behavioral changes in women post-GDM due to difficult conditions in motherhood [58, 60, 950, 954, 970]. The program branding with a challenge system may be particularly important for the following reasons: On the one hand, an unpublished manuscript pointed to slightly fewer habits in adults without a job and adults living with children compared to those with a paid job and not living with children, respectively [106]. The reasons may be fewer stable contexts and more likely habit disruptions in daily family life, respectively. Depending on the timing an intervention is introduced postpartum, women post-GDM with at least one infant at home fall into one or both categories. On the other hand, many women post-GDM are sleep deprived and feel stressed or exhausted [764] and may thus rely more on existing habits [107-109]. This indicates the potential double challenge of establishing new habits and changing old habits in women post-GDM – despite the many new context cues postpartum that normally facilitate habit change.

Unlike most programs for women during or after GDM, one program spanned all perinatal phases including pregnancy, early postpartum, and late postpartum [937] and few other trials covered the two phases pregnancy and postpartum [44, 1048]. A program structure with different perinatal phases offers a promising approach for future programs to shift the more time intense knowledge transfer [1048], postpartum goal setting, and early habit change into pregnancy. This need was confirmed by participants in the *Test TRIANGLE Pilot Study*. Despite targeting the postpartum phase, few programs post-GDM addressed the two *TRIANGLE* postpartum topics of sleep disruptions and pelvic floor health [1039]. Next to breastfeeding, additional postpartum topics in other programs post-GDM contained diastasis rectus abdominis [1039], postpartum depression/emotional health for new mothers [58, 933], pre-pregnancy weight goals [937, 945], and diet for new mothers/weaning diet for babies [933]. In sum, a focus on all perinatal phases seems crucial for future programs for women at risk for GDM and can be targeted with mHealth apps like *TRIANGLE* that allow for features and modules for each perinatal phase.

The modules in former prevention programs post-GDM were often defined by the lifestyle areas nutrition and/or physical activity and/or behavioral determinants. Some programs post-GDM reduced and adapted the 16 core DPP modules to women post-GDM [58, 70, 945]. For the *TRIANGLE* program, we chose the three modules physical activity, nutrition, and psychology/sleep. Modules on psychosocial wellbeing are emerging in health promotion programs for other priority populations, such as the *Danish Healthy High School intervention* [1079] and the *MotiMate* app for weight loss [960]. The usage of the psychology/sleep module by participants in the *Test TRIANGLE Pilot Study* showed an interest of women post-GDM in respective training. Hence, current and future programs post-GDM should consider an additional module on psychosocial wellbeing [71] and sleep.

The flexible pace of the *TRIANGLE* program was novel. A respective need had been identified before [56]. While most women appreciated self-pacing in the *TRIANGLE* program, some women expressed difficulties with the flexible pacing. Therefore, some women may benefit from programs with fix curricula such as those following the DPP modules [39, 58, 60, 70, 73, 74, 945, 1048]. Still, the *TRIANGLE* program offers some smaller unique action sequences for skill training. The fix sequences for some challenges in the *TRIANGLE* program were accepted by program participants in the pilot study. Yet, less women leveled up with increasing difficulty. Further, participants accepted the pre-set duration of three successful weeks for challenge completion, used the opportunity to prolong weekly if a behavior had not been habitual yet, and repeated a challenge at a later point in time if a health habit had been disrupted.

Overall, the *TRIANGLE* program is extensive and promising in themes, components, and scope. It adds new components to current programs post-GDM, such as a novel module on psychosocial wellbeing, the habit formation approach, numerous performance and change objectives formulated as health challenges, and technical support for behavior change in an interactive smartphone app. Still, the *TRIANGLE* program may benefit from more content and some additional components tested in similar programs. In line with a user study that added more content in iterative rounds [66], we found a never-ending need for new content despite positive feedback on current content. A recent survey with women post-GDM showed the need for a walking program, recipes, and weight monitoring [1080]. Further, postpartum women with previous pregnancy complications including GDM requested more content on breastfeeding, being a working mother, postpartum mental health, heathy recipes, detailed diet information, and exercising with an infant [66].

5.4 TRIANGLE program production (Intervention Mapping Step 4)

We chose to develop new program materials for the *TRIANGLE* program to meet the needs of women post-GDM as much as possible. In contrast, most other program developers chose to adapt existing interventions to the needs of women post-GDM [43, 45, 58, 60, 70, 73, 74, 933, 939, 945, 952, 987, 1048]. The DPP formed the most frequently chosen basis while the extent of adaptations varied – depending on available resources and differences in delivery channels between the original and the adapted program.

In comparison to other novel interventions post-GDM, the *TRIANGLE* set of core features and sub-features remains unique although some recent programs explore the challenge area [72], a chat function with a personal health coach [933], and/or a library [66]. To our knowledge, the *TRIANGLE* program is the first smartphone app to encourage daily participation in personal evidence-based health challenges in a self-paced program, combined with the opportunity for text messaging with a personal health coach, and a library with a keyword search. The *TRIANGLE* core features with their respective sub-features will be discussed in the following paragraphs.

The *TRIANGLE* challenge system is based on both industry standards for apps on habit formation and empirical evidence on behavior change at the habit-goal interface. Hence, *TRIANGLE* is among the first evidence-based health apps with habit formation support including self-monitoring via an activity screen, progress visualization, and reminders. A similar novel app for women post-GDM allows participants to write their own challenges [72], yet did not specify system interactivity. Most similar to the *TRIANGLE* challenge system is a recently described app for postpartum women at high cardiometabolic risk after pregnancy complications, with a daily and weekly task list as home screen and checkmarks upon task completion [66]. The *TRIANGLE* challenge system comprised the high number of 136 challenges with chained challenge versions of increasing difficulty for most health behaviors. The data base was extended with some more individual challenges that were written by the health coach upon request by a participant. Further, the system allows for real-time tracking of any behavior stated as a challenge and for a flexible start or termination of a challenge. Thereby, the *TRIANGLE* system addresses the need for flexibility in women post-GDM [764]. Novel habit-based apps for similar target groups were more restrictive, for example by including 10 health habits only [917], targeting a single lifestyle behavior such as increased vegetable consumption [932] or including diet and physical activity habits only [1078].

The *TRIANGLE* app coaching post-GDM seemed unique in providing chat-based messaging, positive psychology coaching, numerous behavior change methods, in-app assessment forms to customize content and feedback, and a keyword search in the personal chat – while mirroring the app features in a coaching platform. Some programs post-GDM provided coaching in the form of workshops [954], by phone [952] or email [70], in coaching callbacks [58], weekly reviews of logbooks [1064] or by a human or virtual health coach in an app [43, 45]. App-based human coaching is gaining popularity according to the latest study protocols for programs post-GDM [45, 933]. Similar to the *TRIANGLE* coaching sub-features, some programs included real-time interaction between users and health coaches [933], the option to push educational information such as videos to a user [933], data export [1048], push notifications [43, 66], and a real-time coaching dashboard to monitor and track participant's health actions [66, 933]. Further, a real-time tailored physical activity coaching system [1081] may be a necessary add-on since increasing physical activity remains most challenging post-GDM [945]. While motivational messages were sent by the coach in the *TRIANGLE* app, some other programs used automated messages via SMS [943, 944, 1082] and/or email [943]. The direct feedback to a *TRIANGLE* coaching message in the chat allowed for a better prioritization and individualization and showed that motivational messages may offer topics to discuss with the health coach. The need for such discussion topics and for coaching initiatives was established in a user study with a similar mHealth program [66]. A recent review concluded that regular support via individualized human coaching may be key for lasting health behavior change post-GDM [44].

Former remote programs post-GDM used single questions or questionnaires for coaching and individualization in different ways. For example, by automated calls allowing participants to either answer "yes"/"no" or type a number to a query such as the number of days with sugary drinks [58]. Further, health coaches asked questions on the phone [950, 1039]. Some trials post-GDM included self-administered questionnaires on lifestyle behaviors [45, 933, 937, 950, 1048] or computer-assisted telephone interviews through a secure study website [937]. The intervals between questions or questionnaires differed. Similar to *TRIANGLE*, most programs post-GDM still relied on an initial paper-based questionnaire. For both clinical study purposes and better individualization, health apps post-GDM should comprise additional questionnaires on behavioral determinants, possible moderators, and mediators for behavior – as shown in a recent web-based study on *MyLifestyleCoach* [1072].

The *TRIANGLE* library corresponds to handbooks/workbooks [48, 60, 937, 939, 942, 945, 1032], brochures with postpartum physical activity and healthy eating tips [937] or web modules [69, 70] in other programs post-GDM. The *TRIANGLE* app library adds an easy navigation per topic, a simple keyword search function, and access to content at all times on women's smartphones. A novel program for postpartum women at risk for cardiometabolic disease further adds a feature to mark favorite content for future use in the app's library [66].

Additional valuable features for apps post-GDM are currently being tested and include diabetes screening reminders/self-monitoring [43], writing own health challenges [72], a goal setting tool [43], progress reports and graphs for daily calorie intake versus calorie targets [933], weight tracking [43, 45, 66, 933], visualized progress toward daily step goal [72], built-in pedometer that translates other types of physical activity into step counts [933], links to a Facebook community page to organize local exercise meetups [43], an online peer support group [45, 1048], a group chat [72], external links [43], a diabetes risk assessment tool [43], interactive games or quizzes [72], and personalization of the library [66]. In addition, automation spanned personalized automated feedback on body weight, diet, and physical activity [43]; a virtual health coach guiding participants through different modules [43], automated telephone self-management support [58], regular automated messages in relation to personal goal setting and achievement [72] or automated food recommendations if the selected food choice does not match the best personal choice [933]. A recent intervention also comprised other platforms for communication, such as FaceTime, Skype, and Zoom for video conferencing [1048]. Some of the mentioned features may require additional features, such as selecting the breastfeeding status to adapt daily calorie intake calculations, a link to a national food data base or the option to add own recipes [43]. So far, women post-GDM appreciated features for diabetes screening such as reminders, setting appointments, and keeping records of results [43]. In contrast, the feedback on a planned diabetes risk assessment tool was mixed [43]. The *TRIANGLE* program covered the essence of some of these features within the coaching feature, yet it needs further automation.

In comparison to other programs post-GDM using multimedia [43, 58, 70, 72, 933, 1048], our data base with 57 videos, eight audios and 241 images seemed extensive. However, other study groups rarely provided details on their content, such as on the 16 short video lessons in the *SPAROW* trial [933]. Future apps may benefit from short educational videos with diverse healthcare professionals, researchers from different lifestyle areas, and women post-GDM [72]. Narrative storytelling videos by other women post-GDM received mixed feedback in a recent user study [43], despite the principal interest in stories from successful women achieving their postpartum goals [66]. Similarly, the optimal length of videos needs to be established for women post-GDM since videos currently range between 3 minutes [933] and 30 minutes [1048]. The use of audio sections was less common, for example for short automated 4-5 minutes calls with queries and narratives post-GDM [58] or voice messages [1082]. Overall, most of these audio and video sections educated without guiding home practice. A recent user study with postpartum women at high cardiometabolic risk showed the importance of diverse images to represent different body shapes and emotional experiences postpartum [66].

The following paragraphs cover the remaining aspects of program production and put them into perspective with other programs. The lifestyle color scheme for the *TRIANGLE* app represents common colors for the three lifestyle areas. The same color scheme appeared in a recent integrative review that stressed the interaction of diet, physical activity and psychosocial wellbeing in women with and after GDM [71]. Regarding the overarching light blue-white color scheme, similar programs post-GDM used light blue and white coloring [66, 72] while others chose more alarming colors such as red [70] or purple [1039], or a mixture of red-blue [1048]. So far, women seemed to accept these diverse color schemes. However, comparative user analyses are pending on which color scheme works best for this target group.

Of the cardiometabolic health-related apps, few provided screenshots of the final products. Compared to commercial products such as the *Noom* app [965] or the *Weight Watchers* app, most science-based apps did not seem to fulfill current industry standards in terms of features and design. Science-based apps often showed a limited use of icons, unmatched colors or an old fashioned design such as in the *Top Tips Habit-Based Weight Loss App* [917] and in the *Habit App for Weight Loss Problem Solving* [1078]. In contrast, fast-paced commercial apps lack the scientific basis for content, behavior change methods, evidence-based features, and clinical efficacy [1083]. Those health apps codeveloped by healthcare professionals, scientists and industrial partners live up to both academic and commercial standards, such as the *VegEze* app [1084] or the *TRIANGLE* app.

Like the *VegEze* app [932], the development of the *TRIANGLE* app may serve as an example for a close cooperation between academia and software engineering companies. Once the program production phase had started, the *TRIANGLE* app was built quickly and proves that products for public health may profit from combining scientific approaches such as Intervention Mapping with industrial know-how and experience. This guarantees scientific evidence and theoretical background while maximizing user experience [932]. Our team of software engineers consisted of six persons while most academic projects involved one app developer only, including a similar PhD project [1085]. Still, to some extent the *TRIANGLE* program reflects the lengthy development process of health programs in academia [86, 1086].

Few other programs post-GDM engaged in user testing of digital interventions, for example to evaluate a smartphone app design [43] or as part of a rapid iterative app design [66]. One program involved the pre-tested *Liva* app [45]. In contrast, other novel apps post-GDM directly started or plan to start with a clinical pilot trial [72, 933]. As shown in the *TRIANGLE* user study, the feedback by end users before a clinical trial is valuable to test overall acceptance and usability and allows for user-centered adaptations. In our case, the user feedback may have contributed to the improvements in the uMARS ratings after some adaptations in the *TRIANGLE* app between the user study and the clinical pilot trial. Further, the *Health-e Mums* user study showed that if an app post-GDM was to succeed, it would need to have all the features of the leading health and fitness apps and some additional post-GDM specific features [43].

According to a recent review, 61% of the trials applying Intervention Mapping were pilot-tested [114]. The results of the *Test TRIANGLE Pilot Study* confirmed the importance of a clinical pilot trial since it uncovered different practical aspects than the user study. The pilot trial showed the challenge of choosing the right program duration, measurement tools, and clinical outcomes for a large trial, future program implementation, and evaluation as well as what can be automated in terms of coaching. Uptake of intervention content by participants in a predefined study time frame remains challenging and may require additional measures, even when using mHealth [91]. Still, the *TRIANGLE* program shows improved exposure to content compared to earlier programs post-GDM such as the *MAGDA* trial [60]. After some more adaptations following the *Test TRIANGLE Pilot Study*, we expect further improvements in adherence and uptake of the *TRIANGLE* program.

5.5 Outlook Intervention Mapping Step 5 and 6

Once health promoters have developed and pilot tested an intervention, they need to further detail the program's implementation and evaluation in existing healthcare systems.

5.5.1 Intervention Mapping Step 5: Implementation plan

Intervention Mapping Step 5 guides program planners to address potential program adopters, implementers, and maintainers. The final product of Intervention Mapping Step 5 is the program implementation plan with fully designed implementation interventions (Figure 5.1) [116]. Intervention Mapping integrates the RE-AIM framework [1087, 1088]. The framework may help to understand the impact of the *TRIANGLE* program in a real-world setting in the five dimensions Reach, Effectiveness, Adoption, Implementation, and Maintenance (RE-AIM). The implementation planning might require to recruit new members for the project team and screen the implementation research. This includes first attempts to involve general practitioners post-GDM [1065] and findings from similar fields such as weight loss after pregnancy [981, 1051]. In our case, healthcare practitioners in routine care post-GDM need to be targeted as a new priority population to deliver the health coaching [1089]. Similar to Intervention Mapping Step 2, we will formulate outcomes, performance objectives and matrices of change to describe what needs to be changed by whom for actual program use. Theory will inform this process and support the selection of change methods. The aim is to influence the behavior of those in charge of decisions that are related to program adoption, implementation, and maintenance.

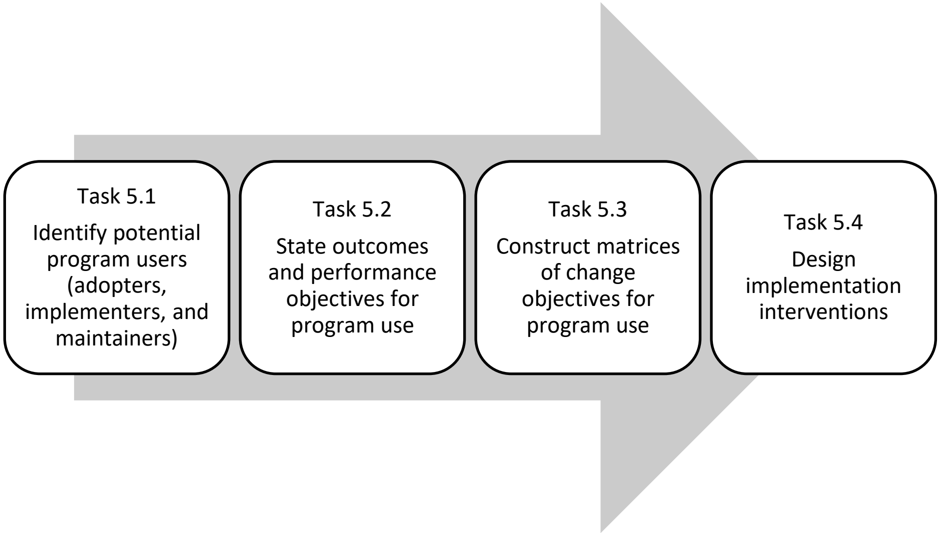

Figure.5.1: Tasks of Intervention Mapping Step 5
(adapted from Eldredge et al., 2016)

Relevant questions for the program implementation plan include: *"Where can the intervention reach women post-GDM?", "In the chosen venues, who would be in charge of adoption, implementation, and maintenance?", "What specific performance would be necessary at adoption, implementation, and maintenance?", "What do representatives of agencies have to do to adopt this program?", "What levels of approval do representatives need and why would the decision maker adopt the program?", "Who will make resources available to implement the program?", "Will the program require different people to implement different components?", "What would motivate performance for each involved party?", "Who will ensure that the program continues as long as it is intended?", and "What would constitute a level of fidelity and completeness consistent with program effectiveness?"* [116].

The *TRIANGLE* intervention has the potential to be incorporated into the German and other healthcare systems for long-term use. The three to six years postpartum mark the highest relative risk for developing T2D after GDM [4]. Hence, the *TRIANGLE* intervention could be prolonged to cover this high-risk period, similar to the four-year Tianjin Prevention Program [49]. Such an approach would also address the prevention of another pregnancy with GDM [998]. Yet, cost-effectiveness calculations are pending to allow for reliable cost estimates in routine care. Healthcare professionals need standardized training to deliver the *TRIANGLE* program due to the human coaching component. Further challenges remain, such as the recruitment of women post-GDM for lifestyle interventions [60, 934], program integration into existing healthcare systems [46, 1039], and program adherence in everyday life [1016]. A longer intervention as part of routine care post-GDM would also allow for long-term outcome measures such as T2D [76].

First attempts of integrating interventions into primary postpartum care are underway [1051]. Some of the larger trials post-GDM have already tested or are currently testing large scale program implementations with 393 women in Finland [50], 1,180 women in China [49], 2,280 women in the US [48], a total target of 1,414 women in India, Sri Lanka, and Bangladesh [987], and a target of 460 women in Denmark [45]. However, few reported implementation process outcomes, which mark a more recent evaluation domain [76]. The Finnish *Implementation Project of the Program for Prevention of Type 2 Diabetes (FIN-D2D)* in a primary healthcare setting with high-risk women for T2D aged ≤ 45 years achieved a one-year follow-up rate of 67%, with beneficial changes in the cardiovascular risk profile [50]. The American *Gestational Diabetes' Effects on Moms (GEM)* study found modestly reduced postpartum weight retention and increased vigorous-intensity physical activity despite only 15% of participants completing all 13 phone sessions [48]. The Tianjin Prevention Program showed one-year completion rates of about 79% in both the intervention and the control group and led to a higher weight loss in the intervention group compared to standard care, especially for overweight women [942].

In the South Asian multi-country study, the authors will further explore determinants for implementation in each local context [987]. The intervention is based on four group sessions, 84 SMS or voice messages, and phone calls – with the option for two additional individual sessions [987]. In contrast, the Danish trial combines three additional postpartum home visits by specialized nurses, mHealth coaching according to a family's needs, and a novel communication system between different healthcare providers for women post-GDM [45]. These trials will provide more insights on different implementation approaches post-GDM. Still, further contextual determinants need to be identified and addressed during implementation planning [1090]. Implementation Mapping based on the Intervention Mapping Step 5 may help to develop further implementation strategies [1091]. Yet, every country has a unique healthcare system and transferability may be limited despite some common factors.

To date, no large trial post-GDM involved an mHealth app, although these technologies are promising for broad and low-cost implementation. A recent large-scale implementation study on a habit-based app to increase vegetable consumption in adults indicates that real-life attrition may be much faster than in clinical studies, with about half of the initial participants remaining after 10 days and 15% after 21 days [1084]. Similarly, the medians of the 15-day and the 30-day retention of mental health apps were 3.9% and 3.3%, respectively [1092]. These studies point to the challenges to achieve long-term engagement with mHealth solutions in healthcare.

5.5.2 Intervention Mapping Step 6: Evaluation plan

Intervention Mapping Step 6 finalizes the preliminary evaluation plan developed during the previous steps as applied in the *TRIANGLE user study* and the *Test TRIANGLE Pilot Study*. The final product of Intervention Mapping Step 6 will be a complete evaluation plan to guide future evaluations of the *TRIANGLE* program (Figure 5.2). So far, we have focused on the program beneficiaries as most important group for feedback early in the process. We will add further questions for other stakeholders to evaluate intervention effects and processes, to verify assessment measures, and to complete the evaluation design. Some of the additional questions will be informed by our previous studies. As discussed in Chapter 4.3.6, a few measures used in the *Test TRIANGLE Pilot Study* will have to be reconsidered – such as the binary behavioral DPP endpoint or the evaluation time frame. Further, we plan on including short-term measures such as validated questionnaires on behavioral determinants and app analytics. While the *Test TRIANGLE Pilot Study* evaluated program efficacy under controlled conditions, a large effectiveness trial needs to test whether the program works in real-world settings. A thorough and well-planned evaluation of the *TRIANGLE* program will allow us to understand both the impact of earlier planning decisions and the program's effectiveness at a larger scale. Following Step 6, the *TRIANGLE* intervention can be implemented and the evaluation can inform program improvements as a vital part of program management [116].

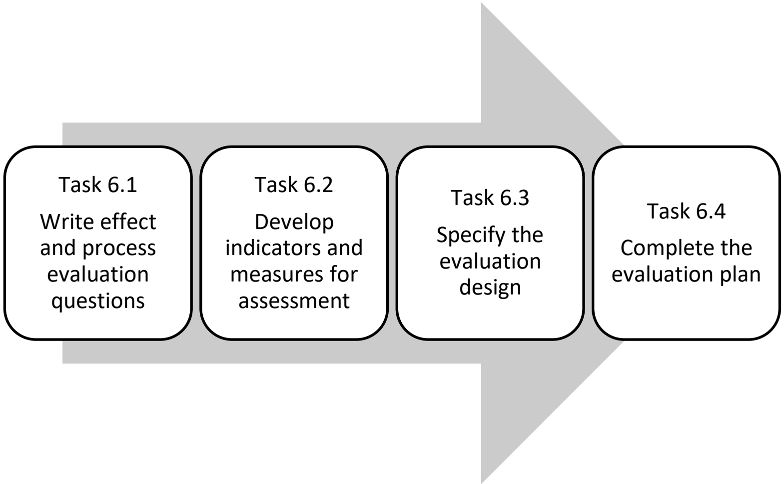

Figure 5.2: Tasks of Intervention Mapping Step 6
(adapted from Eldredge et al., 2016)

Relevant questions to evaluate program effects on behavioral determinants, behaviors or environmental conditions, health, and quality of life: *"Did women post-GDM who participated in the TRIANGLE program increase their knowledge, skills and self-efficacy of relevant lifestyle behaviors compared to those who did not participate?", "What changes in behavior and environmental conditions occurred?", "How much did the health problem change in the designated time frame?", "How much did the quality of life change in the designated time frame?"*[116].

Relevant questions to evaluate implementation processes such as reach, fidelity, and performance include: *"Was the implementation complete and appropriate?", "How well is the fidelity to the program's original design maintained during delivery?", "How do aspects of implementation explain evaluation results?", "What are the program support materials for acceptable delivery of the program and were any additional materials used?", "Was the required dose of the program delivered?", "What are the patterns of incomplete doses and what are the main causes?", "Do staff members have the skills and credentials needed for implementation?", "What barriers occurred for implementation?", "Were any persons who are not members of the intended groups participating and if so, how many?", "Did any other participants suggest new groups that should be included?"* [116].

Additional relevant questions for evaluation stakeholders comprise: *"Have the right priority groups been identified?", "What is the proportion of the intended audience who participate?", "Which groups of participants are underrepresented?", "Do stakeholders agree on the program objectives?", "Were the behaviors and determinants well specified?", "Were change methods well matched to influence determinants?", "Did the practical applications reach the populations and adhere to the behavior change method's parameters?", "How satisfied are participants with the program?", "What are the barriers and facilitators to participation?", "What are opinions of participants and nonparticipants about the program?", "Is the feedback data used for the improvement of program quality?", "How much does the program cost for each unit of benefit?", "How does the program compare to other programs addressing the problem?"* [116].

These questions derived from Intervention Mapping will help to keep the bigger picture in mind, to detect system level change including possible negative effects or mediators, and to constantly prioritize and adapt the *TRIANGLE* program where necessary.

A recent systematic review called for a core outcome set for diabetes after pregnancy prevention trials since the authors discovered 172 different outcomes measured by diverse tools in previous trials [76]. In contrast to Intervention Mapping, the authors grouped the outcome measures into three domains: health status including quality of life and mental health, health behavior including behavioral determinants, and implementation processes including engagement, feasibility, and health economics [76]. The attempted core outcome set must be chosen carefully in a cooperation of stakeholders, with some new measures and a clear prioritization of the existing measures [76]. Once available, this core outcome set may inform future evaluations of the *TRIANGLE* program and other programs post-GDM. Further, reviews on evaluations of related mHealth programs such as for the prevention and control of T2D [87] or for improved nutrition [1093] may provide valuable information.

The evaluation of the effects of mHealth on behaviour change remains challenging [1094, 1095]. Respective guidelines for evaluation and reporting are needed [1096]. The clinical mHealth evaluation may require alternative trial methods to the traditional RCT to better reflect real-world usage and attrition [1003]. So far, we tested the *TRIANGLE* app and related human coaching at a small scale within a pilot RCT. The next steps will be thorough evaluations of the associated coaching platform as integral part of the *TRIANGLE* mHealth program, the possible inclusion of wearable and sensor data, and patterns of intervention use by healthcare providers of women post-GDM. Further, a larger trial will allow us to inspect possible associations between logged data and user demographics, behaviors, and health or quality of life outcomes.

5.6 Strengths and limitations of using Intervention Mapping for this project

The development of effective behavioral programs post-GDM remains challenging due to special needs in the complex postpartum period [935]. Yet, this research project used the Intervention Mapping approach [116] to address some of the challenges within the project's limitations.

5.6.1 Strengths

First, the *TRIANGLE* project was outcome oriented to deliver a pretested program that lives up to the standards of innovative mHealth in the 21st century and that reduces known barriers for women post-GDM. The *TRIANGLE* app belongs to a small proportion of health apps with a theoretical background [1097]. In line with Intervention Mapping, we tried to ensure a good fit between the needs of women post-GDM, scientific evidence, current industry standards for health and fitness apps, and the intervention context. Hence, we started with a comprehensive needs assessment, a multi-theory approach backed up by empirical evidence, interdisciplinary partnerships including academia and industry, and the social ecological model with systems thinking. Further, we involved women post-GDM in a semi-participatory approach for decisive pre-tests on usability and first clinical efficacy. User testing and a randomized-controlled pilot trial indicated that a smartphone app is a suitable delivery channel for a behavioral intervention post-GDM and that women post-GDM are ready to engage into psychosocial training. The studies provided iterative input for adaptations of the *TRIANGLE* app and helped to prepare program implementation and evaluation in routine care.

Second, the project generated knowledge that may serve as a blueprint for future programs post-GDM. We created a comprehensive intervention model post-GDM that considered the requirements of the complex at-risk population and their health problem. This intervention model can be easily modified in case of new research findings. Each Intervention Mapping Step shed light on new aspects when designing an intervention for women post-GDM. We used Intervention Mapping as a descriptive and analytical tool. Intervention Mapping thus allowed for a transparent reporting of steps, tasks, and processes that informed decisions along the way.

Third, the Intervention Mapping approach allowed us to cover more behavioral determinants and respective behavior change methods than usual and to consider important parameters when translating methods into practical applications. We extended current programs by applying habit theory and by generating new program components with technological support for behavior change. The *TRIANGLE* set of core features and sub-features is unique and encourages daily participation. Further, we extended the traditional lifestyle areas of physical activity and nutrition with additional performance objectives and with a module in applied positive psychology and sleep. Overall, Intervention Mapping helped us in planning and developing these new program components.

Fourth, the comparison with other programs post-GDM based on Intervention Mapping revealed the high heterogeneity in current programs and the promise of future initiatives that combine different approaches. The review showed the need for additional intervention components in all current programs to enhance intervention success, including *TRIANGLE*. The additional components start with the choice of environmental agents such as families or healthcare professionals and end with pretested practical applications for relevant stakeholders in routine care.

5.6.2 Limitations

The main benefits of Intervention Mapping also contribute to its main limitations. Limitations of the Intervention Mapping approach lead to a low to medium fidelity in fully using this approach [1098]. Three main limitations hindered us and other health promoters to fully apply the Intervention Mapping approach:

1) Takes a lot of time
2) Requires a lot of human and financial resources
3) Remains somewhat abstract

First, the Intervention Mapping process is very elaborate and holistic and as such time-consuming [1099]. Many health promoters experienced in Intervention Mapping stress the long duration [1100-1103]. The *TRIANGLE* needs assessment alone already took several months, as in a similar project [1018]. Time requirements increase if new data from the at-risk population needs to be acquired [1104]. Hence, we did not conduct formative research and relied on the present knowledge and empirical data since it could be classified as sufficient. Further, we depended on the availability of stakeholders and external experts. Therefore, we did not involve all stakeholders to limit unnecessary extensions of the timeline. A recent review showed that 28% of the programs applying Intervention Mapping did not involve stakeholders and less than half of those who did clarified how [114]. Those applying Intervention Mapping consider full stakeholder participation as not always feasible in practice [114, 1105]. Excluding some stakeholders means that group processes were likely less diverse in idea generation, opinions, and decision making compared to a full inclusion of all stakeholders [116]. Yet, the empirical literature provided many useful insights on different stakeholder perspectives and we were able to draw on years of observation and exchange during clinical visits by women post-GDM. In addition, we needed quick deliverables aiming at an mHealth solution. Innovative digital approaches in health promotion need to be agile with a short time-to-market [1003]. In sum, Intervention Mapping may be too lengthy for fast-paced technologies [1072].

Second, the Intervention Mapping approach requires a lot of staff and financial resources [1099, 1106]. The comprehensiveness of the Intervention Mapping approach thus decreases its feasibility with limited resources [1099]. Regular meetings with several stakeholders and experts require both human and financial resources. The more stakeholders are involved, the higher is the risk for conflicting interests, longer group processes, and higher planning costs. The required external expertise for the different components of the *TRIANGLE* program added to the necessary resources. Hence, we were not able to include experts in all Intervention Mapping-related disciplines, such as behavior and neuroscience, social psychology, and health education – but rather engaged in respective training. To work with Intervention Mapping required extensive training in knowledge and skills of the behavioral sciences such as the eclectic use of theory combining a topic-related, concept-related, and general theories approach [116]. Overall, Intervention Mapping seems better suited for interventions targeting one or two behavior goals than for more holistic programs such as *TRIANGLE*.

Third, Intervention Mapping is practice-oriented, yet in some ways still abstract and complex [1099]. This became apparent in the *TRIANGLE* project when working with the software engineers asking for pragmatic solutions such as a limited set of intuitive app features, few categories in the library, and a first *TRIANGLE* app version for the iOS system only. Further, the numerous abstract tables and matrices in the *TRIANGLE* project are still incomplete since we had to limit the scope in every step. The full scope of Intervention Mapping for women post-GDM would require countless additional matrices for:

- Additional priority populations (e.g. families, healthcare practitioners)
- Subgroups (e.g. Asian culture, single mothers)
- Cardiometabolic risk behaviors (e.g. breastfeeding, smoking)
- Performance objectives (e.g. woman post-GDM fully breastfeeds for at least four months, primary healthcare professional uses the *TRIANGLE* coaching platform for evidence-based lifestyle advice at least once per month per patient)
- Behavioral determinants (e.g. negative affect, self-judgment)
- Change objectives (e.g. primary healthcare professional expresses positive feelings towards using the *TRIANGLE* coaching platform for evidence-based lifestyle advice)
- Behavior change methods (e.g. motivational interviewing, active learning)
- Practical applications (e.g. shared long-term goal setting tool in the *TRIANGLE* app and the *TRIANGLE* coaching platform)

The Intervention Mapping authors encourage health promoters to use the framework regardless of time or resources available and offer various strategies to save time and/or human and financial resources [116]. Other projects showed that Intervention Mapping-based planning of health promotion programs was possible with limited resources [1107-1110]. Hence, we used suggested shortcuts such as rapid assessments, shortened group processes, workshop-type meetings, and a focus on key questions [116]. However, we may have missed some aspects via taking those shortcuts. Similar to other projects [114, 1111, 1112], we conducted Intervention Mapping Steps 1 to 4 since current resources and the scope of this project did not allow for the full Intervention Mapping. Therefore, we have limited proof of clinical efficacy and cost-effectiveness, and no insights on large-scale implementation of the *TRIANGLE* program in the German healthcare system to this day.

5.7 Implications for future research

Health promoters need to extend current prevention programs post-GDM and tackle national or international implementation and evaluation to reach and engage women post-GDM in routine care. In line with systems thinking, the most effective intervention points for changes in system activity [120] still have to be discovered to prevent cardiometabolic disturbances in women post-GDM. Additional environmental agents need to be included at the organization, community and society level despite the challenges to address relevant agents for this rather small and scattered priority population. Targeting the entire family will be an important future component in programs post-GDM [45] since the offspring [1113] and the fathers are also at higher risk for T2D [1114]. Apps such as *TRIANGLE* offer the opportunity for group accounts with sharable data and competitive elements among partners and other family members. Similarly, data may be digitally shared with healthcare practitioners [43]. However, health promoters need to investigate acceptance and usage of such features for all involved parties. Human coaching needs standardized training [58, 60, 1039] and cost estimates. Further, health promoters must advocate reimbursement models such as billing codes for healthcare practitioners to allow them to allocate time for behavioral and lifestyle coaching.

Research efforts on interventions post-GDM must be bundled for faster and better program development that fits the pace of the 21st century. The development time for effective mHealth programs may be reduced with new study designs for innovative digital solutions [1003]. Further, researchers need to grant a better comparability for intervention studies with women post-GDM [76]. So far, the ideal fit for each of the following key components remains to be established for programs post-GDM: timing of the intervention, intervention duration, delivery channel, minimum lifestyle content, core features in mHealth apps, additional program materials, intensity/pacing, subgroups for tailored content, determinants for behavior, behavior change methods, and desired outcomes. Current studies vary largely in these components and in the respective reporting so that they cannot be compared in terms of effectiveness. Different types of one program component may have to be investigated in either separate studies controlled for other components or in large studies with several parallel study arms to prioritize and discover the best fit for programs post-GDM.

Some new insights on women post-GDM require further research, such as the need for technological program delivery [38]. In mHealth, researchers need to find out what level of automation will be acceptable for women post-GDM, which type of technological and social support in behavior change is needed, how to embed evaluations including changes in personal determinants, how artificial intelligence may help to address specific needs of smaller subgroups of women post-GDM, and if women post-GDM desire multi-device usage. A cross-platform development of mHealth apps [1115] may support this process. Further, habits may require additional types of tracking such as experience sampling or mobile-based ecological momentary assessment [1116].

Regarding the *TRIANGLE* program, future studies need to prioritize and investigate the effects of suggested additions such as customized accounts for other priority populations, peer interaction, gamification, intervention start during pregnancy, tailoring for subgroups, and new content. Building on the Intervention Mapping approach, we need to add and test new performance objectives, behavioral determinants, change objectives, behavior change methods, and practical applications. After another iterative round of improvements and the respective Android software programing, the ideal testing would be a full-scale national implementation in German routine care with a thorough evaluation. We are currently testing the *TRIANGLE* app for related disease indications requiring habit change due to the respective encouragement by our study participants.

5.8 Conclusions

The Intervention Mapping approach guided the planning, development, and pilot testing of the smartphone-based *TRANGLE* program to prevent T2D and related cardiometabolic disturbances in women post-GDM. This in-depth project description provides a detailed intervention model that may serve as blueprint for developing similar complex mHealth programs specific to the needs of women post-GDM. The *TRIANGLE* program is among the first programs to target personalized habit change beyond nutrition and physical activity in an interactive mHealth app – including psychosocial wellbeing. It is also among the first programs to allow for flexible pacing, address many different behavioral determinants, and offer diverse behavior change methods. The *TRIANGLE* app fulfills both current commercial and scientific standards due to an academia-industry cooperation. A user study and a multicenter pilot RCT of the *TRIANGLE* program in Germany indicated a high acceptance and perceived impact by women post-GDM, with first clinical effects. Further improvements and an Android version are needed to reach and engage more women post-GDM. So far, we do not know how healthcare practitioners outside the study team will work with the coaching platform. Further, cost-effectiveness estimates and real-world penetration and participation rates are pending. A large implementation intervention in a national routine care setting would help to understand differences in acceptance and usage by subgroups of women post-GDM and by healthcare practitioners. Overall, the *TRIANGLE* program has the potential to improve public health via a client-server model for behavior change support that is easy to adapt, deliver, and disseminate.

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Appendix

Supplementary Table 1: Intervention Mapping core processes to create the logic model of the problem. Part 1. Define the priority population.

POSED QUESTION: "*What demographic (non-behavioral) factors characterize women post-GDM (priority population) at risk for type 2 diabetes (health problem)?*"		
BRAINSTORMED ANSWERS	**ADDITIONS FROM THE REVIEWED EMPIRICAL LITERATURE**	**WORKING LIST OF ANSWERS**
<u>Basic demographics</u> • Female gender • Reproductive age • ≥ 1 child • ≥ 1 pregnancy complicated by GDM • Delayed postpartum phase <u>Overrepresented traits</u> • Overweight or obese • Advanced maternal age • Low socioeconomic status • At-risk ethnicity (Asian, Hispanic, Turkish) • Family history of diabetes • Excess weight gain during pregnancy • The polycystic ovary syndrome • Pre- or postnatal factors of the metabolic syndrome • Multiparity • Pre-existent depression • Married or living with a partner • Working mother	<u>Overrepresented traits</u> • Depressive symptoms or (postpartum) depression • Fertility problems or in-vitro fertilization	<u>Basic demographics</u> • Female gender • Reproductive age • ≥ 1 child • ≥ 1 pregnancy complicated by GDM • Delayed postpartum phase • At high risk for or with present cardiometabolic disturbances post-GDM <u>Overrepresented traits</u> • Pre-pregnancy metabolism with characteristics of the metabolic syndrome, including overweight/obesity • Advanced maternal age • Low socioeconomic status • High-risk ethnicity such as Asian, Hispanic, or Turkish • Family history of diabetes • GDM in a previous pregnancy • Excess weight gain during pregnancy • The polycystic ovary syndrome, fertility problems or in-vitro fertilization • Multiparity • Pre-existent depression • Married or living with a partner and infant(s) • Working mother

Theoretical additions and new research were not feasible at this stage. GDM = gestational diabetes mellitus

Supplementary Table 1 (continued): Part 2. Define the health problem.

POSED QUESTIONS: ***1) "What characterizes type 2 diabetes (health problem) post-GDM, including its related cardiometabolic precursor stages, complications, and comorbidities?", 2) "How many people have it or will get it?"***					
BRAINSTORMED ANSWERS	Cardiometabolic disturbances characterized by combinations of: • (Abdominal) overweight or obesity • High blood pressure • Impaired fasting glucose • Impaired glucose tolerance • Increased glycated hemoglobin • Insulin resistance • Increased low-density lipoprotein cholesterol • Decreased high-density lipoprotein cholesterol • Increased triglycerides • Increased resting heart rate • Pro-inflammatory factors (cytokines or adipokines) • Pro-thrombotic factors Cardiometabolic disease • Type 2 diabetes • Cardiovascular diseases • Metabolic syndrome Cardiometabolic disease complications • Macrovascular complications • Microvascular complications • Acute complications • Other related complications and comorbidities	**ADDITIONS FROM THE REVIEWED EMPIRICAL LITERATURE**	Prevalence (Germany): GDM: 6.81%, thereof: Type 2 diabetes (8 years post-GDM): 52.7% Prevalence (comparable countries) Metabolic syndrome: 50% Odds ratio (comparable countries) Cardiovascular disease: 1.25-1.85	**WORKING LIST OF ANSWERS**	Cardiometabolic disturbances defined as combinations of: • (Abdominal/visceral) overweight/obesity: Increased BMI Increased waist circumference Increased percent body fat/(visceral) fat mass • Increased blood pressure (systolic or diastolic)/hypertension • Dysglycemia: Increased fasting glucose Increased two-hour glucose in oral glucose tolerance test Increased glycated hemoglobin Increased "Insulin Homeostatic Model Assessment of Insulin Resistance" • Dyslipidemia: Increased low-density lipoprotein cholesterol Decreased high-density lipoprotein cholesterol Increased triglycerides Cardiometabolic disease (type 2 diabetes, cardiovascular diseases, metabolic syndrome), related complications and comorbidities

Theoretical additions and new research were not feasible at this stage. BMI = body mass index, GDM = gestational diabetes mellitus

Supplementary Table 1 (continued): Part 3. Define relevant subgroups of the priority population.

POSED QUESTIONS: ***1) "Does the prevalence or severity for type 2 diabetes and related cardiometabolic disturbances vary between demographic subgroups of women post-GDM?", 2) "What segments of women post-GDM have an excess burden from type 2 diabetes-related cardiometabolic disturbances?", 3) "Are there other relevant subgroups for program participation?"***		
BRAINSTORMED ANSWERS	**ADDITIONS FROM THE REVIEWED EMPIRICAL LITERATURE**	**WORKING LIST OF ANSWERS**
Pregnancy-related • Excess weight gain during pregnancy, especially if high pre-pregnancy BMI • Advanced gestational age • GDM diagnosis early in pregnancy • Pre- or postnatal factors of the metabolic syndrome • Higher glucose levels at the time of diagnosis of GDM • Recurrent GDM • Insulin dependency during pregnancy • Multiparity • Postpartum weight retention • (Postpartum) depressive symptoms or fatigue Gene-related • At-risk ethnicities • Family history of diabetes • The polycystic ovary syndrome Other • Overweight or obese • Low socioeconomic status • Physiological disturbances postpartum • Working mothers • Single mothers • Number and age of children living in the household	Pregnancy-related • Large-for-gestational age infant • Preterm delivery Subgroups post-GDM with an excess risk for type 2 diabetes (as defined by the German Guideline for GDM Diagnosis, Therapy and Follow-Up Care) ≥ 2 of the following risk factors: • BMI > 30 kg/m^2 • GDM diagnosis < 20th pregnancy week • Antenatal oral glucose tolerance test: blood glucose at 60 min > 200 mg/dl • Insulin treatment during pregnancy Other • Strong ethnic identity • High fatty liver index • Increased homocysteine levels • Difficulties with childcare	Most relevant subgroups for intervention: • BMI ≥ 23 kg/m^2 • BMI < 23 kg/m^2 Important to keep in mind: • Ethnicity or ethnic identity • Low socioeconomic status • Family history of diabetes • Metabolic status with characteristics of the metabolic syndrome • The polycystic ovary syndrome • Pregnancy and GDM-related factors such as excess weight gain, insulin treatment, early GDM diagnosis < 20th pregnancy week, antenatal glucose value in the oGTT > 200 mg/dl • Postpartum factors such as no/short breastfeeding, postpartum weight retention for a longer period, fatigue or sleeping problems, physiological disturbances, psychological disturbances

Theoretical additions and new research were not feasible at this stage. BMI = body mass index, GDM = gestational diabetes mellitus, oGTT = oral glucose tolerance test

Supplementary Table 1 (continued): Part 4. Characterize implications of the health problem on quality of life.

POSED QUESTIONS: ***1) "How do type 2 diabetes and related cardiometabolic disturbances (post-GDM) affect an individual's quality of life?", 2) "To what extent are different quality of life dimensions such as activities of daily living in family life, work or leisure time affected?", 3) "How does quality of life vary for different subgroups?"***

BRAINSTORMED ANSWERS	THEORETICAL FRAMEWORK	ADDITIONS FROM THE REVIEWED EMPIRICAL LITERATURE	WORKING LIST OF ANSWERS
<u>Short-term:</u> Little or no impact <u>Long-term:</u> • Impaired overall quality of life in varying degrees • All major quality of life domains and most facets affected <u>Subgroups with an impaired quality of life</u> • Single mothers • (Postpartum) depressive symptoms • Overweight or obese • Lower socioeconomic status • Type 2 diabetes-related: number, severity, and duration of cardiometabolic disturbances/disease-related complications/comorbidities; low glycemic control	<u>Physical health domain</u> • Pain and discomfort • Energy and fatigue • Sleep and rest • Mobility • Activities of daily living • Dependence on medication • Working capacity <u>Psychological domain</u> • Negative emotions • Cognitions • Self-esteem • Body image • Spirituality • Personal beliefs <u>Social relationship domain</u> • Personal relations • Practical social support • Sex <u>Environmental domain</u> • Home environment • Financial resources • Recreation and leisure • Safety and security • Access to health or social care • Information and skills • Physical environment • Transport	<u>Short-term:</u> • Little or no overall impact • Postpartum factors: quality of life rated weakest for "discomfort", "sleeping", and "discomfort and symptoms" <u>Long-term effects:</u> Impairments starting at high perceived risk for type 2 diabetes or with a pre-diabetic state; Impairments in all four main quality of life domains and most of their facets (see theoretical framework in the second column), except for: • Safety and security • Access to health or social care • Information and skills • Physical environment • Transport <u>Subgroups</u>: • Perceived fair or poor health • Immigrants • Higher disease severity • Longer disease duration • More complications • Low glycemic control	<u>Short-term:</u> Little or no overall impact, yet some <u>subgroups</u> with impaired quality of life: • Postpartum depression • Single mothers • Lower socioeconomic status • Obese • Perceived fair or poor health • Other postpartum factors: quality of life rated weakest for "discomfort", "sleeping", and "discomfort and symptoms" <u>Long-term:</u> Impairments in all four main quality of life domains and most of their 24 facets (see theoretical framework in the second column and additional findings from the empirical literature in the third column), with several vulnerable subgroups

New research was not feasible at this stage. GDM = gestational diabetes mellitus

Supplementary Table 1 (continued): Part 5. Define relevant risk behaviors.

POSED QUESTIONS: ***1) "What are important risk behaviors (causally) linked to the development of type 2 diabetes and related cardiometabolic disturbances (post-GDM) in terms of increased risk, incidence, prevalence, or burden?", 2) "How do risk behaviors vary for different subgroups?"***		
BRAINSTORMED ANSWERS	**ADDITIONS FROM THE REVIEWED EMPIRICAL LITERATURE**	**WORKING LIST OF ANSWERS**
<u>Nutrition habits</u>: predominant unhealthy pattern, High in: • Energy-dense meals and snacks • Animal-derived products, especially those high in total fat, saturated fat, or cholesterol • (Ultra-) processed food • Caloric drinks • Food cue reactivity • Excess energy intake Low in: • Nutrient-dense meals and snacks • (Fresh) plant products • Non- or minimally processed food • Water, plain tea or coffee intake • Adherence to recommended healthy dietary patterns and macronutrient quality • Controlled or restricted energy intake <u>Physical activity habits</u> • Sedentary, television watching • Low daily physical activity • Insufficient exercise or exercise intensity <u>Psychological and sleep habits</u> • Pessimistic thinking style • Insufficient control of negative emotions • Poor stress management or problem solving • Insufficient meditation, positive emotion, optimistic thinking, or mind-body practices • Insufficient enjoyable leisure time activities • Poor sleep hygiene	<u>Other behaviors</u> • No or limited breastfeeding • Smoking • Shift work <u>Subgroup additions</u> • Low vs. high adherence to health behavior • Planning another pregnancy • Desiring weight loss • High job strain	<u>Nutrition habits</u> • Excess intake of energy-dense meals/snacks • Excess intake of animal-derived products, especially those high in total fat, saturated fat, or cholesterol • Excess intake of (ultra-) processed food • Excess total energy intake • Excess intake of caloric drinks • Insufficient intake of non- to minimally processed food • Insufficient intake of (fresh) plant products • Insufficient intake of water • Non-adherence to recommended healthy dietary patterns and macronutrient quality • Insufficient control of eating behavior <u>Physical activity habits</u> • Insufficient daily physical activity • Insufficient exercise or exercise intensity <u>Psychological and sleep habits</u> • Pessimistic thinking style • Insufficient control of negative emotions • Poor stress management or problem solving • Insufficient meditation, positive emotion, optimistic thinking, or mind-body practices • Insufficient enjoyable leisure time activities • Insufficient sleep-enhancing behaviors <u>Other behaviors</u> • No or limited breastfeeding • Smoking

Theoretical additions and new research were not feasible at this stage.

Supplementary Table 1 (continued): Part 6. Define personal determinants of risk behaviors in the priority population.

POSED QUESTIONS: ***"Why would women post-GDM (priority population) perform cardiometabolic risk behaviors?", "What theory- and evidence-based factors are (causally) related to cardiometabolic risk behaviors?", and "Why would different subgroups behave differently?"***

BRAINSTORMED ANSWERS

- Insufficient motivation
- Lack of clear goals and planning
- Misperceptions of behavioral barriers (competing demands, cultural expectations, lack of energy/childcare/time/financial/ social resources)
- Impaired health or impaired child's health
- Insufficient self-management skills or lacking skills for specific health behaviors
- Insufficient positive outcome expectations
- Strong beliefs about disease heredity
- Insufficient social support for healthy choices or peer pressure for unhealthy choices
- Primary identification as mother, partner, and homemaker, but lack of role model perceptions
- Feelings of failure
- Unhealthy lifestyle-loving (family) identity
- Negative emotions towards health behaviors
- Mental distress
- Insufficient self-efficacy for health behaviors
- Insufficient or biased knowledge on (individual) risk behaviors
- Lack of simple actionable rules
- Optimistic bias and risk attributions to the far future
- Insufficient health-promoting (family) habits

THEORETICAL BACKBONE

- Commitment
- Perceived barriers
- (Perceived) skills
- Outcome expectations and attitudes
- Perceived social norms
- Self-image
- Emotional reaction to behavior
- Perceived self-efficacy
- Behavioral knowledge and awareness
- Perceived risk
- Habits
- Other behaviors as cue to action

ADDITIONS FROM THE EMPIRICAL LITERATURE

- Negative emotions or moods
- Dissatisfying relationship or disagreements with healthcare practitioners
- Strong (cultural) role perceptions
- Partner with low health literacy
- Interfering cultural identity
- Rebellion against previous constraints during gestational diabetes mellitus
- Insufficient or ill-timed repetition of health information
- Lack of cultural-sensitive health information
- Decreasing risk perceptions over time
- Insufficient family-related risk perception
- Exercise-specific: lack of group exercise sessions

WORKING LIST OF ANSWERS

- Insufficient health-promoting (family) habits
  Lack of commitment
- Misperceptions of behavioral barriers
- Insufficient self-management skills or lacking skills for specific health behaviors
- Insufficient positive outcome expectations
- Biased perceptions of social norms or family identity with no or little perceived social support for health behavior
- Insufficient role model perceptions despite primary identification as mother and homemaker, interfering cultural identity, and unhealthy lifestyle-loving identity
- Negative emotions towards health behaviors
- Low self-efficacy
- Insufficient or biased behavioral knowledge
- Low perceived risk or denial of risk

New research was not feasible at this stage. GDM = gestational diabetes mellitus

Supplementary Table 2: Performance objectives for behavioral outcomes.

Behavioral outcomes (BO)	Associated performance objectives (PO) *Woman post-GDM will:*
BO.1. Be physically active with moderate to high intensity for at least 150 minutes per week.	PO.1.1. Use a fitness tracker for daily step count. PO.1.2. Monitor the average daily step count of a week. PO.1.3. If walking less than 10,000 steps a day: Decide to gradually increase daily steps to at least 10,000. PO.1.4. Depending on the personal starting point: Walk at least 5,500 steps on three days a week or every day, at least 8,000 steps on three days a week or every day, and ultimately at least 10,000 steps on three days a week, then per day. PO.1.5. Disrupt longer sedentary periods every 30 min. PO.1.6. If no current exercising: Decide to initiate an exercise routine. PO.1.7. Conduct the fitness self-test at home. PO.1.8. If current exercise volume is less than 150 minutes of moderate to high intensity per week: Decide to gradually increase exercise volume to reach recommended level. PO.1.9. Plan own exercise regimen with healthcare practitioner including frequency, intensity, time, type, volume, and progression of exercise, with specific, measurable, action-oriented, realistic, timely, and self-determined goals. PO.1.10. Implement own exercise regimen. PO.1.11. Use fitness tracker for heart rate monitoring during exercise units. PO.1.12. Engage into active regeneration on non-exercise days. PO.1.13. Engage into active transportation.
BO.2. Consume at least 15 g of dietary fiber per 1,000 kcal energy intake.	PO.2.1. Decide to gradually eat more plant-based non- to minimally processed food with sufficient amounts of whole grain products, legumes, nuts, seeds, fruits, and vegetables to enhance dietary fiber intake to at least 15 g per 1,000 kcal per day. PO.2.2. Communicate health goal to the family to gradually increase dietary fiber intake by eating more whole grain products, legumes, nuts, seeds, fresh fruits, and fresh vegetables. PO.2.3. Establish a healthy family recipe book with at least 30 favorite recipes according to the healthy meal model with a quarter whole grain, a quarter preferably plant-based lean protein, and half fresh fruit or vegetable. PO.2.4. Carefully read food labels for buying or consumption decisions. PO.2.5. Remove unhealthy and ultra-processed food products from home food supplies. PO.2.6. Keep predominantly plant-based non- to minimally processed home food supplies with sufficient whole grain products, legumes, nuts, and seeds. PO.2.7. Establish a weekly family meal planning based on the healthy family recipe book.

BO = behavioral outcome, PO = performance objective

Supplementary Table 2 (continued)

Behavioral outcomes (BO)	Associated performance objectives (PO) *Woman post-GDM will:*
BO.2. Consume at least 15 g of dietary fiber per 1,000 kcal energy intake.	PO.2.8. Write a grocery list for the weekly meal plan, add healthy snacks, and separate a smaller mid-weekly list for fresh products. PO.2.9. Establish healthy grocery shopping strictly according to the grocery list. PO.2.10. Maintain a healthy cooking routine according to the weekly meal plan. PO.2.11. Depending on the starting point, gradually increase eating main meals by the healthy meal model, with a quarter whole grain, a quarter preferably plant-based lean protein, and half fresh fruit or vegetable. PO.2.12. Eat at least two fist size portions of whole grain products a day. PO.2.13. Eat at least one fist size portion of legumes a day. PO.2.14. Eat two hand size portions of fresh fruit a day. PO.2.15. Eat at least three hand size portions of fresh vegetable a day.
BO.3. Consume less than 30% of total energy intake from fat.	PO.3.1. Communicate health goal to the family to gradually limit or replace high-fat food products for a total fat intake of less than 30% of total energy intake. PO.3.2. Get familiar with naturally low-fat food products and meals. PO.3.3. Gradually limit or replace high-fat food products to reduce daily fat intake to less than 30% of total energy intake – especially those derived from animal sources and ultra-processed food. PO.3.4. Establish a low-fat nutrient-protective meal preparation. PO.3.5. Generously use fresh herbs and spices.
BO.4. Consume less than 10% of total energy intake from saturated fat.	PO.4.1. Communicate health goal to the family to gradually limit or replace food products high in saturated fat to lower saturated fat intake to less than 10% of total energy intake. PO.4.2. Get familiar with food products and meals naturally low in saturated fat and trans-fat. PO.4.3. Gradually limit or replace food products high in saturated fat to reduce daily saturated fat intake to less than 10% of total energy intake – especially those derived from animal sources and ultra-processed food products.
BO.5. Reduce body weight by at least 5% if BMI is 23 kg/m^2 or higher, maintain body weight if BMI is less than 23 kg/m^2.	PO.5.1. Keep a food journal to explore own nutrition patterns. Note down personal cues for food intake, eating times, specifics about the eating environment, the type of food, and portion size. Investigate possible associations. PO.5.2. Investigate what to change in own eating situations to select healthier food, eat more mindfully, and to fully enjoy the food. PO.5.3. Create pleasant eating situations in daily life. PO.5.4. Write a personal list with distractions for food cravings with detailed descriptions how to react in particular circumstances. PO.5.5. Implement distractions when a specific food craving emerges. PO.5.6. Eat when hungry, not when thirsty, having an appetite or other needs, and learn to distinguish these sensations.

BMI = body mass index, BO = behavioral outcome, PO = performance objective

Supplementary Table 2 (continued)

Behavioral outcomes (BO)	Associated performance objectives (PO) *Woman post-GDM will:*
BO.5. Reduce body weight by at least 5% if BMI is 23 kg/m^2 or higher, maintain body weight if BMI is less than 23 kg/m^2.	PO.5.7. If BMI is 23 kg/m^2 or higher: Avoid added sugar and sweeteners for at least one week. PO.5.8. If BMI is less than 23 kg/m^2: Limit added sugar intake to less than 25 g per day. PO.5.9. If habitual unhealthy snacking: Get familiar with healthy snacks based on fresh fruit and vegetable. PO.5.10. If habitual unhealthy snacking: Snack fresh fruit or vegetable on the go or at home. PO.5.11. If water intake below 1.5 l: Taste naturally flavored drinking water. PO.5.12. Drink at least 1.5 - 2 l of water or pure herbal tea a day, and limit other drinks to maximum four cups of plain black/green tea or black coffee and one glass of a 3:1 mixed water with juice. PO.5.13. If eating irregularly every day: Keep a meal rhythm. Depending on the starting point, eat at least one meal at a fix time each day and gradually increase to up to three regular meals a day. PO.5.14. If frequent snacking: Limit snacking to two healthy snacks between meals per day. PO.5.15. If BMI is 23 kg/m^2 or higher: Eat one regular sized portion per meal. PO.5.16. If BMI is less than 23 kg/m^2: Replace energy-dense and ultra-processed food products with healthier alternatives. PO.5.17. If overnight fasting habit of less than 12 hours: Gradually extend the overnight fast to at least twelve to sixteen hours between the last and the first food or drink intake other than water. Find out which time slot best aligns with own schedule and family life. PO.5.18. If BMI is 23 kg/m^2 or higher: Lose one to two kilos of body weight per month until own weight goal is reached. PO.5.19. Remain flexible in controlling eating behavior. Commit to a healthy nutrition on a habitual basis, yet stay flexible for special occasions and do not ban entire food categories. Balance exceptions in the next meal or snack, the latest on the next day.
BO.6. Increase wellbeing and sleep, decrease stress perception.	PO.6.1. Practice mindfulness to be fully present during daily experiences. Start with scheduled daily five-minute mindfulness exercises and gradually lower the exercise time to three minutes a day and then to at least three moments a day. PO.6.2. Get familiar with different types of recreational activities and select favorite three. PO.6.3. Maintain a weekly recreational activity routine. Start with one scheduled recreational activity per week and gradually increase to three scheduled recreational activities per week. PO.6.4. Enhance infant's sleep with list of recommended actions. PO.6.5. Enhance own sleep with list of recommended actions. PO.6.6. Maintain a daily progressive muscle relaxation routine. Start with a scheduled daily 18-minute progressive muscle relaxation exercise and gradually lower the exercise time to seven minutes and then to several short full muscle relaxation moments during the day. PO.6.7. Practice gratitude by reviewing the positive things happening on a regular day. Start with two items per day and gradually increase to four items.

BMI = body mass index, BO = behavioral outcome, PO = performance objective

Supplementary Table 2 (continued)

Behavioral outcomes (BO)	Associated performance objectives (PO) *Woman post-GDM will:*
BO.6. Increase wellbeing and sleep, decrease stress perception.	PO.6.8. Identify the most predominant one or two automatic negative thoughts in own thinking style and select corresponding positive thoughts to replace them with. PO.6.9. Notice automatic negative thoughts, acknowledge them and replace them with the according positive thoughts. PO.6.10. Get familiar with emotional positivity and learn how to strengthen positive emotions in daily life. Start by focusing on one positive emotion. Think about three situations in the past when the chosen emotion was present. Think about three concrete situations in the upcoming week to feel that chosen emotion, imagine them in detail and write them down. PO.6.11. Establish a weekly routine to strengthen positive emotions. PO.6.12. Get familiar with seven steps for problem solving and learn to apply them. PO.6.13. Establish a problem-solving routine using seven recommended steps. Start with a particular problem. Describe the problem, then the target state in as much detail as possible. Brainstorm at least three different ways to reach the target state, then choose the most achievable path for the upcoming four weeks. Break the selected path down into milestones and schedule them. Work towards each milestone. Once the steps are completed, evaluate each step. PO.6.14. Establish a prioritization routine of current and upcoming activities with a decision matrix. PO.6.15. Get familiar with character strengths and identify the top three personal strengths. PO.6.16. Focus on the top three personal strengths in daily life.
BO.7. Adhere to the mHealth program and enhance self-management.	PO.7.1. Participate in mHealth program on at least five out of seven days per week. PO.7.2. Communicate with healthcare practitioners via mHealth app. PO.7.3. Take recommended questionnaires in mHealth app to become aware of current behaviors and to assess discrepancies between current and recommended behavior. PO.7.4. Select and commit to own long-term health goals in mHealth app. PO.7.5. Select and commit to health actions in mHealth app. PO.7.6. Set reminders, schedule, or link chosen health actions to repeated contexts. PO.7.7. Monitor own progress of health actions and health goals in mHealth app on a weekly basis. PO.7.8. Reschedule missed or skipped health actions. PO.7.9. Evaluate own performance in chosen health actions and health goals in mHealth app when recommended. PO.7.10. Adapt chosen health goals and health actions when necessary.

BO = behavioral outcome, mHealth = mobile health, PO = performance objective

Supplementary Table 3: Matrices of change. Change objectives for performance objective 1.1.

PO.1.1. Use a fitness tracker for daily step count. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.1.a. Get informed about the benefits of using a fitness tracker and learn how to use it for step counting. CKR.1.1.b. Decide to commit to using a fitness tracker to monitor daily step count. CKR.1.1.c. Acknowledge the habitual character of using a fitness tracker for daily step count and the need to change environmental cues to establish automaticity.	PB.1.1.a. Get informed about possible perceived barriers using a fitness tracker for daily step count and identify personal barriers. PB.1.1.b. Get informed about possible solutions to overcome perceived barriers using a fitness tracker for daily step count and implement the most suitable solutions. PB.1.1.c. Expect and resist hindering social pressure by family members or the wider social network when starting to use a fitness tracker.	SSE.1.1.a. Feel confident about using a fitness tracker for daily step count. SSE.1.1.b. Express confidence in ability to correctly use a fitness tracker for daily step count, or to learn how to do so. SSE.1.1.c. Feel capable of noticing automaticity and of altering cues that trigger the use of a fitness tracker for daily step count.	OEA.1.1.a. Expect that using a fitness tracker will raise own awareness for actual daily step count and contribute valuable data to be able to monitor the individual average daily step count. OEA.1.1.b. Notice the advantages of using a fitness tracker for daily step count. OEA.1.1.c. Feel positive about monitoring own steps with a fitness tracker.	SN.1.1.a. Notice that most physically fit individuals use a fitness tracker to monitor their daily step count. SN.1.1.b. Notice usually wearing a fitness tracker to monitor daily steps does not need approval by others. SN.1.1.c. Notice own social resources and find role models or supporters in own or extended social network who regularly use a fitness tracker for daily step count.	SIH.1.1.a. Consistently maintain using a fitness tracker to check daily step count until habitual. SIH.1.1.b. Identify as a health-conscious person who usually wears a fitness tracker for daily step count. SIH.1.1.c. Identify as a healthy homemaker and role model who guides own children and partner to be consistent and to become aware of the importance of daily walking.	ER.1.1.a. Expect initial discomfort when starting to use a fitness tracker for daily step count. ER.1.1.b. Notice using a fitness tracker for step counting is fun. ER.1.1.c. Feel great about having used a fitness tracker for step counting.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.2.

PO.1.2. Monitor the average daily step count of a week. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.2.a. Get informed about the benefits of monitoring the average daily step count of a week, and learn to do so. CKR.1.2.b. Decide to monitor the average daily step count with a fitness tracker. CKR.1.2.c. Acknowledge the habitual character of monitoring the average daily step count of a week and the need to change environmental cues to establish automaticity.	PB.1.2.a. Get informed about possible perceived barriers monitoring the average daily step count of a week and identify personal barriers. PB.1.2.b. Get informed about possible solutions to overcome perceived barriers monitoring the average daily step count of a week and implement the most suitable solutions. PB.1.2.c. Schedule a day and time to monitor the average daily step count.	SSE.1.2.a. Feel confident about monitoring the average daily step count. SSE.1.2.b. Express confidence in ability to monitor the average daily step count of a week, or to learn to do so. SSE.1.2.c. Feel capable of noticing automaticity and of altering cues that trigger monitoring the average daily step count of a week.	OEA.1.2.a. Expect that monitoring the average daily step count will raise own awareness and contribute valuable information for individualized recommendations. OEA.1.2.b. Notice the advantages of monitoring the average daily step count of a week and of receiving individual recommendations. OEA.1.2.c. Feel positive about monitoring the average daily step count of a week and of receiving individual recommendations.	SN.1.2.a. Notice that most physically fit individuals monitor their average daily step count of a week. SN.1.2.b. Notice that regularly monitoring the average daily step count of a week does not need approval by others. SN.1.2.c. Notice own social resources and find role models or supporters in own or extended social network who monitor their average daily step count of a week.	SIH.1.2.a. Consistently maintain monitoring the average daily step count every week until habitual. SIH. 1.2.b. Identify as a health-conscious person who wants to be aware of the average daily step count at the end of each week. SIH.1.2.c. Identify as a healthy homemaker and role model who guides own children and partner to monitor own steps.	ER.1.2.a. Expect initial discomfort when starting to monitor the average daily step count of a week. ER.1.2.b. Notice that monitoring the average daily step count of a week is fun and does not translate to constraints. ER.1.2.c. Feel great about having used the provided fitness tracker for monitoring the average daily step count.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.3.

PO.1.3. If walking less than 10,000 steps a day: Decide to gradually increase daily steps to at least 10,000. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.3.a. Acknowledge insufficient daily steps as personal risk factor for cardiometabolic disease. CKR.1.3.b. Get informed about the benefits of increasing daily steps and learn strategies to gradually increase them. CKR.1.3.c. Decide to commit to the strategies to increase daily steps.	PB.1.3.a. Get informed about possible perceived barriers deciding to gradually increase daily step count and identify personal barriers. PB.1.3.b. Get informed about possible solutions to overcome perceived barriers deciding to gradually increase daily steps and implement the most suitable solutions.	SSE.1.3.a. Feel confident about being able to make the decision to increase daily steps. SSE.1.3.b. Express confidence in ability to decide to gradually increase daily steps.	OEA.1.3.a. Expect that deciding to gradually increase daily steps forms the basis to reach the ultimate goal of at least 10,000 steps a day. OEA.1.3.b Notice the advantages of gradually increasing daily steps. OEA.1.3.c. Feel positive about gradually increasing daily steps.	SN.1.3.a. Notice that physically fit individuals once decided to gradually increase their daily steps to reach 10,000 steps a day. SN.1.3.b. Notice that own decision to gradually increase daily steps to at least 10,000 steps a day does not need approval by others. SN.1.3.c. Notice own social resources and find role models or supporters in social network who support the decision to aim for the recommended 10,000 steps a day.	SIH.1.3.a. Identify as a health-conscious person who desires to increase daily steps to reach the recommended 10,000 steps a day. SIH.1.3.b. Identify as a healthy homemaker and role model who guides own children and partner to be decisive and to opt for health behaviors such as daily walking.	ER.1.3.a. Expect initial discomfort when confronted with the decision to gradually increase daily steps to at least 10,000 steps a day. ER.1.3.b. Feel great about having made the decision to gradually increase daily steps to reach the recommended 10,000 steps a day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.4.

PO.1.4. Depending on the personal starting point: Walk at least 5,500 steps on three days a week or every day, at least 8,000 steps on three days a week or every day, and ultimately at least 10,000 steps on three days a week, then every day. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.4.a. Get informed about the benefits of taking on the next higher daily step goal and learn strategies to do so. CKR.1.4.b. Identify those strategies that are best suitable for own lifestyle. CKR.1.4.c. Acknowledge the habitual character of walking and the need to change environmental cues to establish automaticity. CKR.1.4.d. Decide to commit to the individually recommended daily step goal and to the chosen strategies.	PB.1.4.a. Get informed about perceived barriers reaching the daily step goal and identify personal barriers. PB.1.4.b. Get informed about possible solutions to overcome perceived barriers reaching daily step goal and implement the most suitable solutions. PB.1.4.c. Expect and resist hindering social pressure by family members or the wider social network when starting to work towards daily step goal.	SSE.1.4.a. Feel confident about reaching the individually recommended daily step goal. SSE.1.4.b. Express confidence in ability to reach the individually recommended step goal, or to learn to do so. SSE.1.4.c. Feel capable of noticing automaticity in daily activity behavior and of altering cues that trigger walking until the daily step goal is reached.	OEA.1.4.a. Expect that following the individually recommended daily step goals ultimately leads to walking at least 10,000 steps a day. OEA.1.4.b. Notice the advantages of following the recommended daily step goal. OEA.1.4.c. Feel positive about reaching the individually recommended daily step goal.	SN.1.4.a. Notice that physically fit individuals gradually increased their daily steps to reach 10,000 steps a day. SN.1.4.b. Notice that a daily step goal does not need approval by others and can be met even if social network or culture do not support it. SN.1.4.c. Notice own social resources and find role models or supporters in own or extended social network who usually reach the recommended 10,000 steps a day.	SIH.1.4.a. Once having reached the recommended 10,000 steps a day, consistently maintain walking 10,000 steps a day with bouts of at least 10 minutes until habitual. SIH.1.4.b. Identify as a health-conscious person who walks at least 10,000 steps a day. SIH.1.4.c. Identify as a role model who guides own children and partner to be active as much as possible and walk at least 10,000 steps a day.	ER.1.4.a. Expect initial discomfort when not used to walking the next higher number of daily steps. ER.1.4.b. Notice that walking is fun. ER.1.4.c. Feel great about having walked the recommended steps on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.5.

PO.1.5. Disrupt longer sedentary periods every 30 min. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.5.a. Acknowledge long sedentary periods as personal risk factor for cardiometabolic disease. CKR.1.5.b. Get informed about the benefits of disrupting longer sedentary periods, and learn to do so. CKR.1.5.c. Acknowledge the habitual character of sedentary behavior and the need to change environmental cues to establish new automaticity. CKR.1.5.d. Decide to commit to the strategies to disrupt longer sedentary periods.	PB.1.5.a. Get informed about possible perceived barriers disrupting longer sedentary periods and identify personal barriers. PB.1.5.b. Get informed about possible solutions to overcome perceived barriers disrupting longer sedentary periods and implement the most suitable solutions. PB.1.5.c. Expect and resist hindering social pressure by family members or the wider social network when starting to disrupt longer sedentary periods.	SSE.1.5.a. Feel confident about disrupting longer sedentary periods every 30 min. SSE.1.5.b. Express confidence in ability to disrupting longer sedentary periods every 30 min, or to learn to do so. SSE.1.5.c. Feel capable of noticing automaticity in sedentary behavior and of altering cues that trigger disrupting longer sedentary periods every 30 min.	OEA.1.5.a. Expect that disrupting longer sedentary periods will lead to numerous health benefits and reduce own cardiometabolic risk. OEA.1.5.b. Express positive feelings towards the benefits of disrupting longer sedentary periods every 30 min. OEA.1.5.c. Notice the advantages of disrupting longer sedentary periods every 30 min.	SN.1.5.a. Notice that health-conscious individuals usually disrupt longer sedentary periods. SN.1.5.b. Notice that disrupting longer sedentary periods does not need approval by others. SN.1.5.c. Notice own social resources and find role models or supporters in own or extended social network who usually disrupt longer sedentary periods.	SIH.1.5.a. Consistently maintain disrupting sedentary periods until habitual. SIH.1.5.b. Identify as a health-conscious person who usually disrupts longer sedentary periods. SIH.1.5.c. Identify as a healthy homemaker and role model who guides own children and partner to usually disrupt longer sedentary periods every 30 minutes if possible.	ER.1.5.a. Expect initial discomfort when not yet used to disrupting longer sedentary periods every 30 min. ER.1.5.b. Notice that disrupting longer sedentary periods enhances own energy and is fun. ER.1.5.c. Feel great about having disrupted a longer sedentary period every 30 min.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.6.

PO.1.6. If no current exercising: Decide to initiate an exercise routine. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.6.a. Acknowledge non-exercising as personal risk factor for cardiometabolic disease. CKR.1.6.b. Get informed about the benefits of regular exercising and learn strategies to do so. CKR.1.6.c. Acknowledge the habitual character of an exercise routine and the need to change environmental cues to establish an exercise routine. CKR.1.6.d. Decide to commit to the recommended strategies to initiate an exercise routine.	PB.1.6.a. Get informed about possible perceived barriers deciding to initiate an exercise routine and identify personal barriers. PB.1.6.b. Get informed about possible solutions to overcome perceived barriers to deciding to initiate an exercise routine and implement the most suitable solutions.	SSE.1.6.a. Feel confident about being able to make the decision to initiate an exercise routine. SSE.1.6.b. Express confidence in ability to decide to initiate an exercise routine.	OEA.1.6.a. Expect that deciding to initiate an exercise routine forms the basis for numerous health benefits including a higher physical fitness and a favorable body composition. OEA.1.6.b Notice the advantages of initiating an exercise routine. OEA.1.6.c. Feel positive about initiating an exercise routine.	SN.1.6.a. Notice that physically fit individuals once decided to initiate an exercise routine. SN.1.6.b. Notice that deciding to initiate an exercise routine does not need approval by others. SN.1.6.c. Notice own social resources and find role models or supporters in own or extended social network who support the decision to initiate an exercise routine.	SIH.1.6.a. Identify as a health-conscious person who desires an exercise routine. SIH.1.6.b. Identify as a healthy homemaker and role model who guides own children and partner to be decisive and to opt for health behaviors such as regular exercising.	ER.1.6.a. Expect initial discomfort when confronted with the decision to initiate an exercise routine. ER.1.6.b. Feel great about having decided to initiate an exercise routine.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.7.

PO.1.7. Conduct the fitness self-test at home. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.7.a. Get informed about the benefits of conducting the fitness self-test at home and learn to conduct it correctly. CKR.1.7.b. Decide to conduct the fitness self-test at home and commit to it.	PB.1.7.a. Schedule a day and time for the fitness self-test at home and commit to keeping the schedule. PB.1.7.b. Expect and resist hindering social pressure by own family when conducting the fitness self-test at home.	SSE.1.7.a. Feel confident about conducting the fitness self-test at home as instructed. SSE.1.7.b. Express confidence in ability to correctly conduct the fitness self-test at home as instructed, or to learn to do so.	OEA.1.7.a. Expect that conducting the fitness self-test at home will provide valuable information for an individualized exercise regimen. OEA.1.7.b. Notice the advantages of conducting the fitness self-test at home for an individualized exercise regimen. OEA.1.7.c. Feel positive about conducting the fitness self-test at home for an individual exercise regimen.	SN.1.7.a. Notice that most physically fit individuals conduct fitness self-tests on a regular basis. SN.1.7.b. Notice that conducting the fitness self-test at home does not need approval by others. SN.1.7.c. Notice own social resources and find role models or supporters in own or extended social network who usually conduct a fitness self-test at home.	SIH.1.7.a. Identify as a health-conscious person who usually conducts a fitness self-test at home. SIH.1.7.b. Identify as a healthy homemaker and role model who guides own children and partner to be decisive and to check their fitness level regularly.	ER.1.7.a. Expect initial discomfort when not being used to conduct the fitness self-test at home. ER.1.7.b. Notice that conducting the fitness self-test at home is fun. ER.1.7.c. Feel great about having conducted the fitness self-test at home.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives of performance objective 1.8.

PO.1.8. If current exercise volume is less than 150 minutes of moderate to high intensity exercise per week: Decide to gradually increase exercise volume to reach recommended level. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.8.a. Acknowledge insufficient exercising as personal risk factor for cardiometabolic disease. CKR.1.8.b. Get informed about the benefits of a weekly exercise volume of at least 150 minutes and learn strategies to achieve it. CKR.1.8.c. Decide to commit to the strategies to increase weekly exercise volume.	PB.1.8.a. Get informed about possible perceived barriers gradually increasing exercise volume to the recommended level and identify personal barriers. PB.1.8.b. Get informed about possible solutions to overcome perceived barriers gradually increasing exercise volume to the recommended level and implement the most suitable solutions.	SSE.1.8.a. Feel confident about the decision to gradually increase exercise volume to the recommended level despite family responsibilities. SSE.1.8.b. Express confidence in ability to decide to gradually increase exercise volume to the recommended level despite family responsibilities, or to learn to do so.	OEA.1.8.a. Expect that deciding to gradually increase exercise volume forms the basis for achieving the recommended volume that leads to multiple health benefits. OEA.1.8.b Notice the advantages of gradually increasing the exercise volume to the recommended level. OEA.1.8.c. Feel positive about decision to gradually increase exercise volume to the recommended level.	SN.1.8.a. Notice that physically fit individuals once decided to gradually increase their exercise volume. SN.1.8.b. Notice that deciding to gradually increase exercise volume does not need approval by others. SN.1.8.c. Notice own social resources and find role models or supporters in own or extended social network who support the decision to gradually increase exercise volume to the recommended level.	SIH.1.8.a. Identify as a health-conscious person who desires to gradually increase exercise volume to the recommended level. SIH.1.8.b. Identify as a healthy homemaker and role model who guides own children and partner to be decisive and to opt for sufficient exercising.	ER.1.8.a. Expect initial discomfort when confronted with the decision to gradually increase exercise volume to the recommended level. ER.1.8.b. Feel great about having decided to gradually increase exercise volume to the recommended level.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.9.

PO.1.9. Plan own exercise regimen with healthcare practitioner including frequency, intensity, time, type, volume, and progression of exercise, with specific, measurable, action-oriented, realistic, timely, and self-determined goals. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.9. Get informed about the benefits of planning own exercise regimen with healthcare practitioner and learn about planning strategies.	PB.1.9.a. Get informed about possible perceived barriers planning own exercise regimen and identify personal barriers. PB.1.9.b. Get informed about possible solutions to overcome perceived barriers planning own exercise regimen and implement the most suitable solutions. PB.1.9.c. Schedule specific days and times for exercising. PB.1.9.d. Expect barriers finding appropriate time to exercise despite family responsibilities.	SSE.1.9.a. Feel confident about planning own exercise regimen with professional support. SSE.1.9.b. Express confidence in ability to plan own exercise regimen with professional support, or to learn to do so.	OEA.1.9.a. Expect that systematically planning the own exercise regimen will lead to the best possible improvements in health outcomes and physical fitness. OEA.1.9.b. Notice the advantages of planning own exercise regimen with healthcare practitioner. OEA.1.9.c. Feel positive about planning own exercise regimen with healthcare practitioner.	SN.1.9.a. Notice that most physically fit individuals plan their exercise regimen and worked together with a healthcare practitioner at one point or another. SN.1.9.b. Notice that planning own exercise regimen does not need approval by others. SN.1.9.c. Notice own social resources and find role models or supporters in own or extended social network who usually plan their own exercise regimens.	SIH.1.9.a. Maintain and adapt own exercise regimen approximately every eight weeks until habitual for individual progress. SIH.1.9.b. Identify as a health-conscious person who usually plans own exercise regimen.	ER.1.9.a. Expect initial discomfort when not used to planning own exercise regimen. ER.1.9.b. Notice that planning own exercise regimen with healthcare practitioner is fun. ER.1.9.c. Feel great about having planned own exercise regimen with healthcare practitioner.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.10.

PO.1.10. Implement own exercise regimen. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.10.a. Get informed about how to commit to own exercise regimen and learn strategies to do so. CKR.1.10.b. Acknowledge the habitual character of an exercise routine and the need to change environmental cues to adhere to it. CKR.1.10.c. Decide to commit to the recommended strategies to implement own exercise regimen.	PB.1.10.a. Get informed about possible perceived barriers implementing own exercise regimen and identify personal barriers. PB.1.10.b. Get informed about possible solutions to overcome perceived barriers implementing own exercise regimen and implement the most suitable solutions. PB.1.10.c. Expect and resist hindering social pressure by family members or the wider social network when starting to implement own exercise regimen.	SSE.1.10.a. Feel confident about implementing own exercise regimen. SSE.1.10.b. Express confidence in ability to implement own exercise regimen, or to learn to do so. SSE.1.10.c. Feel capable of noticing automaticity in own exercising behavior and of altering cues that trigger implementing own exercise regimen.	OEA.1.10.a. Expect that implementing own exercise regimen will lead to numerous health benefits including a better physical fitness. OEA.1.10.b. Notice the advantages of implementing own exercise regimen. OEA.1.10.c. Feel positive about implementing own exercise regimen.	SN.1.10.a. Notice that physically fit individuals consistently implement their own exercise regimen. SN.1.10.b. Notice that implementing own exercise regimen does not need approval by others. SN.1.10.c. Notice own social resources and find role models or supporters in own or extended social network who commit to their own exercise regimen.	SIH.1.10.a. Consistently maintain own exercise regimen until habitual. SIH. 1.10.b. Identify as a health-conscious person who implements own exercise regimen. SIH.1.10.c. Identify as a healthy homemaker and role model who guides own children and partner to consistently implement their plans, especially those related to exercising.	ER.1.10.a. Expect initial discomfort when not used to exercising and focus on the great feeling after each exercise unit. ER.1.10.b. Notice that implementing own exercise regimen is fun. ER.1.10.c. Feel great about having exercised.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.11.

PO.1.11. Use fitness tracker for heart rate monitoring during exercise units. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.11.a. Get informed about the benefits of heart rate monitoring during exercise units and learn to do so. CKR.1.11.b. Acknowledge the habitual character of heart rate monitoring during exercise units and the need to change environmental cues to enable consistent monitoring. CKR.1.11.c. Decide to commit to the recommended strategies to consistently monitor heart rate during exercise units.	PB.1.11.a. Get informed about possible perceived barriers to use fitness tracker for heart rate monitoring during exercise units and identify personal barriers. PB.1.11.b. Get informed about possible solutions to overcome perceived barriers monitoring heart rate during exercise units and implement the most suitable solutions. PB.1.11.c. Expect and resist hindering social pressure by the social network when starting to use fitness tracker for heart rate monitoring during exercise units.	SSE.1.11.a. Feel confident about using fitness tracker for heart rate monitoring during exercise units. SSE.1.11.b. Express confidence in ability to correctly use fitness tracker for heart rate monitoring during exercise units, or to learn to do so. SSE.1.11.c. Feel capable of noticing automaticity in missed heart rate monitoring during exercise units and of altering cues that trigger heart rate monitoring during exercise units.	OEA.1.11.a. Expect that using fitness tracker for heart rate monitoring during exercise units will improve own awareness for the right amount of exertion. OEA.1.11.b. Notice the advantages of using fitness tracker for heart rate monitoring during exercise units. OEA.1.11.c. Feel positive about monitoring own heart rate with fitness tracker during exercise units.	SN.1.11.a. Notice that most physically fit individuals monitor their heart rate during exercise units. SN.1.11.b. Notice that usually wearing a fitness tracker to monitor own heart rate during exercise units does not need approval by others. SN.1.11.c. Notice own social resources and find role models or supporters in own or extended social network who usually use a fitness tracker for heart rate monitoring during exercise units.	SIH.1.11.a. Consistently maintain using a fitness tracker to monitor own heart rate during exercise units until habitual. SIH.1.11.b. Identify as a health-conscious person who usually wears a fitness tracker for heart rate monitoring during exercise units.	ER.1.11.a. Expect initial discomfort when not used to monitoring own heart rate during exercise units. ER.1.11.b. Notice that using fitness tracker for heart rate monitoring during exercise units is enjoyable. ER.1.11.c. Feel great about having used fitness tracker for heart rate monitoring during an exercise unit.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.12.

PO.1.12. Engage into active regeneration on non-exercise days. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.12.a. Get informed about the benefits of active regeneration on non-exercise days and learn strategies to do so. CKR.1.12.b. Notice that active regeneration will reduce risk for aching muscles and improve cardiometabolic health. CKR.1.12.c. Decide to engage into active regeneration on non-exercise days. CKR.1.12.d. Acknowledge the habitual character of regeneration and the need to change environmental cues to engage into active regeneration.	PB.1.12.a. Get informed about possible perceived barriers engaging into active regeneration on non-exercise days and identify personal barriers. PB.1.12.b. Get informed about possible solutions to overcome perceived barriers engaging into active regeneration on non-exercise days and implement the most suitable solutions. PB.1.12.c. Expect and resist hindering social pressure by family members or the wider social network when engaging into active regeneration on non-exercise days.	SSE.1.12.a. Feel confident about engaging into active regeneration on non-exercise days. SSE.1.12.b. Express confidence in ability to engage into active regeneration on non-exercise days, or to learn to do so. SSE.1.12.c. Feel capable of noticing automaticity on regeneration days and of altering cues that trigger engaging into active regeneration on non-exercise days.	OEA.1.12.a. Expect that engaging into active regeneration on non-exercise days leads to less aching muscles and leads to cardiometabolic health benefits. OEA.1.12.b. Notice the advantages of engaging into active regeneration on non-exercise days. OEA.1.12.c. Feel positive about engaging into active regeneration on non-exercise days.	SN.1.12.a. Notice that most physically fit individuals consistently engage into active regeneration on non-exercise days. SN.1.12.b. Notice that usually engaging into active regeneration on non-exercise days does not need approval by others. SN.1.12.c. Notice own social resources and find role models or supporters in social network who usually engage into active regeneration on non-exercise days.	SIH.1.12.a. Consistently maintain active regeneration on non-exercise days until habitual. SIH. 1.12.b. Identify as a health-conscious person who engages into active regeneration on non-exercise days. SIH.1.12.c. Identify as a healthy homemaker and role model who guides own children and partner to enjoy being active together (on non-exercise days).	ER.1.12.a. Expect initial discomfort when not used to engaging into active regeneration on non-exercise days. ER.1.12.b. Notice that engaging into active regeneration on non-exercise days is fun and does not translate to constraints. ER.1.12.c. Feel great about having engaged into active regeneration on non-exercise days.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 1.13.

PO.1.13. Engage into active transportation. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.1.13.a. Get informed about the benefits of active transportation and learn strategies to increase its amount. CKR.1.13.b. Notice that more active transportation will improve cardiometabolic health. CKR.1.13.c. Acknowledge the habitual character of own choice of transportation and the need to change environmental cues to engage into active transportation. CKR.1.13.d. Decide to commit to the strategies to usually engage into active transportation.	PB.1.13.a. Get informed about possible perceived barriers engaging into active transportation and identify personal barriers. PB.1.13.b. Get informed about possible solutions to overcome perceived barriers engaging into active transportation and implement the most suitable solutions. PB.1.13.c. Expect and resist hindering social pressure by family members or the wider social network when starting to engage into active transportation.	SSE.1.13.a. Feel confident about engaging into active transportation. SSE.1.13.b. Express confidence in ability to engage into active transportation, or to learn to do so. SSE.1.13.c. Feel capable of noticing automaticity in transportation choices and of altering cues that trigger engaging into active transportation.	OEA.1.13.a. Expect that engaging into active transportation will lead to numerous health benefits. OEA.1.13.b Notice the advantages of engaging into active transportation. OEA.1.13.c. Feel positive about engaging into active transportation.	SN.1.13.a. Notice that physically fit individuals engage into high amounts of active transportation. SN.1.13.b. Notice that engaging into high amounts of active transportation does not need approval by others. SN.1.13.c. Notice own social resources and find role models or supporters in own or extended social network who usually engage into active transportation.	SIH.1.13.a. Consistently maintain high amounts of active transportation until habitual. SIH.1.13.b. Identify as a health-conscious person who engages into high amounts of active transportation. SIH.1.13.c. Identify as a healthy homemaker and role model who guides own children and partner to engage into active transportation.	ER.1.13.a. Expect initial discomfort when not used to engaging into active transportation. ER.1.13.b. Notice that engaging into active transportation is enjoyable and does not translate to constraints. ER.1.13.c. Feel great about having used active transportation.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.1.

PO.2.1. Decide to gradually eat more plant-based non- to minimally processed food with sufficient amounts of whole grain products, legumes, nuts, seeds, fruits, and vegetables to enhance dietary fiber intake to at least 15 g per 1,000 kcal per day. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.1.a. Acknowledge insufficient intake of plant-based non- to minimally processed food as personal risk factor for cardiometabolic disease. CKR.2.1.b. Get informed about the benefits of eating predominantly plant-based non- to minimally processed food, and learn strategies to do so.	PB.2.1.a. Get informed about possible perceived barriers deciding to eat predominantly plant-based non- to minimally processed food on the long term and identify personal barriers. PB.2.1.b. Get informed about possible solutions to overcome perceived barriers deciding to gradually eat more plant-based non- to minimally processed food and implement the most suitable solutions.	SSE.2.1.a. Feel confident about being able to make the decision to gradually eat more plant-based non- to minimally processed food. SSE.2.1.b. Express confidence in ability to decide to gradually eat more plant-based non- to minimally processed food.	OEA.2.1.a. Expect that deciding to gradually eat more plant-based non- to minimally processed food forms the basis for increasing dietary fiber intake to at least 15 g per 1,000 kcal per day and for enhancing own health. OEA.2.1.b. Feel positive about gradually eating more plant-based non- to minimally processed food.	SN.2.1.a. Notice that own decision to gradually eat more plant-based non- to minimally processed food does not need approval by others. SN.2.1.b. Notice own social resources and find role models or supporters in social network towards the decision to eat predominantly plant-based non- to minimally processed food.	SIH.2.1.a. Identify as a health-conscious person who desires to eat predominantly plant-based non- to minimally processed food as recommended by food authorities. SIH.2.1.b. Identify as a healthy homemaker and role model who guides own children and partner to eat predominantly plant-based non- to minimally processed food as recommended by food authorities.	ER.2.1.a. Expect initial discomfort when confronted with the decision to eat predominantly plant-based non- to minimally processed food over the long term. ER.2.1.b. Feel great about having decided to gradually eat more plant-based non- to minimally processed food.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.2.

PO.2.2. Communicate health goal to the family to gradually increase dietary fiber intake by eating more whole grain products, legumes, nuts, seeds, fresh fruits, and fresh vegetables. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.2.a. Get informed about the benefits of communicating daily fiber goal to the family. CKR.2.2.b. Notice that communicating daily fiber goal to the family will enhance own adherence. CKR.2.2.c. Acknowledge the need to change environmental cues in family life to gradually eat more whole grain products, legumes, nuts, seeds, fresh fruits, and fresh vegetables.	PB.2.2.a. Get informed about possible perceived barriers communicating daily fiber goal to the family. PB.2.2.b. Get informed about possible solutions to overcome perceived barriers communicating daily fiber goal to the family and implement the most suitable solutions.	SSE.2.2.a. Feel confident about communicating daily fiber goal to the family. SSE.2.2.b. Express confidence in ability to communicate daily fiber goal to the family, or to learn to do so.	OEA.2.2.a. Expect that communicating daily fiber goal to the family enhances the likelihood to increase own and family's dietary fiber intake for own and family's health. OEA.2.2.b Notice the advantages of communicating daily fiber goal to the family. OEA.2.2.c. Feel positive about communicating daily fiber goal to the family.	SN.2.2.a. Notice that most individuals with healthy nutrition patterns communicate their nutrition goals such as daily fiber intake to their family. SN.2.2.b. Notice that communicating daily fiber goal to the family may initially interfere with family's preferences, yet may enhance family's health literacy, support, and nutrition behavior. SN.2.2.c. Notice own social resources and find role models or supporters in social network who usually communicate their health goals to their family.	SIH.2.2.a. Identify as a health-conscious person who communicates own nutrition goals such as sufficient dietary fiber intake to the family. SIH.2.2.b. Identify as a healthy homemaker and role model who guides own children and partner to communicate their health goals to the family.	ER.2.2.a. Expect initial discomfort when not used to communicating own nutrition goals such as sufficient dietary fiber intake to the family. ER.2.2.b. Feel great about having communicated daily fiber goal to the family.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.3.

PO.2.3. Establish a healthy family recipe book with at least 30 favorite recipes according to the healthy meal model with a quarter whole grain products, a quarter preferably plant-based lean protein, and half fresh fruit or vegetable. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.3.a. Get informed about the benefits of establishing a healthy family recipe book, and learn strategies to do so. CKR.2.3.b. Acknowledge the habitual character of using recipes and the need to change environmental cues for a healthy family recipe book. CKR.2.3.c. Decide to commit to the strategies to establish a healthy family recipe book.	PB.2.3.a. Get informed about possible perceived barriers establishing a healthy family recipe book and identify personal and family's barriers. PB.2.3.b. Get informed about possible solutions to overcome perceived barriers establishing a healthy family recipe book and implement the most suitable solutions. PB.2.3.c. Schedule specific days and times with own family to work on a healthy family recipe book.	SSE.2.3.a. Feel confident about establishing a healthy family recipe book together with own family. SSE.2.3.b. Express confidence in ability to establish a healthy family recipe book together with own family, or to learn to do so.	OEA.2.3.a. Expect that establishing a healthy family recipe book will lead to the best possible support by family members to jointly change nutrition patterns. OEA.2.3.b. Notice the advantages of establishing a healthy family recipe book together with own family. OEA.2.3.c. Feel positive about establishing a healthy family recipe book together with own family.	SN.2.3.a. Notice that most families with healthy nutrition patterns own a healthy family recipe book. SN.2.3.b. Notice that establishing a healthy family recipe book may initially interfere with family's preferences or identity, yet ultimately lead to new nutritional norms within the family. SN.2.3.c. Notice own social resources and find role models or supporters in own or extended social network who own a healthy family recipe book.	SIH.2.3.a. Consistently expand family recipe book with healthy favorite recipes of own family. SIH.2.3.b. Identify as a health-conscious homemaker who owns a healthy family recipe book and supports own family in choosing healthy meals.	ER.2.3.a. Expect initial discomfort when not used to searching for or adapting recipes according to the healthy meal model. ER.2.3.b. Notice that establishing a healthy family recipe book is fun. ER.2.3.c. Feel great about having established a healthy family recipe book.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.4.

PO.2.4. Carefully read food labels for buying or consumption decisions.
Woman post-GDM will:

Commitment, behavioral knowledge, and perceived risk (CKR)	Perceived barriers (PB)	Perceived skills and self-efficacy (SSE)	Outcome expectations and attitudes (OEA)	Perceived social norms (SN)	Self-image and habits (SIH)	Emotional reaction to behavior (ER)
CKR.2.4.a. Get informed about the benefits of carefully reading food labels, and learn strategies to do so. CKR.2.4.b. Notice that carefully reading food labels will enhance own adherence to nutrition goals. CKR.2.4.c. Acknowledge the habitual character of buying or consumption decisions and the need to change environmental cues to read food labels. CKR.2.4.d. Decide to commit to the strategies to read food labels for buying or consumption decisions.	PB.2.4.a. Get informed about possible perceived barriers carefully reading food labels and identify personal barriers. PB.2.4.b. Get informed about possible solutions to overcome perceived barriers carefully reading food labels and implement the most suitable solutions. PB.2.4.c. Expect and resist hindering social pressure by family members or the wider social network when carefully reading food labels for buying or consumption decisions.	SSE.2.4.a. Feel confident about being able to carefully read food labels for buying or consumption decisions. SSE.2.4.b. Express confidence in ability to carefully read food labels for buying or consumption decisions, or to learn to do so. SSE.2.4.c. Feel capable of noticing automaticity in buying or consumption decisions and of altering cues that trigger reading food labels.	OEA.2.4.a. Expect that carefully reading food labels for buying or consumption decisions will enhance own and family's nutrition patterns and health. OEA.2.4.b Notice the advantages of carefully reading food labels for buying or consumption decisions. OEA.2.4.c. Feel positive about carefully reading food labels for buying or consumption decisions.	SN.2.4.a. Notice that individuals with healthy nutrition patterns started by carefully reading food labels for buying or consumption decisions. SN.2.4.b. Notice that carefully reading food labels for buying or consumption decisions may initially interfere with family's preferences, yet ultimately lead to new nutritional norms within the family. SN.2.4.c. Notice own social resources and find role models or supporters in social network who carefully read food labels for buying or consumption decisions.	SIH.2.4.a. Consistently maintain reading food labels of unfamiliar food products until habitual. SIH.2.4.b. Identify as a health-conscious person who carefully reads food labels for buying or consumption decisions. SIH.2.4.c. Identify as a healthy homemaker and role model who guides own children and partner to carefully read food labels of unfamiliar food products for buying or consumption decisions.	ER.2.4.a. Expect initial discomfort when not used to carefully read food labels for buying or consumption decisions. ER.2.4.b. Notice that carefully reading food labels is fun. ER.2.4.c. Feel great about having read food labels for a buying or consumption decision.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.5.

PO.2.5. Remove unhealthy and ultra-processed food products from home food supplies. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.5.a. Acknowledge that unhealthy home food supplies drastically increase the likelihood for consumption. CKR.2.5.b. Get informed about the benefits of removing unhealthy and ultra-processed food products from home food supplies, and learn strategies to do so. CKR.2.5.c. Notice that removing unhealthy and ultra-processed food products from home food supplies will enhance adherence to own nutrition goals.	PB.2.5.a. Get informed about possible perceived barriers removing unhealthy and ultra-processed food products from home food supplies and identify personal and family's barriers. PB.2.5.b. Get informed about solutions to overcome perceived barriers removing unhealthy and ultra-processed food products from home food supplies and implement the most suitable solutions. PB.2.5.c. Expect and resist social pressure when removing unhealthy and ultra-processed food products from home food supplies.	SSE.2.5.a. Feel confident about being able to remove unhealthy and ultra-processed food products from home food supplies. SSE.2.5.b. Express confidence in ability to remove unhealthy and ultra-processed food products from home food supplies, or to learn to do so.	OEA.2.5.a. Expect that removing unhealthy and ultra-processed food products from home food supplies will enhance own and family's nutrition patterns and health. OEA.2.5.b Notice the advantages of removing unhealthy and ultra-processed food products from home food supplies. OEA.2.5.c. Feel positive about removing unhealthy and ultra-processed food products from home food supplies.	SN.2.5.a. Notice that individuals with healthy nutrition patterns started by removing unhealthy food products from home food supplies. SN.2.5.b. Notice that removing unhealthy and ultra-processed food products from home food supplies may initially interfere with family's preferences or identity, yet ultimately lead to new nutritional norms within the family.	SIH.2.5.a. Identify as a health-conscious person without unhealthy and ultra-processed food products in home food supplies. SIH.2.5.b. Identify as a healthy homemaker and role model who guides own children and partner to remove unhealthy and ultra-processed food products from home food supplies.	ER.2.5.a. Expect initial discomfort when removing unhealthy and ultra-processed food products from home food supplies. ER.2.5.b. Notice that removing unhealthy and ultra-processed food products from home food supplies is enjoyable. ER.2.5.c. Feel great about having removed unhealthy and ultra-processed food products from home food supplies.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.6.

PO.2.6. Keep predominantly plant-based non- to minimally processed home food supplies with sufficient whole grain products, legumes, nuts, and seeds. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.6.a. Get informed about the benefits of healthy home food supplies and learn strategies to manage them. CKR.2.6.b. Acknowledge that healthy home food supplies increase the adherence to own nutrition goals. CKR.2.6.c. Acknowledge the habitual character of keeping healthy home food supplies and the need to change environmental cues to keep them this way. CKR.2.6.d. Decide to implement the strategies to keep and manage healthy home food supplies.	PB.2.6.a. Get informed about possible perceived barriers keeping healthy home food supplies and identify personal and family's barriers. PB.2.6.b. Get informed about possible solutions to overcome perceived barriers keeping healthy home food supplies and implement the most suitable solutions. PB.2.6.c. Expect and resist social pressure by family members when keeping healthy home food supplies and schedule a week day and time with family to go grocery shopping with a healthy shopping list.	SSE.2.6.a. Feel confident about keeping healthy home food supplies in daily family life. SSE.2.6.b. Express confidence in ability to keep healthy home food supplies in daily family life, or to learn to do so. SSE.2.6.c. Feel capable of noticing automaticity in managing home food supplies and of altering cues for keeping healthy home food supplies.	OEA.2.6.a. Expect that keeping healthy home food supplies will enhance own and family's nutrition patterns and health. OEA.2.6.b Notice the advantages of keeping healthy home food supplies in daily family life. OEA.2.6.c. Feel positive about keeping healthy home food supplies in daily family life.	SN.2.6.a. Notice that individuals and families with healthy nutrition patterns maintain healthy home food supplies. SN.2.6.b. Notice that keeping healthy home food supplies may initially interfere with family's preferences or identity, yet ultimately lead to new nutritional norms within the family. SN.2.6.c. Notice own social resources and find role models or supporters in own or extended social network who maintain healthy home food supplies in own family.	SIH.2.6.a. Consistently maintain healthy home food supplies until habitual in daily family life. SIH.2.6.b. Identify as a health-conscious person who maintains healthy home food supplies. SIH.2.6.c. Identify as a healthy homemaker and role model who guides own children and partner to keep healthy home food supplies.	ER.2.6.a. Expect initial discomfort when not used to keeping healthy home food supplies. ER.2.6.b. Notice that keeping healthy home food supplies is enjoyable and does not translate to constraints. ER.2.6.c. Feel great about maintaining healthy home food supplies in daily family life.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.7.

PO.2.7. Establish a weekly family meal planning based on the healthy family recipe book. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.7.a. Get informed about the benefits of weekly family meal planning and learn strategies to do so. CKR.2.7.b. Acknowledge the habitual character of family meals and the need to change environmental cues to plan healthy family meals. CKR.2.7.c. Decide to implement the strategies to establish a weekly family meal planning.	PB.2.7.a. Get informed about possible perceived barriers establishing a weekly family meal planning and identify personal and family's barriers. PB.2.7.b. Get informed about possible solutions to overcome perceived barriers establishing a weekly family meal planning and implement the most suitable solutions. PB.2.7.c. Schedule a specific day and time with family to plan weekly family meals. State mutual goals, such as one favorite meal selected by each family member per week.	SSE.2.7.a. Feel confident about establishing weekly family meal planning. SSE.2.7.b. Express confidence in ability to establish a weekly family meal planning routine, or to learn to do so. SSE.2.7.c. Feel capable of noticing automaticity in family meals and of altering cues that trigger a weekly family meal planning based on the healthy family recipe book.	OEA.2.7.a. Expect that establishing a weekly family meal planning will lead to the best possible support by family members to jointly change nutrition patterns. OEA.2.7.b. Notice the advantages of a weekly family meal planning. OEA.2.7.c. Feel positive about establishing a weekly family meal planning.	SN.2.7.a. Notice that most families with healthy nutrition patterns roughly plan their weekly meals together. SN.2.7.b. Notice that establishing a weekly family meal planning may initially interfere with family's preferences or identity, yet ultimately lead to new norms within the family. SN.2.7.c. Notice own social resources and find role models or supporters in own or extended social network who maintain weekly family meal planning.	SIH.2.7.a. Consistently maintain weekly family meal planning until habitual. SIH.2.7.b. Identify as a health-conscious person who maintains weekly family meal planning and places the weekly meal plan in the kitchen. SIH.2.7.c. Identify as a healthy homemaker and role model who guides own children and partner in meal planning.	ER.2.7.a. Expect initial discomfort when not used to a weekly family meal planning routine. ER.2.7.b. Notice that weekly family meal planning is fun. ER.2.7.c. Feel great about having planned family meals for one week.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.8.

PO.2.8. Write a grocery list for the weekly meal plan and add healthy snacks. Split the grocery list into a smaller mid-weekly list for fresh products. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.8.a. Get informed about the benefits of writing a healthy grocery list and learn strategies to do so. CKR.2.8.b. Acknowledge the habitual character of grocery lists and the need to change environmental cues to write a healthy grocery list. CKR.2.8.c. Decide to implement the strategies to write a healthy grocery list**.**	PB.2.8.a. Get informed about possible perceived barriers writing a healthy grocery list and identify personal and family's barriers. PB.2.8.b. Get informed about possible solutions to overcome perceived barriers writing a healthy grocery list and implement the most suitable solutions.	SSE.2.8.a. Feel confident about writing a healthy grocery list. SSE.2.8.b. Express confidence in ability to write a healthy grocery list, or to learn to do so. SSE.2.8.c. Feel capable of noticing automaticity in grocery lists and of altering cues for writing a healthy grocery list.	OEA.2.8.a. Expect that writing a healthy grocery list will lead to support by family members to jointly change nutrition patterns to enhance health. OEA.2.8.b. Notice the advantages of writing a healthy grocery list. OEA.2.8.c. Feel positive about writing a healthy grocery list.	SN.2.8.a. Notice that most families with healthy nutrition patterns write healthy grocery lists. SN.2.8.b. Notice that writing a healthy grocery list may initially interfere with family's preferences or identity, yet ultimately lead to new norms within the family. SN.2.8.c. Notice own social resources and find role models or supporters in own or extended social network who usually write a healthy grocery list.	SIH.2.8.a. Consistently maintain writing a healthy grocery list until habitual. SIH.2.8.b. Identify as a health-conscious person who writes a healthy grocery list. SIH.2.8.c. Identify as a role model who guides own children and partner in writing healthy grocery lists.	ER.2.8.a. Expect initial discomfort when not used to writing a healthy grocery list. ER.2.8.b. Notice that writing a healthy grocery list is enjoyable. ER.2.8.c. Feel great about having written a healthy grocery list.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.9.

PO.2.9. Establish healthy grocery shopping strictly according to the grocery list. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.9.a. Get informed about the benefits of healthy grocery shopping strictly according to the grocery list and learn strategies to do so. CKR.2.9.b. Acknowledge the habitual character of grocery shopping and the need to change environmental cues to shop strictly according to the grocery list. CKR.2.9.c. Decide to commit to the strategies for healthy grocery shopping.	PB.2.9.a. Get informed about possible perceived barriers establishing healthy grocery shopping and identify personal and family's barriers. PB.2.9.b. Get informed about possible solutions to overcome perceived barriers establishing healthy shopping routine strictly according to the grocery list and implement the most suitable solutions. PB.2.9.c. Expect and resist hindering social pressure by family members when establishing healthy grocery shopping strictly according to the grocery list.	SSE.2.9.a. Feel confident about establishing healthy grocery shopping strictly according to the grocery list. SSE.2.9.b. Express confidence in ability to establish healthy grocery shopping strictly according to the grocery list, or to learn to do so. SSE.2.9.c. Feel capable of noticing automaticity in grocery shopping behavior and of altering cues for healthy grocery shopping strictly according to the grocery list.	OEA.2.9.a. Expect that establishing healthy grocery shopping strictly according to the grocery list will lead to healthier nutrition patterns and enhance health. OEA.2.9.b. Notice the advantages of establishing healthy grocery shopping strictly according to the grocery list. OEA.2.9.c. Feel positive about establishing healthy grocery shopping strictly according to the grocery list.	SN.2.9.a. Notice that most families with healthy nutrition patterns go grocery shopping with a healthy grocery list. SN.2.9.b. Notice that establishing healthy grocery shopping strictly according to the grocery list may initially interfere with family's preferences or identity, yet ultimately lead to new grocery shopping norms in the family. SN.2.9.c. Notice own social resources and find role models or supporters in own or extended social network who maintain a healthy grocery shopping routine.	SIH.2.9.a. Consistently maintain healthy grocery shopping strictly according to the grocery list until habitual. SIH.2.9.b. Identify as a health-conscious person who does not deviate from the grocery list despite temptations while grocery shopping. SIH.2.9.c. Identify as healthy homemaker and role model who guides own children and partner in healthy grocery shopping despite temptations.	ER.2.9.a. Expect initial discomfort when not used to healthy grocery shopping strictly according to a grocery list. ER.2.9.b. Notice that healthy grocery shopping strictly according to the grocery list is enjoyable. ER.2.9.c. Feel great about having adhered to the healthy grocery list during grocery shopping.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.10.

PO.2.10. Maintain a healthy cooking routine according to the weekly meal plan. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.10.a. Get informed about the benefits of a healthy cooking routine and learn to do so. CKR.2.10.b. Acknowledge the habitual character of cooking and the need to change environmental cues to keep a healthy cooking routine. CKR.2.10.c. Decide to commit to the strategies for a healthy cooking routine.	PB.2.10.a. Get informed about possible perceived barriers maintaining a healthy cooking routine and identify personal and family's barriers. PB.2.10.b. Get informed about possible solutions to overcome perceived barriers to a healthy cooking routine and implement the most suitable solutions. PB.2.10.c. Schedule specific days and times with family to work on common barriers to a healthy cooking routine. PB.2.10.d. Routinely take notes when and why planned meals changed.	SSE.2.10.a. Feel confident about maintaining a healthy cooking routine in daily family life. SSE.2.10.b. Express confidence in ability to maintain a healthy cooking routine in daily family life, or to learn to do so. SSE.2.10.c. Feel capable of noticing automaticity in own cooking behavior and of altering cues for healthy cooking.	OEA.2.10.a. Expect that maintaining a healthy cooking routine in daily family life will improve own and family's nutrition and health. OEA.2.10.b. Notice the advantages of maintaining a healthy cooking routine in daily family life. OEA.2.10.c. Feel positive about maintaining a healthy cooking routine in daily family life.	SN.2.10.a. Notice that most families with healthy nutrition patterns maintain a healthy cooking routine in daily family life. SN.2.10.b. Notice that establishing a healthy cooking routine in daily family life may initially interfere with family's preferences or identity, yet ultimately lead to new nutritional norms within the family. SN.2.10.c. Notice own social resources and find role models or supporters in own or extended social network who maintain a healthy cooking routine.	SIH.2.10.a. Consistently maintain a healthy cooking routine in daily family life until habitual. SIH.2.10.b. Identify as a health-conscious person who maintains a healthy cooking routine. SIH.2.10.c. Identify as a healthy homemaker and role model who guides own children and partner in maintaining a healthy cooking routine.	ER.2.10.a. Expect initial discomfort when not used to a healthy cooking routine in daily family life. ER.2.10.b. Notice that healthy cooking according to the weekly meal plan is enjoyable. ER.2.10.c. Feel great about having cooked a healthy meal according to the meal plan.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.11.

PO.2.11. Depending on the starting point, gradually increase eating main meals by the healthy meal model, with a quarter whole grain, a quarter preferably plant-based lean protein, and half fresh fruit or vegetable. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.11.a. Get informed about the benefits of eating according to the healthy meal model and learn strategies to do so. CKR.2.11.b. Acknowledge the habitual character of eating the main meals of a day and the need to change environmental cues to eat according to the healthy meal model. CKR.2.11.c. Decide to commit to the strategies for eating according to the healthy meal model.	PB.2.11.a. Get informed about possible perceived barriers to eat the main meals according to the healthy meal model and identify personal barriers. PB.2.11.b. Get informed about possible solutions to overcome perceived barriers to eat according to the healthy meal model and implement the most suitable solutions. PB.2.11.c. Expect and resist hindering social pressure by family members or the wider social network when eating according to the healthy meal model.	SSE.2.11.a. Feel confident about eating main meals according to the healthy meal model. SSE.2.11.b. Express confidence in ability to eat main meals according to the healthy meal model, or to learn to do so. SSE.2.11.c. Feel capable of noticing automaticity in own meal composition and of altering cues for eating main meals according to the healthy meal model.	OEA.2.11.a. Expect that eating main meals according to the healthy meal model will lead to numerous health benefits and decrease own cardiometabolic risk. OEA.2.11.b. Notice the advantages of eating according to the healthy meal model. OEA.2.11.c. Feel positive about eating according to the healthy meal model.	SN.2.11.a. Notice that most individuals with healthy nutrition patterns routinely eat balanced meals. SN.2.11.b. Notice that eating according to the healthy meal model does not need approval by others. SN.2.11.c. Notice own social resources and find role models or supporters in own or extended social network who eat similar to the healthy meal model.	SIH.2.11.a. Consistently maintain eating according to the healthy meal model until habitual. SIH.2.11.b. Identify as a health-conscious person who eats balanced meals. SIH.2.11.c. Identify as a role model who guides own children and partner in eating balanced meals.	ER.2.11.a. Expect initial discomfort when not used to eat according to the healthy meal model. ER.2.11.b. Notice that eating according to the healthy meal model is enjoyable. ER.2.11.c. Feel great about having eaten a main meal according to the healthy meal model.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.12.

PO.2.12. Eat at least two fist size portions of whole grain products a day. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.12.a. Acknowledge insufficient whole grain intake as personal risk factor for cardiometabolic disease. CKR.2.12.b. Get informed about the benefits of eating sufficient whole grains and learn to do so. CKR.2.12.c. Acknowledge the habitual character and the need to change environmental cues to eat at least two fist size portions of whole grain products a day. CKR.2.12.d. Decide to commit to the strategies for eating at least two fist size portions of whole grain products a day.	PB.2.12.a. Get informed about possible perceived barriers eating at least two fist size portions of whole grain products a day and identify personal barriers. PB.2.12.b. Get informed about possible solutions to overcome perceived barriers eating at least two fist size portions of whole grain products a day and implement the most suitable solutions. PB.2.12.c. Expect and resist hindering social pressure when eating at least two fist size portions of whole grain products a day.	SSE.2.12.a. Feel confident about eating at least two fist size portions of whole grain products a day. SSE.2.12.b. Express confidence in ability to eat at least two fist size portions of whole grain products a day, or to learn to do so. SSE.2.12.c. Feel capable of noticing automaticity in eating behavior and of altering cues for eating at least two fist size portions of whole grain products a day.	OEA.2.12.a. Expect that eating at least two fist size portions of whole grain products a day will lead to numerous health benefits and decrease own cardiometabolic risk. OEA.2.12.b. Notice the advantages of eating at least two fist size portions of whole grain products a day. OEA.2.12.c. Feel positive about eating at least two fist size portions of whole grain products a day.	SN.2.12.a. Notice that most individuals with healthy nutrition patterns routinely eat at least two fist size portions of whole grain products a day. SN.2.12.b. Notice that eating at least two fist size portions of whole grain products a day does not need approval by others. SN.2.12.c. Notice own social resources and find role models or supporters in social network who eat at least two fist size portions of whole grain products a day.	SIH.2.12.a. Consistently maintain eating at least two fist size portions of whole grain products a day until habitual. SIH.2.12.b. Identify as a health-conscious person who consistently eats at least two fist size portions of whole grain products a day. SIH.2.12.c. Identify as a role model who guides own children and partner in consistently eating at least two fist size portions of whole grain products a day.	ER.2.12.a. Expect initial discomfort when not used to eating at least two fist size portions of whole grain products a day. ER.2.12.b. Notice that eating at least two fist size portions of whole grain products a day is enjoyable. ER.2.12.c. Feel great about having eaten at least two fist size portions of whole grain products on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.13.

PO.2.13. Eat at least one fist size portion of legumes a day. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.13.a. Get informed about the benefits of eating at least one fist size portion of legumes a day and learn strategies to do so in daily life. CKR.2.13.b. Acknowledge the habitual character of eating at least one fist size portion of legumes and the need to change environmental cues. CKR.2.13.c. Decide to commit to the strategies for eating at least one fist size portion of legumes a day.	PB.2.13.a. Get informed about possible perceived barriers eating at least one fist size portion of legumes a day and identify personal barriers. PB.2.13.b. Get informed about possible solutions to overcome perceived barriers eating at least one fist size portion of legumes a day and implement the most suitable solutions. PB.2.13.c. Expect and resist hindering social pressure by family members or the wider social network when eating at least one fist size portion of legumes a day.	SSE.2.13.a. Feel confident about eating at least one fist size portion of legumes a day. SSE.2.13.b. Express confidence in ability to eat at least one fist size portion of legumes a day, or to learn to do so. SSE.2.13.c. Feel capable of noticing automaticity in eating behavior and of altering cues that trigger eating at least one fist size portion of legumes a day.	OEA.2.13.a. Expect that eating at least one fist size portion of legumes a day will lead to numerous health benefits and decrease own cardiometabolic risk. OEA.2.13.b. Notice the advantages of eating at least one fist size portion of legumes a day. OEA.2.13.c. Feel positive about eating at least one fist size portion of legumes a day.	SN.2.13.a. Notice that most individuals with healthy nutrition patterns routinely eat at least one fist size portion of legumes a day. SN.2.13.b. Notice that eating at least one fist size portion of legumes a day does not need approval by others. SN.2.13.c. Notice own social resources and find role models or supporters in own or extended social network who eat at least one fist size portion of legumes a day.	SIH.2.13.a. Consistently maintain eating at least one fist size portion of legumes a day until habitual. SIH.2.13.b. Identify as a health-conscious person who consistently eats at least one fist size portion of legumes a day. SIH.2.13.c. Identify as a role model who guides own children and partner in eating at least one fist size portion of legumes a day.	ER.2.13.a. Expect initial discomfort when not used to eating at least one fist size portion of legumes a day. ER.2.13.b. Notice that eating at least one fist size portion of legumes a day is enjoyable. ER.2.13.c. Feel great about having eaten at least one fist size portion of legumes on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.14.

PO.2.14. Eat two hand size portions of fresh fruit a day. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.14.a. Acknowledge insufficient fresh fruit intake as personal risk factor for cardiometabolic disease. CKR.2.14.b. Get informed about the benefits of eating sufficient fresh fruit and learn strategies to do so in daily life. CKR.2.14.c. Acknowledge the habitual character eating two hand size portions of fresh fruit a day and the need to change environmental cues. CKR.2.14.d. Decide to commit to eating two hand size portions of fresh fruit a day.	PB.2.14.a. Get informed about possible perceived barriers eating two hand size portions of fresh fruit a day and identify personal barriers. PB.2.14.b. Get informed about possible solutions to overcome perceived barriers eating two hand size portions of fresh fruit a day and implement the most suitable solutions. PB.2.14.c. Expect and resist hindering social pressure by family members or the wider social network when eating two hand size portions of fresh fruit a day.	SSE.2.14.a. Feel confident about eating two hand size portions of fresh fruit a day. SSE.2.14.b. Express confidence in ability to eat two hand size portions of fresh fruit a day, or to learn to do so. SSE.2.14.c. Feel capable of noticing automaticity in eating behavior and of altering cues that trigger eating two hand size portions of fresh fruit a day.	OEA.2.14.a. Expect that eating two hand size portions of fresh fruit a day will lead to numerous health benefits and decrease own cardiometabolic risk. OEA.2.14.b. Notice the advantages of eating two hand size portions of fresh fruit a day. OEA.2.14.c. Feel positive about eating two hand size portions of fresh fruit a day.	SN.2.14.a. Notice that most individuals with healthy nutrition patterns routinely eat two hand size portions of fresh fruit a day. SN.2.14.b. Notice that eating two hand size portions of fresh fruit a day does not need approval by others. SN.2.14.c. Notice own social resources and find role models or supporters in own or extended social network who eat two hand size portions of fresh fruit a day.	SIH.2.14.a. Consistently maintain eating two hand size portions of fresh fruit a day until habitual. SIH.2.14.b. Identify as a health-conscious person who consistently eats two hand size portions of fresh fruit a day. SIH.2.14.c. Identify as a role model who guides own children and partner in consistently eating two hand size portions of fresh fruit a day.	ER.2.14.a. Expect initial discomfort when not used to eating two hand size portions of fresh fruit a day. ER.2.14.b. Notice that eating two hand size portions of fresh fruit a day is enjoyable. ER.2.14.c. Feel great about having eaten two hand size portions of fresh fruit on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 2.15.

PO.2.15. Eat at least three hand size portions of fresh vegetable a day. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.2.15.a. Acknowledge insufficient fresh vegetable intake as cardiometabolic risk factor. CKR.2.15.b. Get informed about the benefits of eating sufficient fresh vegetable and learn strategies to do so. CKR.2.15.c. Acknowledge the habitual character of eating at least three hand size portions of fresh vegetable a day and the need to change environmental cues. CKR.2.15.d. Decide to commit to eating at least three hand size portions of fresh vegetable a day.	PB.2.15.a. Get informed about possible perceived barriers eating at least three hand size portions of fresh vegetable a day and identify personal barriers. PB.2.15.b. Get informed about possible solutions to overcome perceived barriers eating at least three hand size portions of fresh vegetable a day and implement the most suitable solutions. PB.2.15.c. Expect and resist hindering social pressure when eating at least three hand size portions of fresh vegetable a day.	SSE.2.15.a. Feel confident about eating at least three hand size portions of fresh vegetable a day. SSE.2.15.b. Express confidence in ability to eat at least three hand size portions of fresh vegetable a day, or to learn to do so. SSE.2.15.c. Feel capable of noticing automaticity in eating behavior and of altering cues that trigger eating at least three hand size portions of fresh vegetable a day.	OEA.2.15.a. Expect that eating at least three hand size portions of fresh vegetable a day will lead to numerous health benefits and decrease own cardiometabolic risk. OEA.2.15.b. Notice the advantages of eating at least three hand size portions of fresh vegetable a day. OEA.2.15.c. Feel positive about eating at least three hand size portions of fresh vegetable a day.	SN.2.15.a. Notice that most individuals with healthy nutrition patterns routinely eat at least three hand size portions of fresh vegetable a day. SN.2.15.b. Notice that eating at least three hand size portions of fresh vegetable a day does not need approval by others. SN.2.15.c. Notice own social resources and find role models or supporters social network who eat at least three hand size portions of fresh vegetable a day.	SIH.2.15.a. Consistently maintain eating at least three hand size portions of fresh vegetable a day until habitual. SIH.2.15.b. Identify as a health-conscious person who consistently eats at least three hand size portions of fresh vegetable a day. SIH.2.15.c. Identify as a role model who guides own children and partner in consistently eating at least three hand size portions of fresh vegetable a day.	ER.2.15.a. Expect initial discomfort when not used to eating at least three hand size portions of fresh vegetable a day. ER.2.15.b. Notice that eating at least three hand size portions of fresh vegetable a day is enjoyable. ER.2.15.c. Feel great about eating at least three hand size portions of fresh vegetable on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 3.1.

PO.3.1. Communicate health goal to the family to gradually limit or replace high-fat food products for a total fat intake of less than 30% of total energy intake. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.3.1.a. Get informed about the benefits of communicating reduced fat intake goal to the family. CKR.3.1.b. Notice that communicating reduced fat intake goal to the family will enhance own adherence. CKR.3.1.c. Acknowledge the need to communicate and change environmental cues in family life to gradually limit or replace high-fat food products.	PB.3.1.a. Get informed about possible perceived barriers communicating reduced fat intake goal to the family. PB.3.1.b. Get informed about possible solutions to overcome perceived barriers communicating reduced fat intake goal to the family and implement the most suitable solutions.	SSE.3.1.a. Feel confident about communicating reduced fat intake goal to the family. SSE.3.1.b. Express confidence in ability to communicate reduced fat intake goal to the family, or to learn to do so.	OEA.3.1.a. Expect that communicating reduced fat intake goal to the family enhances the likelihood to gradually limit or replace high-fat food products and to enhance own and family's nutrition and health. OEA.3.1.b Notice the advantages of communicating reduced fat intake goal to the family. OEA.3.1.c. Feel positive about communicating reduced fat intake goal to the family.	SN.3.1.a. Notice that individuals with healthy nutrition patterns communicate their nutrition goals such as a reduced fat intake to their family. SN.3.1.b. Notice that communicating reduced fat intake goal to the family may initially interfere with family's preferences or identity, yet may change family's norms. SN.3.1.c. Notice own social resources and find role models or supporters in own or extended social network who usually communicate their nutrition goals to their family.	SIH.3.1.a. Identify as a health-conscious person who communicates own health goals such as a reduced fat intake to the family. SIH.3.1.b. Identify as a healthy homemaker and role model who guides own children and partner to communicate their health goals to the family.	ER.3.1.a. Expect initial discomfort when not used to communicating health goals to the family. ER.3.1.b. Feel great about having communicated reduced fat intake goal to the family.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 3.2.

PO.3.2. Get familiar with naturally low-fat food products and meals. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.3.2. Get informed about the benefits of eating naturally low-fat food products and meals and learn to use them as appropriate alternatives for certain high-fat food products or meals.	PB.3.2.a. Get informed about possible perceived barriers getting familiar with naturally low-fat food products and meals and identify personal barriers. PB.3.2.b. Get informed about possible solutions to overcome perceived barriers getting familiar with naturally low-fat food products and meals and implement the most suitable solutions. PB.3.2.c. Expect and resist hindering social pressure by family members or the wider social network when getting familiar with naturally low-fat food products and meals.	SSE.3.2.a. Feel confident about getting familiar with naturally low-fat food products and meals. SSE.3.2.b. Express confidence in ability to get familiar with naturally low-fat food products and meals, or to learn to do so.	OEA.3.2.a. Expect that getting familiar with naturally low-fat food products and meals will increase own skills for healthy meal preparation and contribute to healthier nutrition choices. OEA.3.2.b. Notice the advantages of getting familiar with naturally low-fat food products and meals. OEA.3.2.c. Feel positive about getting familiar with naturally low-fat food products and meals.	SN.3.2.a. Notice that health-conscious individuals are familiar with naturally low-fat food products and meals. SN.3.2.b. Notice that getting familiar with naturally low-fat food products and meals does not need approval by others. SN.3.2.c. Notice own social resources and find role models or supporters in own or extended social network who are familiar with naturally low-fat food products and meals.	SIH.3.2.a. Identify as a health-conscious person who gets familiar with new products or skills such as naturally low-fat food products, low-fat meal composition, and low-fat meal preparation to enhance health. SIH.3.2.b. Identify as a healthy homemaker and role model who guides own children and partner to get familiar with naturally low-fat food products, low-fat meal composition, and low-fat meal preparation.	ER.3.2.a. Expect initial discomfort when starting to get familiar with naturally low-fat food products and meals. ER.3.2.b. Notice that getting familiar with naturally low-fat food products and meals is fun. ER.3.2.c. Feel great about being familiar with naturally low-fat food products and meals.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 3.3.

PO.3.3. Gradually limit or replace high-fat food products to reduce daily fat intake to less than 30% of total energy intake – especially those derived from animal sources and ultra-processed food products. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.3.3.a. Acknowledge a high daily fat intake as personal risk factor for cardiometabolic disease. CKR.3.3.b. Get informed about the benefits of limiting or replacing high-fat food products; learn strategies to do so. CKR.3.3.c. Acknowledge the habitual character of limiting or replacing high-fat food products and the need to change environmental cues in daily life. CKR.3.3.d. Decide to commit to the strategies for limiting or replacing high-fat food products.	PB.3.3.a. Get informed about possible perceived barriers limiting or replacing high-fat food products and identify personal barriers. PB.3.3.b. Get informed about possible solutions to overcome perceived barriers limiting or replacing high-fat food products and implement the most suitable solutions. PB.3.3.c. Expect and resist hindering social pressure by family members or the wider social network when starting to limit or replace high-fat food products.	SSE.3.3.a. Feel confident about limiting or replacing high-fat food products. SSE.3.3.b. Express confidence in ability to limit or replace high-fat food products, or to learn to do so. SSE.3.3.c. Feel capable of noticing automaticity in daily fat intake and of altering cues that trigger limiting or replacing high-fat food products.	OEA.3.3.a. Expect that limiting or replacing high-fat food products will lead to numerous health benefits and reduce personal cardiometabolic risk. OEA.3.3.b. Express positive feelings towards the benefits of limiting or replacing high-fat food products. OEA.3.3.c. Notice the advantages of limiting or replacing high-fat food products.	SN.3.3.a. Notice that individuals with healthy nutrition patterns habitually limit or replace high-fat food products. SN.3.3.b. Notice that limiting or replacing high-fat food products does not need approval by others. SN.3.3.c. Notice own social resources and find role models or supporters in own or extended social network who limit or replace high-fat food products on a daily basis.	SIH.3.3.a. Consistently maintain limiting or replacing high-fat food products until habitual. SIH.3.3.b. Identify as a health-conscious person who limits or replaces high-fat food products on a daily basis. SIH.3.3.c. Identify as a healthy homemaker and role model who guides own children and partner to limit or replace high-fat food products.	ER.3.3.a. Expect initial discomfort when not used to limiting or replacing high-fat food products. ER.3.3.b. Notice that limiting or replacing high-fat food products is enjoyable. ER.3.3.c. Feel great about having limited or replaced high-fat food products on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 3.4.

PO.3.4. Establish a low-fat nutrient-protective meal preparation. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.3.4.a. Acknowledge high-fat meal preparation as personal risk factor for cardiometabolic disease. CKR.3.4.b. Get informed about the benefits of a low-fat meal preparation and learn strategies to do so. CKR.3.4.c. Acknowledge the habitual character of meal preparation and the need to change environmental cues to establish a low-fat nutrient-protective meal preparation. CKR.3.4.d. Decide to commit to the strategies for a low-fat nutrient-protective meal preparation.	PB.3.4.a. Get informed about possible perceived barriers establishing a low-fat nutrient-protective meal preparation and identify personal and family's barriers. PB.3.4.b. Get informed about possible solutions to overcome perceived barriers establishing a low-fat nutrient-protective meal preparation and implement the most suitable solutions in daily family life. PB.3.4.c. Schedule specific days and times with family to work on common barriers establishing a low-fat nutrient-protective meal preparation.	SSE.3.4.a. Feel confident about establishing a low-fat nutrient-protective meal preparation in daily family life. SSE.3.4.b. Express confidence in ability to establish a low-fat nutrient-protective meal preparation in daily family life, or to learn to do so. SSE.3.4.c. Feel capable of noticing automaticity in choice of meal preparation and of altering cues for a low-fat nutrient-protective meal preparation.	OEA.3.4.a. Expect that establishing a low-fat nutrient-protective meal preparation in daily family life will lead to numerous health benefits and decrease own and family's cardiometabolic risk. OEA.3.4.b. Notice the advantages of establishing a low-fat nutrient-protective meal preparation in daily family life. OEA.3.4.c. Feel positive about establishing a low-fat nutrient-protective meal preparation in daily family life.	SN.3.4.a. Notice that most families with healthy nutrition patterns maintain a low-fat nutrient-protective meal preparation. SN.3.4.b. Notice that establishing a low-fat meal preparation may initially interfere with family's preferences or identity, yet ultimately lead to new nutritional norms within the family. SN.3.4.c. Notice own social resources and find role models or supporters in own or extended social network who maintain a low-fat nutrient-protective meal preparation.	SIH.3.4.a. Consistently maintain a low-fat nutrient-protective meal preparation in daily family life until habitual. SIH.3.4.b. Identify as a health-conscious person who maintains a low-fat nutrient-protective meal preparation. SIH.3.4.c. Identify as a role model who guides own children and partner in choosing low-fat nutrient-protective meal preparations.	ER.3.4.a. Expect initial discomfort when not used to low-fat nutrient-protective meal preparations. ER.3.4.b. Notice that choosing a low-fat nutrient-protective meal preparation is enjoyable. ER.3.4.c. Feel great about having chosen a low-fat nutrient-protective meal preparation on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 3.5.

PO.3.5. Generously use fresh herbs and spices. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.3.5.a. Get informed about the benefits of generously using fresh herbs and spices and learn strategies to do so in daily life. CKR.3.5.b. Acknowledge the habitual character of meal preparation and the need to change environmental cues to generously use fresh herbs and spices. CKR.3.5.c. Decide to commit to the strategies for a generous use of fresh herbs and spices.	PB.3.5.a. Get informed about possible perceived barriers using fresh herbs and spices and identify personal and family's barriers. PB.3.5.b. Get informed about possible solutions to overcome perceived barriers using fresh herbs and spices and implement the most suitable solutions in daily family life.	SSE.3.5.a. Feel confident about using fresh herbs and spices in daily family life. SSE.3.5.b. Express confidence in ability to use fresh herbs and spices in daily family life, or to learn to do so. SSE.3.5.c. Feel capable of noticing automaticity in meal preparation and of altering cues for a generous use of fresh herbs and spices.	OEA.3.5.a. Expect that using fresh herbs and spices in daily family life will lead to numerous health benefits. OEA.3.5.b. Notice the advantages of using fresh herbs and spices. OEA.3.5.c. Feel positive about using fresh herbs and spices.	SN.3.5.a. Notice that most families with healthy nutrition patterns use fresh herbs and spices. SN.3.5.b. Notice that using fresh herbs and spices may initially interfere with family's preferences or identity, yet ultimately lead to new nutritional norms within the family. SN.3.5.c. Notice own social resources and find role models or supporters in own or extended social network who use fresh herbs and spices on a daily basis.	SIH.3.5.a. Consistently maintain to use fresh herbs and spices in daily family life until habitual. SIH.3.5.b. Identify as a health-conscious person who uses fresh herbs and spices. SIH.3.5.c. Identify as a role model who guides own children and partner in using fresh herbs and spices.	ER.3.5.a. Expect initial discomfort when not used to generously add fresh herbs and spices to meals. ER.3.5.b. Notice that using fresh herbs and spices is enjoyable. ER.3.5.c. Feel great about having used fresh herbs and spices on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 4.1.

PO.4.1. Communicate health goal to the family to gradually limit or replace food products high in saturated fat to lower saturated fat intake to less than 10% of total energy intake. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.4.1.a. Get informed about the benefits of communicating reduced saturated fat goal to the family. CKR.4.1.b. Notice that communicating reduced saturated fat goal to the family will enhance own adherence. CKR.4.1.c. Acknowledge the need to communicate and change environmental cues in family life to gradually limit or replace food products high in saturated fat.	PB.4.1.a. Get informed about possible perceived barriers communicating reduced saturated fat goal to the family. PB.4.1.b. Get informed about possible solutions to overcome perceived barriers communicating reduced saturated fat goal to the family and implement the most suitable solutions.	SSE.4.1.a. Feel confident about communicating reduced saturated fat goal to the family. SSE.4.1.b. Express confidence in ability to communicate reduced saturated fat goal to the family, or to learn to do so.	OEA.4.1.a. Expect that communicating reduced saturated fat goal to the family enhances the likelihood to gradually limit or replace food products high in saturated fat to enhance own and family's health. OEA.4.1.b Notice the advantages of communicating reduced saturated fat goal to the family. OEA.4.1.c. Feel positive about communicating reduced saturated fat goal to the family.	SN.4.1.a. Notice that individuals with healthy nutrition patterns communicate their nutrition goals such as reduced saturated fat intake to their family. SN.4.1.b. Notice that communicating reduced saturated fat goal to the family may initially interfere with family's preferences or identity, yet may change family's norms long-term. SN.4.1.c. Notice own social resources and find role models or supporters in social network who usually communicate their nutrition goals to their family.	SIH.4.1.a. Identify as a health-conscious person who communicates own nutrition goals such as reduced saturated fat intake to the family. SIH.4.1.b. Identify as a healthy homemaker and role model who guides own children and partner to communicate their health goals to the family.	ER.4.1.a. Expect initial discomfort when not used to communicating nutrition goals to the family. ER.4.1.b. Feel great about having communicated reduced saturated fat goal to the family.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 4.2.

PO.4.2. Get familiar with food products and meals naturally low in saturated fat and trans fat. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.4.2.a. Get informed about the benefits of eating food products and meals naturally low in saturated fat and trans fat and learn to use them as alternatives for food products high in saturated fat. CKR.4.2.b. Decide to get familiar with food products and meals naturally low in saturated fat and trans fat.	PB.4.2.a. Get informed about possible barriers getting familiar with food products and meals naturally low in saturated fat and trans fat and identify personal barriers. PB.4.2.b. Get informed about possible solutions to overcome perceived barriers getting familiar with food naturally low in saturated fat and trans fat and implement the most suitable solutions. PB.4.2.c. Expect unfavorable reactions by family members when getting familiar with food products and meals low in saturated fat and trans fat.	SSE.4.2.a. Feel confident about getting familiar with food products and meals naturally low in saturated fat and trans fat. SSE.4.2.b. Express confidence in ability to get familiar with food products and meals naturally low in saturated fat and trans fat, or to learn to do so.	OEA.4.2.a. Expect that getting familiar with food products and meals naturally low in saturated fat and trans fat will increase own skills for a healthy meal preparation and contribute to healthier nutrition choices. OEA.4.2.b. Notice the advantages of getting familiar with food products and meals naturally low in saturated fat and trans fat. OEA.4.2.c. Feel positive about getting familiar with food products and meals naturally low in saturated fat and trans fat.	SN.4.2.a. Notice that health-conscious individuals are familiar with food products and meals naturally low in saturated fat and trans fat. SN.4.2.b. Notice that getting familiar with food products and meals naturally low in saturated fat and trans fat does not need approval by others. SN.4.2.c. Notice role models in social network who are familiar with food naturally low in saturated fat and trans fat.	SIH.4.2.a. Identify as a health-conscious person who gets familiar with new products or skills such as food products and meal preparations naturally low in saturated fat and trans fat. SIH.4.2.b. Identify as a healthy homemaker and role model who guides own children and partner to get familiar with food products and meals naturally low in saturated fat and trans fat.	ER.4.2.a. Expect initial discomfort when starting to get familiar with food products and meals naturally low in saturated fat and trans fat. ER.4.2.b. Notice that getting familiar with food products and meals naturally low in saturated fat and trans fat is fun. ER.4.2.c. Feel great about being familiar with food products and meals naturally low in saturated fat and trans fat.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 4.3.

PO.4.3. Gradually limit or replace food products high in saturated fat to reduce daily saturated fat intake to less than 10% of total energy intake – especially those derived from animal sources and ultra-processed food products. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.4.3.a. Accept a daily saturated fat intake of higher than 10% of total energy intake as personal cardiometabolic risk factor. CKR.4.3.b. Get informed about the benefits of limiting food products high in saturated fat; learn strategies to do so. CKR.4.3.c. Acknowledge the habitual character of saturated fat intake and the need to change environmental cues to limit saturated fat intake. CKR.4.3.d. Decide to commit to limiting food products high in saturated fat.	PB.4.3.a. Get informed about possible perceived barriers limiting food products high in saturated fat and identify personal barriers. PB.4.3.b. Get informed about possible solutions to overcome perceived barriers limiting food products high in saturated fat and implement the most suitable solutions. PB.4.3.c. Expect and resist hindering social pressure by family members or the wider social network when starting to limit food products high in saturated fat.	SSE.4.3.a. Feel confident about limiting food products high in saturated fat. SSE.4.3.b. Express confidence in ability to limit food products high in saturated fat, or to learn to do so. SSE.4.3.c. Feel capable of noticing automaticity in saturated fat intake and of altering cues for limiting food products high in saturated fat.	OEA.4.3.a. Expect that limiting food products high in saturated fat will lead to numerous health benefits and reduce own cardiometabolic risk. OEA.4.3.b. Express positive feelings towards the benefits of limiting food products high in saturated fat. OEA.4.3.c. Notice the advantages of limiting food products high in saturated fat.	SN.4.3.a. Notice that individuals with healthy nutrition patterns habitually limit food products high in saturated fat. SN.4.3.b. Notice that limiting food products high in saturated fat does not need approval by others. SN.4.3.c. Notice own social resources and find role models or supporters in social network who limit or replace food products high in saturated fat on a daily basis.	SIH.4.3.a. Consistently maintain limiting or replacing food products high in saturated fat until habitual. SIH.4.3.b. Identify as a health-conscious person who limits or replaces food products high in saturated fat. SIH.4.3.c. Identify as a healthy homemaker and role model who guides own children and partner to limit food products high in saturated fat.	ER.4.3.a. Expect initial discomfort when not used to limiting food products high in saturated fat. ER.4.3.b. Notice that limiting food products high in saturated fat is enjoyable and does not translate to constraints. ER.4.3.c. Feel great about having limited food products high in saturated fat on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objective for performance objective 5.1.

PO.5.1. Keep a food journal to explore own nutrition patterns. Note down personal cues for food intake, eating times, specifics about the eating environment, the type of food, and portion size. Investigate possible associations. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.1.a. Get informed about the benefits of food journaling, how to journal and analyze own nutrition patterns. CKR.5.1.b. Decide to explore own nutrition patterns by food journaling. CKR.5.1.c. Acknowledge the need to change environmental cues to keep a food journal.	PB.5.1.a. Get informed about possible perceived barriers keeping a food journal to explore own nutrition patterns and identify personal barriers. PB.5.1.b. Get informed about possible solutions to overcome perceived barriers keeping a food journal to explore own nutrition patterns and implement the most suitable solutions. PB.5.1.c. Expect and resist hindering social pressure by family members or the wider social network when keeping a food journal.	SSE.5.1.a. Feel confident about keeping a food journal to explore own nutrition patterns. SSE.5.1.b. Express confidence in ability to keep a food journal to explore own nutrition patterns, or to learn to do so. SSE.5.1.c. Feel capable of noticing automaticity in own nutrition patterns and of altering cues for keeping a food journal.	OEA.5.1.a. Expect that keeping a food journal will raise own awareness for nutrition patterns and enable personalized nutrition coaching. OEA.5.1.b. Notice the advantages of keeping a food journal to explore own nutrition patterns. OEA.5.1.c. Feel positive about keeping a food journal to explore own nutrition patterns.	SN.5.1.a. Notice that most individuals with healthy nutrition patterns keep a food journal once in a while to explore their own nutrition patterns. SN.5.1.b. Notice that keeping a food journal to explore own nutrition patterns does not need approval by others.	SIH.5.1.a. Maintain to keep a food journal to explore own nutrition patterns, at least over the course of one week. SIH.5.1.b. Identify as a health-conscious person who keeps a food journal to explore own nutrition patterns.	ER.5.1.a. Expect initial discomfort when starting to keep a food journal to explore own nutrition patterns. ER.5.1.b. Notice that keeping a food journal to explore own nutrition patterns can be enjoyable. ER.5.1.c. Feel great about having kept a food journal on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.2.

PO.5.2. Investigate what to change in own eating situations to select healthier food, eat more mindfully and to fully enjoy the food. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.2.a. Acknowledge mindless eating as personal risk factor for cardiometabolic disease. CKR.5.2.b. Get informed about the benefits of investigating what to change in own eating situations to make them more enjoyable and healthier food choices more likely, and learn to do so. CKR.5.2.c. Decide to investigate what to change in own eating situations to make them more enjoyable and healthier food choices more likely.	PB.5.2.a. Get informed about possible perceived barriers investigating what to change in own eating situations and identify personal barriers. PB.5.2.b. Get informed about possible solutions to overcome perceived barriers investigating what to change in own eating situations and implement the most suitable solutions.	SSE.5.2.a. Feel confident about investigating what to change in own eating situations. SSE.5.2.b. Express confidence in ability to investigate what to change in own eating situations, or to learn to do so.	OEA.5.2.a. Expect that investigating what to change in own eating situations will raise own awareness and enable necessary environmental changes for a more enjoyable and healthier nutrition. OEA.5.2.b. Notice the advantages of investigating what to change in own eating situations. OEA.5.2.c. Feel positive about investigating what to change in own eating situations.	SN.5.2.a. Notice that most individuals with healthy nutrition patterns know what to change in own eating situations in order to select healthier food, eat more mindfully and to fully enjoy the food. SN.5.2.b. Notice that investigating what to change in own eating situations does not need approval by others.	SIH.5.2.a. Identify as a health-conscious person who wants to know what to change in own eating situations in order to select healthier food, eat more mindfully and to fully enjoy the food. SIH.5.2.b. Identify as a healthy homemaker and role model who guides own children and partner to be aware of own eating situations and to favorably change them.	ER.5.2.a. Expect initial discomfort when starting to investigate what to change in own eating situations. ER.5.2.b. Notice that investigating what to change in own eating situations is enjoyable. ER.5.2.c. Feel great about having investigated what to change in own eating situations in order to select healthier food, eat more mindfully and to fully enjoy the food.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.3.

PO.5.3. Create pleasant eating situations in daily life. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.3.a. Get informed about the benefits of creating pleasant eating situations in daily life, and learn strategies to do so. CKR.5.3.b. Acknowledge the habitual character of daily eating situations and the need to change environmental cues to create pleasant eating situations in daily life. CKR.5.3.c. Decide to commit to the strategies and consistently create pleasant eating situations in daily life.	PB.5.3.a. Get informed about possible perceived barriers creating pleasant eating situations in daily life and identify personal barriers. PB.5.3.b. Get informed about possible solutions to overcome perceived barriers creating pleasant eating situations in daily life and implement the most suitable solutions.	SSE.5.3.a. Feel confident about creating pleasant eating situations in daily life. SSE.5.3.b. Express confidence in ability to create pleasant eating situations in daily life, or to learn to do so. SSE.5.3.c. Feel capable of noticing automaticity in own choice of eating situations and of altering cues for creating pleasant eating situations in daily life.	OEA.5.3.a. Expect that creating pleasant eating situations in daily life will positively affect own nutrition patterns and ultimately contribute to numerous health benefits and a lower cardiometabolic risk. OEA.5.3.b. Notice the advantages of creating pleasant eating situations in daily life. OEA.5.3.c. Feel positive about creating pleasant eating situations in daily life.	SN.5.3.a. Notice that most individuals with healthy nutrition patterns are consistently creating pleasant eating situations in daily life. SN.5.3.b. Notice that creating pleasant eating situations in daily life does not need approval by others. SN.5.3.c. Notice own social resources and find role models or supporters in own or extended social network who create pleasant eating situations in daily life.	SIH.5.3.a. Consistently maintain to create pleasant eating situations in daily life until habitual. SIH.5.3.b. Identify as a health-conscious person who creates pleasant eating situations in daily life. SIH.5.3.c. Identify as a healthy homemaker and role model who guides own children and partner to create pleasant eating situations in daily life.	ER.5.3.a. Notice that creating pleasant eating situations in daily life is enjoyable. ER.5.3.b. Feel great about having created a pleasant eating situation on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.4.

PO.5.4. Write a personal list with distractions for food cravings with detailed descriptions how to react in particular circumstances. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.4.a. Acknowledge giving in to food cravings on a regular basis as personal risk factor for cardiometabolic disease. CKR.5.4.b. Get informed about the benefits of writing a personal list with distractions for food cravings, and learn to do so. CKR.5.4.c. Decide to commit to writing a personal list with distractions for food cravings.	PB.5.4.a. Get informed about possible perceived barriers writing a personal list with distractions for food cravings and identify personal barriers. PB.5.4.b. Get informed about possible solutions to overcome perceived barriers writing a personal list with distractions for food cravings and implement the most suitable solutions.	SSE.5.4.a. Feel confident about writing a personal list with distractions for food cravings. SSE.5.4.b. Express confidence in ability to write a personal list with distractions for food cravings, or to learn to do so.	OEA.5.4.a. Expect that writing a personal list with distractions for food cravings will help to counteract in critical situations and ultimately contribute to numerous health benefits and a lower cardiometabolic disease risk. OEA.5.4.b. Notice the advantages of writing a personal list with distractions for food cravings. OEA.5.4.c. Feel positive about writing a personal list with distractions for food cravings.	SN.5.4.a. Notice that most individuals with healthy nutrition patterns have strategies to distract themselves when food cravings occur. SN.5.4.b. Notice that writing a personal list with distractions for food cravings does not need approval by others.	SIH.5.4.a. Identify as a health-conscious person who maintains a personal list with distractions for food cravings until own strategies are habitual. SIH.5.4.b. Identify as a healthy homemaker and role model who guides own children and partner to discover own distractions for food cravings.	ER.5.4.a. Notice that writing a personal list with distractions for food cravings is enjoyable. ER.5.4.b. Feel great about having written a personal list with distractions for food cravings.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.5.

PO.5.5. Implement chosen distractions when a specific food craving emerges. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.5.a. Get informed about the benefits of implementing chosen distractions when a specific food craving emerges. CKR.5.5.b. Acknowledge the habitual character of food cravings and the need to change environmental cues to resist them and to implement chosen distractions. CKR.5.5.c. Decide to commit to the chosen distraction when a specific food craving emerges.	PB.5.5.a. Get informed about possible perceived barriers implementing chosen distraction when a specific food craving emerges and identify personal barriers. PB.5.5.b. Get informed about possible solutions to overcome perceived barriers implementing chosen distraction when a specific food craving emerges and implement the most suitable solutions.	SSE.5.5.a. Feel confident about implementing chosen distraction when a specific food craving emerges. SSE.5.5.b. Express confidence in ability to implement chosen distraction when a specific food craving emerges, or to learn to do so. SSE.5.5.c. Feel capable of noticing automaticity in food craving situations and of altering cues for chosen distraction when a specific food craving emerges.	OEA.5.5.a. Expect that implementing chosen distraction when a specific food craving emerges will limit unhealthy food intake and ultimately contribute to numerous health benefits and decrease own cardiometabolic risk. OEA.5.5.b. Notice the advantages of implementing chosen distraction when a specific food craving emerges. OEA.5.5.c. Feel positive about implementing chosen distraction when a specific food craving emerges.	SN.5.5.a. Notice that most individuals with healthy nutrition patterns implement chosen distractions for specific food cravings. SN.5.5.b. Notice that implementing chosen distraction when a specific food craving emerges does not need approval by others. SN.5.5.c. Notice own social resources and find role models or supporters in own or extended social network who distract themselves when food cravings emerge.	SIH.5.5.a. Maintain implementing chosen distraction when a specific food craving emerges until habitual. SIH.5.5.b. Identify as a health-conscious person who implements chosen distraction when a specific food craving emerges. SIH.5.5.c. Identify as a healthy homemaker and role model who guides own children and partner to implement distractions for food cravings.	ER.5.5.a. Expect initial discomfort when starting to implement chosen distraction when a specific food craving emerges. ER.5.5.b. Notice that implementing chosen distraction when a specific food craving emerges is enjoyable and does not translate to constraints. ER.5.5.c. Feel great about having implemented a chosen distraction for a specific food craving on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.6.

PO.5.6. Eat when hungry, not when thirsty, having an appetite or other needs, and learn to distinguish these sensations. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.6.a. Get informed about the benefits of eating when hungry, not for other needs, and how to do so in daily life. CKR.5.6.b. Acknowledge the habitual character of eating and the need to change environmental cues to support eating when hungry, not for other needs. CKR.5.6.c. Decide to commit to the strategies to consistently eat when hungry, not for other needs.	PB.5.6.a. Get informed about possible perceived barriers eating when hungry, not for other needs and identify personal barriers. PB.5.6.b. Get informed about possible solutions to overcome perceived barriers eating when hungry, not for other needs and implement the most suitable solutions.	SSE.5.6.a. Feel confident about eating when hungry, not for other needs and about learning to distinguish different needs. SSE.5.6.b. Express confidence in ability to eat when hungry, not for other needs and to learn to distinguish different needs. SSE.5.6.c. Feel capable of noticing automaticity in eating behavior and of altering cues for eating when hungry, not for other needs.	OEA.5.6.a. Expect that eating when hungry, not for other needs and learning to distinguish different needs will limit caloric intake and ultimately lead to numerous health benefits including a decreased cardiometabolic risk. OEA.5.6.b. Notice the advantages of eating when hungry, not for other needs. OEA.5.6.c. Feel positive about eating when hungry, not for other needs.	SN.5.6.a. Notice that most individuals with healthy nutrition patterns eat when hungry, not for other needs. SN.5.6.b. Notice that eating when hungry, not for other needs does not need approval by others. SN.5.6.c. Notice own social resources and find role models or supporters in own or extended social network who eat when hungry, not for other needs.	SIH.5.6.a. Maintain eating when hungry, not for other needs until habitual. SIH.5.6.b. Identify as a health-conscious person who eats when hungry, not for other needs. SIH.5.6.c. Identify as a healthy homemaker and role model who guides own children and partner to eat when hungry, not for other needs and to distinguish different needs.	ER.5.6.a. Expect initial discomfort when starting to eat only when hungry, not for other needs. ER.5.6.b. Notice that eating when hungry, not for other needs enhances joy when eating. ER.5.6.c. Feel great about having eaten when hungry, not for other needs.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.7.

PO.5.7. If BMI of 23 kg/m^2 or higher: Avoid added sugar and sweeteners for at least one week. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.7.a. Accept sugar and sweetener consumption as personal cardiometabolic risk factor. CKR.5.7.b. Get informed about the benefits of avoiding added sugar and sweeteners, and learn strategies to do so. CKR.5.7.c. Acknowledge the habitual character of consuming sugar and sweeteners and the need to change environmental cues to avoid them. CKR.5.7.d. Decide to commit to the strategies to consistently avoid added sugar and sweeteners.	PB.5.7.a. Get informed about possible perceived barriers avoiding added sugar and sweeteners and identify personal barriers. PB.5.7.b. Get informed about possible solutions to overcome perceived barriers avoiding added sugar and sweeteners and implement the most suitable solutions.	SSE.5.7.a. Feel confident about avoiding added sugar and sweeteners for at least one week. SSE.5.7.b. Express confidence in ability to avoid added sugar and sweeteners for at least one week, or to learn to do so. SSE.5.7.c. Feel capable of noticing automaticity in sugar and sweetener intake and of altering cues for avoiding added sugar and sweeteners.	OEA.5.7.a. Expect that avoiding added sugar and sweeteners for at least one week will lead to enhanced sweetness sensitization and ultimately decrease own cardiometabolic risk. OEA.5.7.b. Notice the advantages of avoiding added sugar and sweeteners for at least one week. OEA.5.7.c. Feel positive about avoiding added sugar and sweeteners for at least one week.	SN.5.7.a. Notice that most individuals with healthy nutrition patterns avoid added sugar and sweeteners. SN.5.7.b. Notice that avoiding added sugar and sweeteners for at least one week does not need approval by others. SN.5.7.c. Notice own social resources and find role models or supporters in own or extended social network who consistently avoid added sugar and sweeteners.	SIH.5.7.a. Maintain avoiding added sugar and sweeteners until habitual. SIH.5.7.b. Identify as a health-conscious person who avoids added sugar and sweeteners. SIH.5.7.c. Identify as a healthy homemaker and role model who guides own children and partner to avoid added sugar and sweeteners.	ER.5.7.a. Expect initial discomfort when starting to consistently avoid added sugar and sweeteners. ER.5.7.b. Notice that avoiding added sugar and sweeteners can be enjoyable. ER.5.7.c. Feel great about having avoided added sugar and sweeteners on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.8.

PO.5.8. If BMI of less than 23 kg/m²: Limit added sugar intake to less than 25 g per day. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.8.a. Accept sugar consumption as personal cardiometabolic risk factor. CKR.5.8.b. Get informed about the benefits of limiting added sugar intake, and learn strategies to do so. CKR.5.8.c. Acknowledge the habitual character of consuming sugar and the need to change environmental cues to limit added sugar intake to less than 25 g per day. CKR.5.8.d. Decide to commit to the strategies to limit added sugar intake to less than 25 g per day.	PB.5.8.a. Get informed about possible perceived barriers limiting added sugar intake to less than 25 g per day and identify personal barriers. PB.5.8.b. Get informed about possible solutions to overcome perceived barriers limiting added sugar intake to less than 25 g per day and implement the most suitable solutions.	SSE.5.8.a. Feel confident about limiting added sugar intake to less than 25 g per day. SSE.5.8.b. Express confidence in ability to limit added sugar intake to less than 25 g per day, or to learn to do so. SSE.5.8.c. Feel capable of noticing automaticity in sugar intake and of altering cues for limiting added sugar intake to less than 25 g per day.	OEA.5.8.a. Expect that limiting added sugar intake to less than 25 g per day will decrease own cardiometabolic risk. OEA.5.8.b. Notice the advantages of limiting added sugar intake to less than 25 g per day. OEA.5.8.c. Feel positive about limiting added sugar intake to less than 25 g per day.	SN.5.8.a. Notice that most individuals with healthy nutrition patterns limit added sugar intake to less than 25 g per day. SN.5.8.b. Notice that limiting added sugar intake to less than 25 g per day does not need approval by others. SN.5.8.c. Notice own social resources and find role models or supporters in own or extended social network who consistently limit added sugar intake to less than 25 g per day.	SIH.5.8.a. Maintain limiting added sugar intake to less than 25 g per day until habitual. SIH.5.8.b. Identify as a health-conscious person who limits added sugar intake to less than 25 g per day. SIH.5.8.c. Identify as a healthy homemaker and role model who guides own children and partner to limit added sugar intake to less than 25 g per day.	ER.5.8.a. Expect initial discomfort when starting to limit added sugar intake to less than 25 g per day. ER.5.8.b. Notice that limiting added sugar intake to less than 25 g per day is enjoyable and does not translate to constraints. ER.5.8.c. Feel great about having limited added sugar intake to less than 25 g on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.9.

PO.5.9. If habitual unhealthy snacking: Get familiar with healthy snacks based on fresh fruit and vegetable. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.9.a. Acknowledge energy-dense snack intake as personal risk factor for cardiometabolic disease. CKR.5.9.b. Get informed about the benefits of being familiar with healthy snacks and learn strategies to do so. CKR.5.9.c. Decide to commit to the strategies to get familiar with healthy snacks based on fresh fruit and vegetable.	PB.5.9.a. Get informed about possible perceived barriers getting familiar with healthy snacks based on fresh fruit and vegetable and identify personal barriers. PB.5.9.b. Get informed about possible solutions to overcome perceived barriers getting familiar with healthy snacks based on fresh fruit and vegetable and implement the most suitable solutions.	SSE.5.9.a. Feel confident about getting familiar with healthy snacks based on fresh fruit and vegetable. SSE.5.9.b. Express confidence in ability to get familiar with healthy snacks based on fresh fruit and vegetable, or to learn to do so.	OEA.5.9.a. Expect that getting familiar with healthy snacks based on fresh fruit and vegetable will lead to healthier snacking behavior und ultimately to numerous health benefits. OEA.5.9.b. Notice the advantages of getting familiar with healthy snacks based on fresh fruit and vegetable. OEA.5.9.c. Feel positive about getting familiar with healthy snacks based on fresh fruit and vegetable.	SN.5.9.a. Notice that most individuals with healthy nutrition patterns are familiar with healthy snacking based on fresh fruit and vegetable. SN.5.9.b. Notice that getting familiar with healthy snacks based on fresh fruit and vegetable does not need approval by others. SN.5.9.c. Notice own social resources and find role models or supporters in own or extended social network who are familiar with fresh fruit and vegetable snacks.	SIH.5.9.a. Identify as a health-conscious person who wants to be familiar with healthy snacks based on fresh fruit and vegetable. SIH.5.9.b. Identify as a healthy homemaker and role model who guides own children and partner to get familiar with healthy snacks based on fresh fruit and vegetable.	ER.5.9.a. Expect initial discomfort when starting to get familiar with healthy snacks based on fresh fruit and vegetable. ER.5.9.b. Notice that getting familiar with healthy snacks based on fresh fruit and vegetable is fun. ER.5.9.c. Feel great about being familiar with healthy snacks based on fresh fruit and vegetable.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.10.

PO.5.10. If habitual unhealthy snacking: Snack fresh fruit or vegetable on the go or at home. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.10.a. Accept unhealthy snacking as personal cardiometabolic risk factor. CKR.5.10.b. Get informed about the benefits of snacking fresh fruit or vegetable, and learn strategies to do so. CKR.5.10.c. Acknowledge the habitual character of snacking and the need to change environmental cues to snack fresh fruit or vegetable on the go or at home. CKR.5.10.d. Decide to commit to the strategies to snack fresh fruit or vegetable on the go or at home.	PB.5.10.a. Get informed about possible perceived barriers snacking fresh fruit or vegetable on the go or at home and identify personal barriers. PB.5.10.b. Get informed about possible solutions to overcome perceived barriers snacking fresh fruit or vegetable on the go or at home and implement the most suitable solutions. PB.5.10.c. Expect and resist hindering social pressure by family members or the wider social network when snacking fresh fruit or vegetable on the go or at home.	SSE.5.10.a. Feel confident about snacking fresh fruit or vegetable on the go or at home. SSE.5.10.b. Express confidence in ability to snack fresh fruit or vegetable on the go or at home, or to learn to do so. SSE.5.10.c. Feel capable of noticing automaticity in snacking behavior and of altering cues for snacking fresh fruit or vegetable on the go or at home, such as displaying fresh fruit and vegetable clearly visible at home.	OEA.5.10.a. Expect that snacking fresh fruit or vegetable on the go or at home will limit caloric intake, increase dietary fiber and anti-inflammatory nutrient intake, and ultimately decrease own cardiometabolic risk. OEA.5.10.b. Notice the advantages of snacking fresh fruit or vegetable on the go or at home. OEA.5.10.c. Feel positive about snacking fresh fruit or vegetable on the go or at home.	SN.5.10.a. Notice that most individuals with healthy nutrition patterns routinely snack fresh fruit or vegetable on the go or at home. SN.5.10.b. Notice that snacking fresh fruit or vegetable on the go or at home does not need approval by others. SN.5.10.c. Notice own social resources and find role models or supporters in own or extended social network who consistently snack fresh fruit or vegetable on the go or at home.	SIH.5.10.a. Consistently maintain snacking fresh fruit or vegetable on the go or at home instead of unhealthy snacks until habitual. SIH.5.10.b. Identify as a health-conscious person who snacks fresh fruit or vegetable on the go or at home. SIH.5.10.c. Identify as a role model who guides own children and partner in replacing unhealthy snacks with fresh fruit or vegetable on the go or at home.	ER.5.10.a. Expect initial discomfort when not used to snacking fresh fruit or vegetable on the go or at home. ER.5.10.b. Notice that snacking fresh fruit or vegetable on the go or at home is enjoyable and does not translate to constraints. ER.5.10.c. Feel great about having snacked fresh fruit or vegetable on the go or at home on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.11.

PO.5.11. If water intake below 1.5 l: Taste naturally flavored drinking water. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.11.a. Acknowledge consuming most drinks other than water, plain tea or black coffee as personal risk factor for cardiometabolic disease. CKR.5.11.b. Get informed about the benefits of drinking naturally flavored water, and learn to do so. CKR.5.11.c. Decide to taste naturally flavored drinking water.	PB.5.11.a. Get informed about possible perceived barriers tasting naturally flavored drinking water and identify personal barriers. PB.5.11.b. Get informed about possible solutions to overcome perceived barriers tasting naturally flavored drinking water and implement the most suitable solutions.	SSE.5.11.a. Feel confident about tasting naturally flavored drinking water. SSE.5.11.b. Express confidence in ability to taste naturally flavored drinking water, or to learn to do so.	OEA.5.11.a. Expect that tasting naturally flavored drinking water will raise own awareness to drink more water and ultimately contribute to numerous health benefits. OEA.5.11.b. Notice the advantages of tasting naturally flavored drinking water. OEA.5.11.c. Feel positive about tasting naturally flavored drinking water.	SN.5.11.a. Notice that most individuals with healthy nutrition patterns know and routinely drink tasty variants of naturally flavored drinking water. SN.5.11.b. Notice that tasting naturally flavored drinking water does not need approval by others. SN.5.11.c. Notice own social resources and find role models or supporters in own or extended social network who know many tasty variants of naturally flavored drinking water.	SIH.5.11.a. Identify as a health-conscious person who tastes and knows many variants of naturally flavored drinking water. SIH.5.11.b. Identify as a healthy homemaker and role model who guides own children and partner to taste naturally flavored drinking water.	ER.5.11.a. Notice that tasting naturally flavored drinking water can be enjoyable. ER.5.11.b. Feel great about having tasted different variants of naturally flavored drinking water on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.12.

PO.5.12. Drink at least 1.5 - 2 l of water or plain herbal tea a day, and limit other drinks to maximum four cups of plain black/green tea or black coffee and one glass of a 3:1 mixed water with juice. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.12.a. Get informed about the benefits of drinking at least 1.5 - 2 l of water a day and of limiting other drinks as specified. CKR.5.12.b. Acknowledge the habitual character of drinking and the need to change environmental cues to drink at least 1.5 - 2 l of water a day, and to limit other drinks as specified. CKR.5.12.c. Decide to drink at least 1.5 - 2 l of water a day, and to limit other drinks as specified.	PB.5.12.a. Get informed about possible perceived barriers drinking at least 1.5 - 2 l of water a day, and limiting other drinks as specified, and identify personal barriers. PB.5.12.b. Get informed about possible solutions to overcome perceived barriers drinking at least 1.5 - 2 l of water a day and limiting other drinks as specified, and implement the most suitable solutions.	SSE.5.12.a. Feel confident about drinking at least 1.5 - 2 l of water a day, and about limiting other drinks as specified. SSE.5.12.b. Express confidence in ability to drink at least 1.5 - 2 l of water a day, and to limit other drinks as specified, or to learn to do so. SSE.5.12.c. Feel capable of noticing automaticity in drinking behavior and of altering cues for drinking at least 1.5 - 2 l of water a day and for limiting other drinks as specified.	OEA.5.12.a. Expect that drinking at least 1.5 - 2 l of water a day, and limiting other drinks as specified leads to sufficient hydration, less caloric intake and ultimately to numerous health benefits decreasing own cardiometabolic risk. OEA.5.12.b. Notice the advantages of drinking at least 1.5 - 2 l of water a day, and of limiting other drinks as specified. OEA.5.12.c. Feel positive about drinking at least 1.5 - 2 l of water a day, and about limiting other drinks as specified.	SN.5.12.a. Notice that most individuals with healthy nutrition patterns habitually drink at least 1.5 - 2 l of water a day, and limit other drinks. SN.5.12.b. Notice that drinking at least 1.5 - 2 l of water a day, and limiting other drinks does not need approval by others and is possible even if social network does not support it. SN.5.12.c. Notice own social resources and find role models or supporters in social network who drink at least 1.5 - 2 l of water a day and limit other drinks as specified.	SIH.5.12.a. Consistently maintain drinking at least 1.5 - 2 l of water a day, and limiting other drinks as specified until habitual. SIH.5.12.b. Identify as a health-conscious person who drinks at least 1.5 - 2 l of water a day, and who limits other drinks as recommended. SIH.5.12.c. Identify as a healthy homemaker and role model who guides own children and partner to drink appropriate amounts of water each day, and limit other drinks as specified.	ER.5.12.a. Expect initial discomfort when starting to drink at least 1.5 - 2 l of water a day, and to limit other drinks as specified. ER.5.12.b. Notice that drinking at least 1.5 - 2 l of water a day, and limiting other drinks as specified is enjoyable. ER.5.12.c. Feel great about having consumed at least 1.5 - 2 l of water a day, and about having limited other drinks as specified on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.13.

PO.5.13. If eating irregularly every day: Keep a meal rhythm. Depending on the starting point, eat at least one meal at a fix time each day and gradually increase to up to three regular meals a day. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.13.a. Get informed about the benefits of keeping a meal rhythm, and learn to do so. CKR.5.13.b. Acknowledge the habitual character of eating and the need to change environmental cues to keep a meal rhythm. CKR.5.13.c. Decide to commit to the strategies to keep a meal rhythm.	PB.5.13.a. Get informed about possible perceived barriers keeping a meal rhythm, and identify personal barriers. PB.5.13.b. Get informed about possible solutions to overcome perceived barriers keeping a meal rhythm and implement the most suitable solutions.	SSE.5.13.a. Feel confident about keeping a meal rhythm. SSE.5.13.b. Express confidence in ability to keep a meal rhythm, or to learn to do so. SSE.5.13.c. Feel capable of noticing automaticity in eating behavior and of altering cues for a fix meal rhythm.	OEA.5.13.a. Expect that keeping a meal rhythm leads to healthier nutrition patterns and will ultimately decrease own cardiometabolic risk. OEA.5.13.b. Notice the advantages of keeping a meal rhythm. OEA.5.13.c. Feel positive about keeping a meal rhythm.	SN.5.13.a. Notice that most health-conscious individuals have a meal rhythm. SN.5.13.b. Notice that keeping a meal rhythm does not need approval by others and is possible even if social network or culture do not support it, but that social support especially by the family facilitates own success. SN.5.13.c. Notice own social resources and find role models or supporters in own or extended social network who follow a fix meal rhythm.	SIH.5.13.a. Maintain a meal rhythm until habitual. SIH.5.13.b. Identify as a health-conscious person with a meal rhythm. SIH.5.13.c. Identify as a healthy homemaker and role model who guides own children and partner to keep a meal rhythm.	ER.5.13.a. Notice that keeping a meal rhythm is enjoyable. ER.5.13.b. Feel great about having maintained the meal rhythm on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.14.

PO.5.14. If frequent snacking: Limit snacking to two healthy snacks between meals per day. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.14.a. Get informed about the benefits of limited snacking, and learn strategies to do so. CKR.5.14.b. Acknowledge the habitual character of snacking and the need to change environmental cues to limit snacking to two healthy snacks between meals per day. CKR.5.14.c. Decide to commit to the strategies to limit snacking to two healthy snacks between meals per day.	PB.5.14.a. Get informed about possible perceived barriers limiting snacks to two healthy snacks between meals per day and identify personal barriers. PB.5.14.b. Get informed about possible solutions to overcome perceived barriers limiting snacks to two healthy snacks between meals per day and implement the most suitable solutions.	SSE.5.14.a. Feel confident about limiting snacking to two healthy snacks between meals per day. SSE.5.14.b. Express confidence in ability to limit snacking to two healthy snacks between meals per day, or to learn to do so. SSE.5.14.c. Feel capable of noticing automaticity in snacking behavior and of altering cues to limit snacking to two healthy snacks between meals per day.	OEA.5.14.a. Expect that limiting snacks to two healthy snacks between meals per day will lead to numerous health benefits and decrease own cardiometabolic risk. OEA.5.14.b. Notice the advantages of limiting snacks to two healthy snacks between meals per day. OEA.5.14.c. Feel positive about limiting snacks to two healthy snacks between meals per day.	SN.5.14.a. Notice that health-conscious individuals consistently limit snacks. SN.5.14.b. Notice that limiting snacks to two healthy snacks between meals per day does not need approval by others. SN.5.14.c. Notice own social resources and find role models or supporters in own or extended social network who limit snacking to two healthy snacks between meals per day.	SIH.5.14.a. Maintain limited snacking of two healthy snacks between meals per day until habitual. SIH.5.14.b. Identify as a health-conscious person who limits snacking to two healthy snacks between meals per day. SIH.5.14.c. Identify as a healthy homemaker and role model who guides own children and partner to limit snacking to two healthy snacks between meals per day.	ER.5.14.a. Expect initial discomfort when starting to limit snacking to two healthy snacks between meals per day. ER.5.14.b. Notice that limiting snacks to two healthy snacks between meals per day is enjoyable. ER.5.14.c. Feel great about having limited snacking to two healthy snacks between meals on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.15.

PO.5.15. If BMI of 23 kg/m² or higher: Eat one regular sized portion per meal. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.15.a. Get informed about the benefits of eating one regular sized portion per meal, and learn strategies to do so in daily life. CKR.5.15.b. Acknowledge the habitual character of portion size and the need to change environmental cues to eat one regular sized portion per meal. CKR.5.15.c. Decide to commit to the strategies to eat one regular sized portion per meal.	PB.5.15.a. Get informed about possible perceived barriers eating one regular sized portion per meal and identify personal barriers. PB.5.15.b. Get informed about possible solutions to overcome perceived barriers eating one regular sized portion per meal and implement the most suitable solutions.	SSE.5.15.a. Feel confident about eating one regular sized portion per meal. SSE.5.15.b. Express confidence in ability to eat one regular sized portion per meal, or to learn to do so. SSE.5.15.c. Feel capable of noticing automaticity in portion size and of altering cues to eat one regular sized portion per meal.	OEA.5.15.a. Expect that eating one regular sized portion per meal will limit caloric intake and decrease own cardiometabolic risk. OEA.5.15.b. Notice the advantages of eating one regular sized portion per meal. OEA.5.15.c. Feel positive about eating one regular sized portion per meal.	SN.5.15.a. Notice that most individuals with healthy nutrition patterns eat one regular sized portion per meal. SN.5.15.b. Notice that eating one regular sized portion per meal does not need approval by others. SN.5.15.c. Notice own social resources and find role models or supporters in own or extended social network who eat one regular sized portion per meal.	SIH.5.15.a. Consistently maintain eating one regular sized portion per meal until habitual. SIH.5.15.b. Identify as a health-conscious person who eats one regular sized portion per meal. SIH.5.15.c. Identify as a healthy homemaker and role model who guides own children and partner to eat an appropriate portion per meal.	ER.5.15.a. Notice that eating one regular sized portion per meal can be enjoyable. ER.5.15.b. Feel great about having eaten one regular sized portion per meal on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.16.

PO.5.16. If BMI of higher than 23 kg/m^2: Replace energy-dense and ultra-processed food products with healthier alternatives. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.16.a. Get informed about the benefits of replacing energy-dense and ultra-processed food products. CKR.5.16.b. Acknowledge the habitual character of replacing energy-dense and ultra-processed food products and the need to change related environmental cues. CKR.5.16.c. Decide to commit to the strategies to replace energy-dense and ultra-processed food products.	PB.5.16.a. Get informed about possible perceived barriers replacing energy-dense and ultra-processed food products and identify personal barriers. PB.5.16.b. Get informed about possible solutions to overcome perceived barriers replacing energy-dense and ultra-processed food products and implement the most suitable solutions.	SSE.5.16.a. Feel confident about replacing energy-dense and ultra-processed food products. SSE.5.16.b. Express confidence in ability to replace energy-dense and ultra-processed food products, or to learn to do so. SSE.5.16.c. Feel capable of noticing automaticity in food choices and of altering cues to replace energy-dense and ultra-processed food products.	OEA.5.16.a. Expect that replacing energy-dense and ultra-processed food products will decrease own cardiometabolic risk. OEA.5.16.b. Notice the advantages of replacing energy-dense and ultra-processed food products. OEA.5.16.c. Feel positive about replacing energy-dense and ultra-processed food products.	SN.5.16.a. Notice that most individuals with healthy nutrition patterns replace energy-dense and ultra-processed food products. SN.5.16.b. Notice that replacing energy-dense and ultra-processed food products does not need approval by others. SN.5.16.c. Notice own social resources and find role models or supporters in social network who usually replace energy-dense and ultra-processed food products.	SIH.5.16.a. Consistently maintain replacing energy-dense and ultra-processed food products until habitual. SIH.5.16.b. Identify as a health-conscious person who replaces energy-dense and ultra-processed food products. SIH.5.16.c. Identify as a healthy homemaker and role model who guides own children and partner to replace energy-dense and ultra-processed food products.	ER.5.16.a. Expect initial discomfort when starting to replace energy-dense and ultra-processed food products. ER.5.16.b. Notice that replacing energy-dense and ultra-processed food products can be enjoyable. ER.5.16.c. Feel great about having replaced energy-dense and ultra-processed food products on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.17.

PO.5.17. If overnight fasting habit of less than 12 hours: Gradually extend the overnight fast to at least twelve to sixteen hours between the last and the first food or drink intake other than water. Find out which time slot best aligns with own schedule and family life. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.17.a. Get informed about the benefits of gradually extending the overnight fast to at least twelve to sixteen hours, and learn to do so. CKR.5.17.b. Acknowledge the habitual character of overnight fasting and the need to change environmental cues to extend the overnight fast to at least twelve to sixteen hours. CKR.5.17.c. Decide to commit to the strategies to extend the overnight fast to at least twelve to sixteen hours.	PB.5.17.a. Get informed about possible perceived barriers gradually extending the overnight fast to at least twelve to sixteen hours, and identify personal barriers. PB.5.17.b. Get informed about possible solutions to overcome perceived barriers gradually extending the overnight fast to at least twelve to sixteen hours and implement the most suitable solutions.	SSE.5.17.a. Feel confident about being able to gradually extend the overnight fast to at least twelve to sixteen hours. SSE.5.17.b. Express confidence in ability to gradually extend the overnight fast to at least twelve to sixteen hours, or to learn to do so. SSE.5.17.c. Feel capable of noticing automaticity in overnight fasting and of altering cues to extend the overnight fast of at least twelve to sixteen hours.	OEA.5.17.a. Expect that gradually extending the overnight fast to at least twelve to sixteen hours will lead to numerous health benefits and decrease own cardiometabolic risk. OEA.5.17.b Notice the advantages of gradually extending the overnight fast to at least twelve to sixteen hours. OEA.5.17.c. Feel positive about gradually extending the overnight fast to at least twelve to sixteen hours.	SN.5.17.a. Notice that health-conscious individuals habitually extend their overnight fast. SN.5.17.b. Notice that gradually extending the overnight fast to at least twelve to sixteen hours may initially interfere with family's preferences for family meal times, but lead to new habits and norms. SN.5.17.c. Notice own social resources and find role models or supporters in own or extended social network who keep an overnight fast of at least twelve to sixteen hours.	SIH.5.17.a. Maintain an extended overnight fast of at least twelve to sixteen hours until habitual. SIH.5.17.b. Identify as a health-conscious person with an extended overnight fast of at least twelve to sixteen hours.	ER.5.17.a. Expect initial discomfort when gradually extending the overnight fast to at least twelve to sixteen hours. ER.5.17.b. Notice that gradually extending the overnight fast to at least twelve to sixteen hours is enjoyable. ER.5.17.c. Feel great about having extended the overnight fast to at least twelve to sixteen hours on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.18.

PO.5.18. If BMI of 23 kg/m² or higher: Lose one to two kilos of body weight per month until own weight goal is reached. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.18.a. Acknowledge a BMI of 23 kg/m² or higher as personal risk factor for cardiometabolic disease. CKR.5.18.b. Get informed about the benefits of losing one to two kilos per month until own weight goal is reached, and learn strategies to do so in daily life. CKR.5.18.c. Decide to commit to losing one to two kilos per month until own weight goal is reached.	PB.5.18.a. Get informed about possible perceived barriers losing one to two kilos per month until own weight goal is reached and identify personal barriers. PB.5.18.b. Get informed about possible solutions to overcome perceived barriers losing one to two kilos per month until own weight goal is reached and implement the most suitable solutions in daily family life.	SSE.5.18.a. Feel confident about losing one to two kilos per month until own weight goal is reached. SSE.5.18.b. Express confidence in ability to lose one to two kilos per month until own weight goal is reached, or to learn to do so.	OEA.5.18.a. Expect that losing one to two kilos per month until own weight goal is reached leads to numerous health benefits and decreases own cardiometabolic risk. OEA.5.18.b. Notice the advantages of losing one to two kilos per month until own weight goal is reached. OEA.5.18.c. Feel positive about losing one to two kilos per month until own weight goal is reached.	SN.5.18.a. Notice that most individuals who successfully and sustainably lost weight did not lose more than one to two kilos per month until they reached their weight goal. SN.5.18.b. Notice that losing one to two kilos per month does not need approval by others. SN.5.18.c. Notice own social resources and find role models or supporters in social network who lose or lost one to two kilos of body weight per month.	SIH.5.18.a. Consistently maintain losing one to two kilos per month until own weight goal is reached. SIH.5.18.b. Identify as a health-conscious person who consistently loses one to two kilos per month until own weight goal is reached. SIH.5.18.c. Identify as a healthy homemaker and role model who guides own children and partner to aim for or maintain a healthy body weight.	ER.5.18.a. Expect initial discomfort when not used to losing one to two kilos per month until own weight goal is reached. ER.5.18.b. Notice that losing one to two kilos per month is enjoyable. ER.5.18.c. Feel great about having lost one to two kilos during a given month.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 5.19.

PO.5.19. Remain flexible while controlling eating behavior. Commit to a healthy nutrition on a habitual basis, yet stay flexible for special occasions and do not ban entire food categories. Balance exceptions in the next meal or snack, the latest on the next day. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.5.19.a. Acknowledge rigid control of eating behaviors as personal risk factor for disordered eating with negative health consequences. CKR.5.19.b. Get informed about the benefits of remaining flexible in controlling eating behavior and learn strategies to do so. CKR.5.19.c. Commit to the strategies for remaining flexible in controlling eating behavior.	PB.5.19.a. Get informed about possible perceived barriers remaining flexible in controlling eating behavior and identify personal barriers. PB.5.19.b. Get informed about possible solutions to overcome perceived barriers remaining flexible in controlling eating behavior and implement the most suitable solutions. PB.5.19.c. Expect and resist hindering social pressure by family members or the wider social network when remaining flexible in controlling eating behavior.	SSE.5.19.a. Feel confident about remaining flexible in controlling eating behavior. SSE.5.19.b. Express confidence in ability to remain flexible in controlling eating behavior, or to learn to do so. SSE.5.19.c. Feel capable of noticing automaticity in controlling eating behavior.	OEA.5.19.a. Expect that remaining flexible in controlling eating behavior will lead to numerous benefits and ultimately decrease own cardiometabolic risk. OEA.5.19.b. Notice the advantages of remaining flexible in controlling eating behavior. OEA.5.19.c. Feel positive about remaining flexible in controlling eating behavior.	SN.5.19.a. Notice that most health-conscious individuals remain flexible in controlling their eating behaviors. SN.5.19.b. Notice that remaining flexible in controlling eating behavior does not need approval by others and is possible even if social network or culture do not support it, but that social support facilitates own success. SN.5.19.c. Notice own social resources and find role models or supporters in own or extended social network who remain flexible in controlling eating behaviors.	SIH.5.19.a. Remain flexible in controlling eating behavior until habitual. SIH.5.19.b. Identify as a health-conscious person who remains flexible in controlling eating behavior. SIH.5.19.c. Identify as a role model who guides own children and partner in remaining flexible in controlling eating behavior.	ER.5.19.a. Expect initial discomfort when not used to remaining flexible in controlling eating behavior. ER.5.19.b. Notice that remaining flexible in controlling eating behavior is enjoyable. ER.5.19.c. Feel great about remaining flexible in controlling eating behavior.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.1.

PO.6.1. Practice mindfulness to be fully present during daily experiences. Start with scheduled daily five-minute mindfulness exercises and gradually lower the exercise time to three minutes a day and then to at least three moments throughout the day. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.1.a. Acknowledge stress as personal risk factor for cardiometabolic disease. CKR.6.1.b. Get informed about the benefits of a mindfulness practice and learn strategies to do so. CKR.6.1.c. Acknowledge the habitual character of mindfulness and the need to change environmental cues to establish a mindfulness practice. CKR.6.1.d. Decide to commit to the strategies for practicing mindfulness.	PB.6.1.a. Get informed about possible perceived barriers practicing mindfulness and identify personal barriers. PB.6.1.b. Get informed about possible solutions to overcome perceived barriers practicing mindfulness and implement the most suitable solutions. PB.6.1.c. Expect and resist hindering social pressure by family members or the wider social network when practicing mindfulness.	SSE.6.1.a. Feel confident about practicing mindfulness. SSE.6.1.b. Express confidence in ability to practice mindfulness, or to learn to do so. SSE.6.1.c. Feel capable of noticing automaticity of daily behaviors and stress reactions and of altering cues for a daily mindfulness practice.	OEA.6.1.a. Expect that practicing mindfulness will lead to numerous health benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.1.b. Notice the advantages of practicing mindfulness. OEA.6.1.c. Feel positive about practicing mindfulness.	SN.6.1.a. Notice that health-conscious individuals who successfully and sustainably changed health behaviors practice mindfulness. SN.6.1.b. Notice that practicing mindfulness does not need approval by others. SN.6.1.c. Notice own social resources and find role models or supporters in own or extended social network who practice mindfulness daily.	SIH.6.1.a. Consistently maintain a daily mindfulness practice until habitual. SIH.6.1.b. Identify as a health-conscious person who practices mindfulness daily. SIH.6.1.c. Identify as a role model who guides own children and partner in being mindful and fully present during daily experiences.	ER.6.1.a. Expect initial discomfort when not used to practicing mindfulness. ER.6.1.b. Notice that practicing mindfulness is enjoyable. ER.6.1.c. Feel great about having practiced mindfulness on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.2.

PO.6.2. Get familiar with different types of recreational activities and select favorite three. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.2.a. Acknowledge insufficient recreation as personal risk factor for cardiometabolic disease. CKR.6.2.b. Get informed about the benefits of being familiar with different types of recreational activities and of knowing favorite three activities. CKR.6.2.c. Decide to get familiar with different types of recreational activities and to select favorite three.	PB.6.2.a. Get informed about possible perceived barriers getting familiar with different types of recreational activities and identify personal barriers. PB.6.2.b. Get informed about possible solutions to overcome perceived barriers getting familiar with different types of recreational activities and implement the most suitable solutions.	SSE.6.2.a. Feel confident about getting familiar with different types of recreational activities and about selecting favorite three. SSE.6.2.b. Express confidence in ability to get familiar with different types of recreational activities and to select favorite three, or to learn to do so.	OEA.6.2.a. Expect that getting familiar with different types of recreational activities and selecting favorite three increases the likelihood to engage into recreational activities on a regular basis. OEA.6.2.b. Notice the advantages of getting familiar with different types of recreational activities and of selecting favorite three. OEA.6.2.c. Feel positive about getting familiar with different types of recreational activities and selecting favorite three.	SN.6.2.a. Notice that health-conscious individuals are familiar with different types of recreational activities and know their favorite ones. SN.6.2.b. Notice that getting familiar with different types of recreational activities does not need approval by others. SN.6.2.c. Notice own social resources and find role models or supporters in own or extended social network who favor similar types of recreational activities.	SIH.6.2.a. Identify as a health-conscious person who is familiar with different types of recreational activities and who knows the favorite ones. SIH.6.2.b. Identify as a healthy homemaker and role model who guides own children and partner to be familiar with different types of recreational activities and to know their favorite ones.	ER.6.2.a. Expect initial discomfort when confronted with the decision to select favorite three recreational activities. ER.6.2.b. Notice that getting familiar with different types of recreational activities is enjoyable. ER.6.2.c. Feel great about being familiar with different types of recreational activities and about knowing favorite three.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.3.

PO.6.3. Maintain a weekly recreational activity routine. Start with one scheduled recreational activity per week and gradually increase to three scheduled recreational activities per week. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.3.a. Accept insufficient recreation as personal cardiometabolic risk factor. CKR.6.3.b. Get informed about the benefits of a weekly recreational routine and learn to do so. CKR.6.3.c. Acknowledge the habitual character of (insufficient) recreation and the need to change environmental cues for a recreational routine. CKR.6.3.d. Decide to commit to the strategies for maintaining a weekly recreational activity routine.	PB.6.3.a. Get informed about possible perceived barriers maintaining a weekly recreational activity routine and identify personal barriers. PB.6.3.b. Get informed about possible solutions to overcome perceived barriers maintaining a weekly recreational activity routine and implement the most suitable solutions. PB.6.3.c. Expect and resist hindering social pressure by family members or the wider social network when maintaining a weekly recreational activity routine.	SSE.6.3.a. Feel confident about maintaining a weekly recreational activity routine. SSE.6.3.b. Express confidence in ability to maintain a weekly recreational activity routine, or to learn to do so. SSE.6.3.c. Feel capable of noticing automaticity in (insufficient) recreation and of altering cues to maintain sufficient recreational activities.	OEA.6.3.a. Expect that maintaining a weekly recreational activity routine leads to numerous health benefits, facilitates other health behavior, and decreases own cardiometabolic risk. OEA.6.3.b. Notice the advantages of maintaining a weekly recreational activity routine. OEA.6.3.c. Feel positive about maintaining a weekly recreational activity routine.	SN.6.3.a. Notice that health-conscious individuals maintain a weekly recreational activity routine. SN.6.3.b. Notice that maintaining a weekly recreational activity routine does not need approval by others. SN.6.3.c. Notice own social resources and find role models or supporters in own or extended social network who have a weekly recreational activity routine with similar interests.	SIH.6.3.a. Maintain a weekly recreational activity routine until habitual. SIH.6.3.b. Identify as a health-conscious person who maintains a weekly recreational activity routine. SIH.6.3.c. Identify as a healthy homemaker and role model who guides own children and partner to maintain their own weekly recreational activity routines.	ER.6.3.a. Notice that maintaining a weekly recreational activity routine is enjoyable. ER.6.3.b. Feel great about having completed the scheduled recreational activities in a given week.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.4.

PO.6.4. Enhance infant's sleep with list of recommended actions. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.4.a. Get informed about how to enhance infant's sleep and implement recommendations suitable for own infant. CKR.6.4.b. Acknowledge the habitual character of own infant's sleep hygiene and the need to change environmental cues to enhance infant's sleep. CKR.6.4.c. Decide to commit to the strategies for enhancing infant's sleep.	PB.6.4.a. Get informed about possible perceived barriers enhancing infant's sleep and identify personal barriers. PB.6.4.b. Get informed about possible solutions to overcome perceived barriers enhancing infant's sleep and implement the most suitable solutions.	SSE.6.4.a. Feel confident about enhancing infant's sleep. SSE.6.4.b. Express confidence in ability to enhance infant's sleep, or to learn to do so. SSE.6.4.c. Feel capable of noticing automaticity in bedtime behaviors and of altering cues for enhancing infant's sleep.	OEA.6.4.a. Expect that enhancing infant's sleep will lead to numerous benefits including the facilitation of own health behavior. OEA.6.4.b. Notice the advantages of enhancing infant's sleep. OEA.6.4.c. Feel positive about enhancing infant's sleep.	SN.6.4.a. Notice that health-conscious individuals enhance their infant's sleep. SN.6.4.b. Notice that enhancing infant's sleep may initially interfere with family's preferences or identity, yet may ultimately lead to new (bedtime) behaviors within the family.	SIH.6.4.a. Consistently maintain enhancing infant's sleep until habitual. SIH. 6.4.b. Identify as a health-conscious person who enhances infant's sleep.	ER.6.4.a. Expect initial discomfort when not used to take measures to enhance infant's sleep. ER.6.4.b. Notice that enhancing infant's sleep is enjoyable. ER.6.4.c. Feel great about having enhanced infant's sleep on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.5.

PO.6.5. Enhance own sleep with list of recommended actions. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.5.a. Acknowledge insufficient sleep or low sleep quality as personal risk factor for cardiometabolic disease. CKR.6.5.b. Get informed about the benefits of enhancing own sleep, and learn strategies to do so. CKR.6.5.c. Acknowledge the habitual character of own sleep hygiene and the need to change environmental cues to enhance own sleep. CKR.6.5.d. Decide to commit to the strategies for enhancing own sleep.	PB.6.5.a. Get informed about possible perceived barriers enhancing own sleep with recommended actions and identify personal barriers. PB.6.5.b. Get informed about possible solutions to overcome perceived barriers enhancing own sleep and implement the most suitable solutions. PB.6.5.c. Expect and resist hindering social pressure by family members when starting to implement recommended actions to enhance own sleep.	SSE.6.5.a. Feel confident about enhancing own sleep with recommended actions. SSE.6.5.b. Express confidence in ability to implement recommended actions to enhance own sleep, or to learn to do so.	OEA.6.5.a. Expect that enhancing own sleep will lead to numerous health benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.5.b. Notice the advantages of enhancing own sleep with recommended actions. OEA.6.5.c. Feel positive about enhancing own sleep with recommended actions.	SN.6.5.a. Notice that health-conscious individuals consistently take recommended actions to enhance own sleep. SN.6.5.b. Notice that enhancing own sleep with recommended actions may initially interfere with family's preferences or identity, yet may ultimately lead to new bedtime behaviors within the family.	SIH.6.5.a. Consistently enhance own sleep with recommended actions until habitual. SIH.6.5.b. Identify as a health-conscious person who enhances own sleep with recommended actions. SIH.6.5.c. Identify as a healthy homemaker and role model who guides own children and partner to enhance their sleep with recommended actions.	ER.6.5.a. Expect initial discomfort when not used to enhancing own sleep with recommended actions. ER.6.5.b. Notice that enhancing own sleep with recommended actions is enjoyable. ER.6.5.c. Feel great about having enhanced own sleep with recommended actions on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.6.

PO.6.6. Maintain a daily progressive muscle relaxation routine. Start with a scheduled daily 18-minute progressive muscle relaxation exercise and gradually lower the exercise time to seven minutes and then to several short full muscle relaxation moments during the day. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.6.a. Accept insufficient relaxation as personal cardiometabolic risk factor. CKR.6.6.b. Get informed about the benefits of maintaining a progressive muscle relaxation routine and learn to do so. CKR.6.6.c. Acknowledge the habitual character of progressive muscle relaxation and the need to change environmental cues to maintain a routine. CKR.6.6.d. Decide to commit to the strategies for a progressive muscle relaxation routine.	PB.6.6.a. Get informed about possible perceived barriers maintaining a progressive muscle relaxation routine and identify personal barriers. PB.6.6.b. Get informed about possible solutions to overcome personal perceived barriers maintaining a progressive muscle relaxation routine and implement the most suitable solutions. PB.6.6.c. Expect and resist hindering social pressure by family members when maintaining a progressive muscle relaxation routine.	SSE.6.6.a. Feel confident about maintaining a progressive muscle relaxation routine. SSE.6.6.b. Express confidence in ability to maintain a progressive muscle relaxation routine, or to learn to do so.	OEA.6.6.a. Expect that maintaining a progressive muscle relaxation routine will lead to numerous health benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.6.b. Notice the advantages of maintaining a progressive muscle relaxation routine. OEA.6.6.c. Feel positive about maintaining a progressive muscle relaxation routine.	SN.6.6.a. Notice that health-conscious individuals maintain a daily relaxation routine. SN.6.6.b. Notice that maintaining a progressive muscle relaxation routine does not need approval by others. SN.6.6.c. Notice own social resources and find role models or supporters in own or extended social network who maintain a progressive muscle relaxation routine.	SIH.6.6.a. Maintain daily progressive muscle relaxation until habitual. SIH.6.6.b. Identify as a health-conscious person with a daily progressive muscle relaxation routine. SIH.6.6.c. Identify as a healthy homemaker and role model who guides own children and partner to maintain relaxation routines.	ER.6.6.a. Expect initial discomfort when starting a progressive muscle relaxation routine. ER.6.6.b. Notice that maintaining a progressive muscle relaxation routine is enjoyable. ER.6.6.c. Feel great about having completed a progressive muscle relaxation exercise on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.7.

PO.6.7. Practice gratitude by reviewing the positive things happening on a regular day. Start with two items per day and gradually increase to four items. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.7.a. Acknowledge insufficient positive emotion as personal cardiometabolic risk factor. CKR.6.7.b. Get informed about the benefits of gratitude, and learn to practice it in daily life. CKR.6.7.c. Acknowledge the habitual character of own emotions and the need to change environmental cues to feel gratitude. CKR.6.7.d. Decide to commit to the strategies for practicing gratitude daily.	PB.6.7.a. Get informed about possible perceived barriers practicing gratitude daily and identify personal barriers. PB.6.7.b. Get informed about possible solutions to overcome perceived barriers practicing gratitude daily and implement the most suitable solutions.	SSE.6.7.a. Feel confident about practicing gratitude daily. SSE.6.7.b. Express confidence in ability to practice gratitude daily, or to learn to do so.	OEA.6.7.a. Expect that practicing gratitude daily will lead to numerous health benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.7.b. Notice the advantages of practicing gratitude daily. OEA.6.7.c. Feel positive about practicing gratitude daily.	SN.6.7.a. Notice that health-conscious and happy individuals practice gratitude every day. SN.6.7.b. Notice own social resources and find role models or supporters in own or extended social network who practice gratitude daily.	SIH.6.7.a. Maintain a daily gratitude practice until habitual. SIH.6.7.b. Identify as a health-conscious person who practices gratitude on a daily basis. SIH.6.7.c. Identify as a healthy homemaker and role model who guides own children and partner to feel grateful for the little things in daily life.	ER.6.7.a. Notice that practicing gratitude daily is enjoyable. ER.6.7.b. Feel great about having practiced gratitude on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.8.

PO.6.8. Identify the most predominant one or two automatic negative thoughts in own thinking style and corresponding positive thoughts to replace them with. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.8.a. Acknowledge automatic negative thoughts as personal cardiometabolic risk factor. CKR.6.8.b. Acknowledge the importance of identifying the most predominant automatic negative thoughts and corresponding positive thoughts as preparatory step to action. CKR.6.8.c. Decide to identify the most predominant one or two automatic negative thoughts and corresponding positive thoughts to replace them with.	PB.6.8.a. Get informed about possible perceived barriers identifying the most predominant one or two automatic negative thoughts and corresponding positive thoughts and identify personal barriers. PB.6.8.b. Get informed about possible solutions to overcome perceived barriers identifying the most predominant one or two automatic negative thoughts and corresponding positive thoughts, and implement the most suitable solutions.	SSE.6.8.a. Feel confident about identifying the most predominant one or two automatic negative thoughts and corresponding positive thoughts. SSE.6.8.b. Express confidence in ability to identify the most predominant one or two automatic negative thoughts and corresponding positive thoughts, or to learn to do so.	OEA.6.8.a. Expect that identifying the most predominant one or two automatic negative thoughts and corresponding positive thoughts will raise own awareness of thinking patterns. OEA.6.8.b. Notice the advantages of identifying the most predominant one or two automatic negative thoughts and corresponding positive thoughts. OEA.6.8.c. Feel positive about identifying the most predominant one or two automatic negative thoughts and corresponding positive thoughts.	SN.6.8.a. Notice that health-conscious individuals know and replace their most predominant automatic negative thoughts with corresponding positive thoughts.	SIH.6.8.a. Identify as a health-conscious person who notices automatic negative thoughts and knows the corresponding positive thoughts to replace them with. SIH.6.8.b. Identify as a healthy homemaker and role model who guides own children and partner to identify automatic negative thoughts and to train corresponding positive thoughts to replace them with.	ER.6.8.a. Expect initial discomfort when noticing the most predominant one or two automatic negative thoughts. ER.6.8.b. Notice that identifying the most predominant one or two automatic negative thoughts and corresponding positive thoughts to replace them with is enjoyable. ER.6.8.c. Feel great about having identified the most predominant one or two automatic negative thoughts and corresponding positive thoughts to replace them with.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.9.

PO.6.9. Notice automatic negative thoughts, acknowledge them and replace them with the according positive thoughts. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.9.a. Get informed about the benefits of noticing automatic negative thoughts, acknowledging them and replacing them with the according positive thoughts, and learn to do so. CKR.6.9.b. Acknowledge the habitual character of thoughts and the need to change environmental cues for changing thoughts. CKR.6.9.c. Decide to notice automatic negative thoughts, to acknowledge them and to replace them with the according positive thoughts.	PB.6.9.a. Get informed about possible perceived barriers noticing automatic negative thoughts, acknowledging them and replacing them with the according positive thoughts and identify personal barriers. PB.6.9.b. Get informed about possible solutions to overcome perceived barriers noticing automatic negative thoughts, acknowledging them and replacing them with the according positive thoughts and implement the most suitable solutions.	SSE.6.9.a. Feel confident about noticing automatic negative thoughts, acknowledging them and replacing them with the according positive thoughts. SSE.6.9.b. Express confidence in ability to notice automatic negative thoughts, to acknowledge them, and to replace them with the according positive thoughts, or to learn to do so.	OEA.6.9.a. Expect that noticing automatic negative thoughts, acknowledging them and replacing them with the according positive thoughts will lead to numerous health benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.9.b. Notice the advantages of becoming aware of automatic negative thoughts, acknowledging them and replacing them with the according positive thoughts.	SN.6.9.a. Notice that most health-conscious individuals trained becoming aware of automatic negative thoughts, acknowledging them and replacing them with corresponding positive thoughts.	SIH.6.9.a. Identify as a health-conscious person who notices automatic negative thoughts, acknowledges them and replaces them with the according positive thoughts. SIH.6.9.b. Identify as a healthy homemaker and role model who guides own children and partner towards positive thoughts.	ER.6.9.a. Notice that replacing automatic negative thoughts with according positive thoughts is enjoyable. ER.6.9.b. Feel great about having noticed automatic negative thoughts, having acknowledged and replaced them with the according positive thoughts on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.10.

PO.6.10. Get familiar with emotional positivity and learn how to strengthen positive emotions in daily life. Start by focusing on one positive emotion. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.10.a. Acknowledge insufficient emotional positivity as personal cardiometabolic risk factor. CKR.6.10.b. Decide to get familiar with emotional positivity and to learn how to strengthen positive emotions in daily life.	PB.6.10.a. Get informed about possible perceived barriers getting familiar with emotional positivity and learning how to strengthen positive emotions in daily life and identify personal barriers. PB.6.10.b. Get informed about possible solutions to overcome perceived barriers getting familiar with emotional positivity and learning how to strengthen positive emotions in daily life and implement the most suitable solutions.	SSE.6.10.a. Feel confident about getting familiar with emotional positivity and about learning how to strengthen positive emotions in daily life. SSE.6.10.b. Express confidence in ability to get familiar with emotional positivity and to learn how to strengthen positive emotions in daily life, or to learn to do so.	OEA.6.10.a. Expect that getting familiar with emotional positivity and learning how to strengthen positive emotions in daily life will ultimately contribute to better emotional control, enhance happiness, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.10.b. Notice the advantages of getting familiar with emotional positivity and of learning how to gradually strengthen positive emotions in daily life.	SN.6.10.a. Notice that health-conscious individuals are familiar with emotional positivity and strengthen positive emotions in daily life. SN.6.10.b. Notice own social resources and find role models or supporters in own or extended social network who live emotional positivity.	SIH.6.10.a. Identify as a health-conscious person who wants to be familiar with emotional positivity and strengthens positive emotions in daily life. SIH.6.10.b. Identify as a healthy homemaker and role model who guides own children and partner to be familiar with emotional positivity and with strategies to strengthen positive emotions in daily life.	ER.6.10.a. Notice that being familiar with emotional positivity and learning how to strengthen positive emotions in daily life is enjoyable. ER.6.10.b. Feel great about being familiar with emotional positivity and having learned how to strengthen positive emotions in daily life on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.11.

PO.6.11. Establish a weekly routine to strengthen positive emotions. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.11.a. Get informed about the benefits of a weekly routine to strengthen positive emotions, and learn to do so. CKR.6.11.b. Acknowledge the habitual character of own emotions and the need to change environmental cues to strengthen positive emotions. CKR.6.11.c. Decide to commit to the strategies for establishing a weekly routine to strengthen positive emotions.	PB.6.11.a. Get informed about possible perceived barriers establishing a weekly routine to strengthen positive emotions and identify personal barriers. PB.6.11.b. Get informed about possible solutions to overcome perceived barriers establishing a weekly routine to strengthen positive emotions and implement the most suitable solutions.	SSE.6.11.a. Feel confident about establishing a weekly routine to strengthen positive emotions. SSE.6.11.b. Express confidence in ability to establish a weekly routine to strengthen positive emotions, or to learn to do so.	OEA.6.11.a. Expect that establishing a weekly routine to strengthen positive emotions will lead to numerous health benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.11.b. Notice the advantages of establishing a weekly routine to strengthen positive emotions. OEA.6.11.c. Feel positive about establishing a weekly routine to strengthen positive emotions.	SN.6.11.a. Notice that health-conscious individuals consistently strengthen positive emotions.	SIH.6.11.a. Maintain a weekly routine to strengthen positive emotions until habitual. SIH.6.11.b. Identify as a health-conscious person who strengthens positive emotions. SIH.6.11.c. Identify as a healthy homemaker and role model who guides own children and partner to strengthen positive emotions.	ER.6.11.a. Notice that establishing a weekly routine to strengthen positive emotions is enjoyable. ER.6.11.b. Feel great about having maintained a weekly routine to strengthen positive emotions during a regular week.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.12.

PO.6.12. Get familiar with seven steps for problem solving and learn to apply them. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.12.a. Get informed about the benefits of the seven steps for problem solving and learn to apply them. CKR.6.12.b. Decide to get familiar with seven steps for problem solving and commit to learning to apply them.	PB.6.12.a. Get informed about possible perceived barriers getting familiar with seven steps for problem solving or learning to apply them and identify personal barriers. PB.6.12.b. Get informed about possible solutions to overcome perceived barriers getting familiar with seven steps for problem solving or learning to apply them and implement the most suitable solutions.	SSE.6.12.a. Feel confident about getting familiar with seven steps for problem solving and about learning to apply them. SSE.6.12.b. Express confidence in ability to get familiar with seven steps for problem solving, or to learn to do so.	OEA.6.12.a. Expect that getting familiar with seven steps for problem solving and learning to apply them will lead to numerous benefits, increase own problem solving capacity and contribute to enhanced health behavior. OEA.6.12.b. Notice the advantages of getting familiar with seven steps for problem solving and of learning to apply them. OEA.6.12.c. Feel positive about getting familiar with seven steps for problem solving and about learning to apply them.	SN.6.12.a. Notice that health-conscious individuals have efficient problem solving skills. SN.6.12.b. Notice own social resources and find role models or supporters in own or extended social network who are familiar with efficient problem solving skills.	SIH.6.12.a. Identify as a health-conscious person who wants to be skilled in efficient problem solving. SIH.6.12.b. Identify as a healthy homemaker and role model who guides own children and partner to be familiar with efficient problem solving strategies.	ER.6.12.a. Notice that getting familiar with seven steps for problem solving and about learning to apply them is enjoyable. ER.6.12.b. Feel great about being familiar with seven steps for problem solving and about having learned to apply them on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.13.

PO.6.13. Establish a problem-solving routine using seven recommended steps. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.13.a. Get informed about the benefits of applying a problem solving routine using seven recommended steps, and learn to establish it in daily life. CKR.6.13.b. Acknowledge the habitual character of (insufficient) problem solving and the need to change environmental cues to establish a problem solving routine using seven recommended steps. CKR.6.13.c. Decide to commit to establishing a problem solving routine using seven recommended steps.	PB.6.13.a. Get informed about possible perceived barriers establishing a problem solving routine using seven recommended steps and identify personal barriers. PB.6.13.b. Get informed about possible solutions to overcome perceived barriers establishing a problem solving routine and implement the most suitable solutions.	SSE.6.13.a. Feel confident about establishing a problem solving routine using seven recommended steps. SSE.6.13.b. Express confidence in ability to establish a problem solving routine using seven recommended steps, or to learn to do so.	OEA.6.13.a. Expect that establishing a problem solving routine using seven recommended steps will lead to numerous benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.13.b. Notice the advantages of establishing a problem solving routine using seven recommended steps. OEA.6.13.c. Feel positive about establishing a problem solving routine using seven recommended steps.	SN.6.13.a. Notice that health-conscious individuals maintain a problem solving routine. SN.6.13.b. Notice own social resources and find role models or supporters in own or extended social network who consistently apply effective strategies for problem solving.	SIH.6.13.a. Maintain a problem solving routine using seven recommended steps until habitual. SIH.6.13.b. Identify as a health-conscious person with problem solving skills. SIH.6.13.c. Identify as a healthy homemaker and role model who guides own children and partner to solve problems effectively.	ER.6.13.a. Expect initial discomfort when starting to establish a problem solving routine using seven recommended steps. ER.6.13.b. Notice that applying a problem solving routine with seven recommended steps is enjoyable. ER.6.13.c. Feel great about having used the seven recommended steps for a given problem.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.14.

PO.6.14. Establish a prioritization routine of current and upcoming activities with a decision matrix. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.14.a. Get informed about the benefits of a prioritizing routine, and learn to establish it in daily life. CKR.6.14.b. Acknowledge the habitual character of prioritization and the need to change environmental cues to establish a new effective prioritization routine. CKR.6.14.c. Decide to commit to the strategies for establishing a prioritization routine.	PB.6.14.a. Get informed about possible perceived barriers prioritizing current and upcoming activities with a decision matrix, and identify personal barriers. PB.6.14.b. Get informed about possible solutions to overcome perceived barriers prioritizing with a decision matrix and implement the most suitable solutions.	SSE.6.14.a. Feel confident about prioritizing current and upcoming activities with a decision matrix. SSE.6.14.b. Express confidence in ability to prioritize current and upcoming activities with a decision matrix, or to learn to do so.	OEA.6.14.a. Expect that prioritizing current and upcoming activities with a decision matrix will lead to numerous health benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.14.b. Notice the advantages of prioritizing current and upcoming activities with a decision matrix. OEA.6.14.c. Feel positive about prioritizing current and upcoming activities with a decision matrix.	SN.6.14.a. Notice that health-conscious individuals maintain an efficient prioritization routine. SN.6.14.b. Notice that prioritizing current and upcoming activities does not need approval by others. SN.6.14.c. Notice own social resources and find role models or supporters in own or extended social network who use effective prioritization strategies on a daily basis.	SIH.6.14.a. Maintain a prioritization routine with a decision matrix until habitual. SIH.6.14.b. Identify as a health-conscious person with prioritization skills. SIH.6.14.c. Identify as a healthy homemaker and role model who guides own children and partner to prioritize current and upcoming activities.	ER.6.14.a. Expect initial discomfort when starting to prioritize current and upcoming activities with a decision matrix. ER.6.14.b. Notice that prioritizing current and upcoming activities with a decision matrix is enjoyable. ER.6.14.c. Feel great about having prioritized current and upcoming activities with a decision matrix on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.15.

PO.6.15. Get familiar with character strengths and identify the top three personal strengths. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.15.a. Get informed about the benefits of being familiar with character strengths and of knowing the top three personal strengths, and learn to identify them. CKR.6.15.b. Decide to get familiar with character strengths and to identify the top three personal strengths.	PB.6.15.a. Get informed about possible perceived barriers getting familiar with character strengths and own top three personal strengths and identify personal barriers. PB.6.15.b. Get informed about possible solutions to overcome perceived barriers getting familiar with character strengths and own top three personal strengths and implement the most suitable solutions.	SSE.6.15.a. Feel confident about getting familiar with character strengths and about identifying the top three personal strengths. SSE.6.15.b. Express confidence in ability to get familiar with character strengths and to identify the top three personal strengths, or to learn to do so.	OEA.6.15.a. Expect that getting familiar with character strengths and identifying the top three personal strengths will raise own awareness about character strengths and allow to work with them for better wellbeing. OEA.6.15.b. Notice the advantages of getting familiar with character strengths and of identifying the top three personal strengths. OEA.6.15.c. Feel positive about getting familiar with character strengths and about identifying the top three personal strengths.	SN.6.15.a. Notice that most health-conscious individuals are familiar with character strengths and know their personal top strengths. SN.6.15.b. Notice own social resources and find role models or supporters in own or extended social network who are familiar with character strengths.	SIH.6.15.a. Identify as a health-conscious person who is familiar with personal character strengths. SIH.6.15.b. Identify as a healthy homemaker and role model who guides own children and partner to identify their character strengths.	ER.6.15.a. Notice that getting familiar with character strengths and identifying the top three personal strengths is enjoyable. ER.6.15.b. Feel great about being familiar with character strengths and having identified the top three personal strengths.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 6.16.

PO.6.16. Focus on the top three personal strengths in daily life. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.6.16.a. Get informed about the benefits of focusing on the top three personal strengths in daily life, and learn to do so. CKR.6.16.b. Acknowledge the habitual character of denying or using personal strengths and the need to change environmental cues to focus on the top three personal strengths in daily life. CKR.6.16.c. Decide to commit to focusing on the top three personal strengths in daily life.	PB.6.16.a. Get informed about possible perceived barriers focusing on the top three personal strengths in daily life and identify personal barriers. PB.6.16.b. Get informed about possible solutions to overcome personal perceived barriers focusing on the top three personal strengths in daily life and implement the most suitable solutions.	SSE.6.16.a. Feel confident about focusing on the top three personal strengths in daily life. SSE.6.16.b. Express confidence in ability to focus on the top three personal strengths in daily life, or to learn to do so.	OEA.6.16.a. Expect that focusing on the top three personal strengths in daily life will lead to numerous benefits, facilitate other health behavior, and decrease own cardiometabolic risk. OEA.6.16.b. Notice the advantages of focusing on the top three personal strengths in daily life. OEA.6.16.c. Feel positive about focusing on the top three personal strengths in daily life.	SN.6.16.a. Notice that health-conscious individuals focus on their personal strengths in daily life. SN.6.16.b. Notice own social resources and find role models or supporters in own or extended social network who focus on their character strengths in daily life.	SIH.6.16.a. Consistently focus on the top three personal strengths in daily life until habitual. SIH.6.16.b. Identify as a health-conscious person who focuses on the top three personal strengths in daily life. SIH.6.16.c. Identify as a healthy homemaker and role model who guides own children and partner to focus on their strengths in daily life.	ER.6.16.a. Notice that focusing on the top three personal strengths in daily life is enjoyable. ER.6.16.b. Feel great about having focused on the top three personal strengths on a regular day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.1.

PO.7.1. Participate in the mHealth program on at least five out of seven days per week. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.1.a. Get informed about the benefits of participating in the mHealth program, and learn strategies to do so on at least five out of seven days per week. CKR.7.1.b. Decide to commit to participating in the mHealth program on at least five out of seven days per week.	PB.7.1.a. Get informed about possible perceived barriers participating in the mHealth program on at least five out of seven days per week and identify personal barriers. PB.7.1.b. Get informed about possible solutions to overcome perceived barriers participating in the mHealth program on at least five out of seven days per week.	SSE.7.1.a. Feel confident about participating in the mHealth program on at least five out of seven days per week. SSE.7.1.b. Express confidence in ability to participate in the mHealth program on at least five out of seven days per week.	OEA.7.1.a. Expect that participating in the mHealth program on at least five out of seven days per week will facilitate health behavior change and improve cardiometabolic health. OEA.7.1.b Notice the advantages of participating in the mHealth program on at least five out of seven days per week. OEA.7.1.c. Feel positive about participating in the mHealth program on at least five out of seven days per week.	SN.7.1.a. Notice that most health-conscious individuals regularly participate(d) in a health program. SN.7.1.b. Notice that participating in the mHealth program on at least five out of seven days per week may initially interfere with family's preferences or identity, yet may enhance family's health literacy and ultimately lead to new norms in the family. SN.7.1.c. Notice own social resources and find role models or supporters in social network who participate(d) in a health program on a daily basis.	SIH.7.1.a. Identify as a health-conscious person who participates in the mHealth program on at least five out of seven days per week. SIH.7.1.b. Identify as a healthy homemaker and role model who guides own children and partner to participate in preventive health measures.	ER.7.1.a. Notice that participating in the mHealth program on at least five out of seven days per week is enjoyable. ER.7.1.b. Feel great about having participated in the mHealth program on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.2.

PO.7.2. Communicate with healthcare practitioners via mHealth app. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.2.a. Get informed about the benefits of communicating with healthcare practitioners via mHealth. CKR.7.2.b. Acknowledge the habitual character connecting with healthcare practitioners and the need to change environmental cues to communicate via mHealth. CKR.7.2.c. Decide to commit to the strategies to effectively communicate with healthcare practitioners via mHealth.	PB.7.2.a. Get informed about possible perceived barriers communicating with healthcare practitioners via mHealth and identify personal barriers. PB.7.2.b. Get informed about possible solutions to overcome perceived barriers communicating with healthcare practitioners via mHealth and implement the most suitable solutions.	SSE.7.2.a. Feel confident about communicating with healthcare practitioners via mHealth. SSE.7.2.b. Express confidence in ability to communicate with healthcare practitioners via mHealth, or to learn to do so.	OEA.7.2.a. Expect that communicating with healthcare practitioners via mHealth enhances the likelihood to increase own health behavior according to evidence-based recommendations. OEA.7.2.b Notice the advantages of communicating with healthcare practitioners via mHealth. OEA.7.2.c. Feel positive about communicating with healthcare practitioners via mHealth.	SN.7.2.a. Notice that many health-conscious individuals communicate with their healthcare practitioners via mHealth. SN.7.2.b. Notice that communicating with healthcare practitioners via mHealth does not need approval by others. SN.7.2.c. Find role models or supporters in own or extended social network who usually communicate with healthcare practitioners via mHealth.	SIH.7.2.a. Maintain communicating with healthcare practitioners via mHealth until habitual. SIH.7.2.b. Identify as a health-conscious person who communicates with healthcare practitioners via mHealth. SIH.7.2.c. Identify as a healthy homemaker and role model who guides own children and partner to use modern technology for healthcare.	ER.7.2.a. Expect initial discomfort when not used to communicating with healthcare practitioners via mHealth. ER.7.2.b. Notice that communicating with healthcare practitioners via mHealth is enjoyable. ER.7.2.c. Feel great about having communicated with healthcare practitioners via mHealth on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.3.

PO.7.3. Take recommended questionnaires in mHealth app to become aware of current behaviors and to assess discrepancies between current and recommended behavior. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.3.a. Get informed about the benefits and importance of taking questionnaires in mHealth app to assess own health behavior, and learn to do so. CKR.7.3.b. Acknowledge the habitual character assessing own health behaviors and the need to change environmental cues to take questionnaires in mHealth app to assess own health behavior. CKR.7.3.c. Decide to commit to the strategies for taking questionnaires in mHealth app.	PB.7.3.a. Get informed about possible perceived barriers taking questionnaires in mHealth app to assess own health behavior and identify personal barriers. PB.7.3.b. Get informed about possible solutions to overcome perceived barriers taking questionnaires in mHealth app to assess own health behavior and implement the most suitable solutions.	SSE.7.3.a. Feel confident about taking questionnaires in mHealth app to assess own health behavior. SSE.7.3.b. Express confidence in ability to take questionnaires in mHealth app to assess own health behavior, or to learn to do so.	OEA.7.3.a. Expect that taking questionnaires in mHealth app to assess own health behavior enhances the likelihood to increase own health behavior according to evidence-based recommendations. OEA.7.3.b Notice the advantages of taking questionnaires in mHealth app to regularly assess own health behavior. OEA.7.3.c. Feel positive about taking questionnaires in mHealth app to assess own health behavior.	SN.7.3.a. Notice that many health-conscious individuals use mHealth to assess their own health behavior on a regular basis. SN.7.3.b. Notice that taking questionnaires in mHealth app does not need approval by others. SN.7.3.c. Notice own social resources and find role models or supporters in own or extended social network who usually assess own health behavior via mHealth.	SIH.7.3.a. Maintain taking questionnaires in mHealth app to assess own health behavior until habitual. SIH.7.3.b. Identify as a health-conscious person who takes regular questionnaires to assess own health behavior.	ER.7.3.a. Expect initial discomfort when not used to taking questionnaires in mHealth app to assess own health behavior. ER.7.3.b. Notice that taking questionnaires in mHealth app to assess own health behavior is enjoyable. ER.7.3.c. Feel great about having taken a questionnaire in mHealth app to assess own health behavior on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.4.

PO.7.4. Select and commit to own long-term health goals in mHealth app. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.4.a. Get informed about the benefits of selecting and committing to own health goals in mHealth app, and learn to do so. CKR.7.4.b. Acknowledge the habitual character of selecting own health goals to stay committed and the need to change environmental cues to do so via mHealth. CKR.7.4.c. Decide to use the strategies for selecting and committing to own health goals in mHealth app.	PB.7.4.a. Get informed about possible perceived barriers selecting and committing to own health goals in mHealth app and identify personal barriers. PB.7.4.b. Get informed about possible solutions to overcome perceived barriers selecting and committing to own health goals in mHealth app and implement the most suitable solutions. PB.7.4.c. Expect and resist hindering social pressure by family members or the wider social network when committing to chosen health goals.	SSE.7.4.a. Feel confident about selecting and committing to own health goals in mHealth app. SSE.7.4.b. Express confidence in ability to select and commit to own health goals in mHealth app, or to learn to do so.	OEA.7.4.a. Expect that selecting and committing to own health goals in mHealth app enhances the likelihood to achieve own goals and ultimately decrease cardiovascular risk. OEA.7.4.b Notice the advantages of selecting and committing to own health goals in mHealth app. OEA.7.4.c. Feel positive about selecting and about committing to own health goals in mHealth app.	SN.7.4.a. Notice that health-conscious individuals select and commit to own health goals, many of them in mHealth apps. SN.7.4.b. Notice that selecting and committing to own health goals in mHealth app does not need approval by others. SN.7.4.c. Notice own social resources and find role models or supporters in own or extended social network who commit to their chosen health goals (via mHealth).	SIH.7.4.a. Maintain committed to own health goals in mHealth app and adapt them every once in a while until habitual. SIH.7.4.b. Identify as a health-conscious person who selects and commits to own health goals. SIH.7.4.c. Identify as a healthy homemaker and role model who guides own children and partner to select and commit to their chosen health goals.	ER.7.4.a. Expect initial discomfort when not used to selecting and committing to own health goals in mHealth app. ER.7.4.b. Notice that selecting and committing to own health goals in mHealth app is enjoyable. ER.7.4.c. Feel great about having selected and committed to a chosen health goal in mHealth app on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.5.

PO.7.5. Select and commit to health actions in mHealth app. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.5.a. Get informed about the benefits and importance of selecting and committing to health actions in mHealth app, and learn to do so. CKR.7.5.b. Acknowledge the habitual character of selecting health actions to stay committed and the need to change environmental cues to do so via mHealth. CKR.7.5.c. Decide to use the strategies for selecting and committing to health actions in mHealth app.	PB.7.5.a. Get informed about possible perceived barriers selecting and committing to health actions in mHealth app and identify personal barriers. PB.7.5.b. Get informed about possible solutions to overcome perceived barriers selecting and committing to health actions in mHealth app and implement the most suitable solutions. PB.7.5.c. Expect and resist hindering social pressure by family members or the wider social network when committing to chosen health actions.	SSE.7.5.a. Feel confident about selecting and committing to health actions in mHealth app. SSE.7.5.b. Express confidence in ability to select and commit to health actions in mHealth app, or to learn to do so.	OEA.7.5.a. Expect that selecting and committing to health actions in mHealth app enhances the likelihood to consistently complete health actions and ultimately decrease own cardiovascular risk. OEA.7.5.b Notice the advantages of selecting and committing to health actions in mHealth app. OEA.7.5.c. Feel positive about selecting and about committing to health actions in mHealth app.	SN.7.5.a. Notice that health-conscious individuals select and commit to health actions, many of them in mHealth apps. SN.7.5.b. Notice that selecting and committing to health actions in mHealth app does not need approval by others. SN.7.5.c. Notice own social resources and find role models or supporters in own or extended social network who commit to their chosen health actions.	SIH.7.5.a. Maintain committed to chosen health actions in mHealth app and select new health actions every once in a while until habitual. SIH.7.5.b. Identify as a health-conscious person who selects and commits to health actions. SIH.7.5.c. Identify as a healthy homemaker and role model who guides own children and partner to select their own health actions and to commit to chosen health actions.	ER.7.5.a. Expect initial discomfort when not used to selecting and committing to health actions in mHealth app. ER.7.5.b. Notice that selecting and committing to health actions in mHealth app is enjoyable. ER.7.5.c. Feel great about having selected and committed to chosen health actions in mHealth app on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.6.

PO.7.6. Set reminders, schedule, or link chosen health actions to repeated contexts. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.6.a. Get informed about the benefits and importance of setting reminders, scheduling, or linking chosen health actions to repeated contexts, and learn to do so. CKR.7.6.b. Acknowledge the habitual character of setting reminders, scheduling, or linking chosen health actions to repeated contexts and the need to change environmental cues to do so. CKR.7.6.c. Decide to use the strategies for setting reminders, scheduling, or linking chosen health actions to repeated contexts.	PB.7.6.a. Get informed about perceived barriers to set reminders, schedule or link chosen health actions to repeated contexts and identify personal barriers. PB.7.6.b. Get informed about possible solutions to overcome perceived barriers setting reminders, scheduling, or linking chosen health actions to repeated contexts and implement the most suitable solutions. PB.7.6.c. Expect and resist social pressure when setting reminders, scheduling, or linking health actions to repeated contexts.	SSE.7.6.a. Feel confident about setting reminders, scheduling, or linking chosen health actions to repeated contexts. SSE.7.6.b. Express confidence in ability to set reminders, schedule, or link chosen health actions to repeated contexts, or to learn to do so.	OEA.7.6.a. Expect that setting reminders, scheduling, or linking chosen health actions to repeated contexts enhances the likelihood to routinely complete health actions and to ultimately decrease own cardiometabolic risk. OEA.7.6.b Notice the advantages of setting reminders, scheduling, or linking chosen health actions to repeated contexts. OEA.7.6.c. Feel positive about setting reminders, scheduling, or linking chosen health actions to repeated contexts.	SN.7.6.a. Notice that health-conscious individuals set reminders, schedule, or link chosen health actions to repeated contexts. SN.7.6.b. Notice that setting reminders, scheduling, or linking chosen health actions to repeated contexts does not need approval by others, but that social support facilitates own success. SN.7.6.c. Notice own social resources and find role models or supporters in social network who set reminders, schedule, or link chosen health actions to repeated contexts.	SIH.7.6.a. Maintain setting reminders, scheduling, or linking chosen health actions to repeated contexts until habitual. SIH.7.6.b. Identify as a health-conscious person who sets reminders, schedules, or links chosen health actions to repeated contexts. SIH.7.6.c. Identify as a healthy homemaker and role model who guides own children and partner to set reminders, schedule, or link chosen health actions to repeated contexts.	ER.7.6.a. Expect initial discomfort when not used to setting reminders, scheduling, or linking chosen health actions to repeated contexts. ER.7.6.b. Notice that setting reminders, scheduling, or linking chosen health actions to repeated contexts is enjoyable. ER.7.6.c. Feel great about having set reminders, scheduled, or linked chosen health actions to repeated contexts on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.7.

PO.7.7. Monitor own progress of health actions and health goals in mHealth app on a weekly basis. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.7.a. Get informed about the benefits and importance of monitoring own progress of health actions and health goals in mHealth app, and learn to do so. CKR.7.7.b. Acknowledge the habitual character of monitoring health behavior and the need to change environmental cues to monitor own progress of health actions and health goals in mHealth app. CKR.7.7.c. Decide to commit to monitoring own progress of health actions and health goals in mHealth app.	PB.7.7.a. Get informed about possible perceived barriers monitoring own progress of health actions and health goals in mHealth app and identify personal barriers. PB.7.7.b. Get informed about possible solutions to overcome perceived barriers monitoring own progress of health actions and health goals in mHealth app and implement the most suitable solutions.	SSE.7.7.a. Feel confident about monitoring own progress of health actions and health goals in mHealth app. SSE.7.7.b. Express confidence in ability to monitor own progress of health actions and health goals in mHealth app, or to learn to do so.	OEA.7.7.a. Expect that monitoring own progress of health actions and health goals in mHealth app enhances the likelihood to increase own health behavior according to evidence-based recommendations and to decrease own cardiometabolic risk. OEA.7.7.b Notice the advantages of monitoring own progress of health actions and health goals in mHealth app. OEA.7.7.c. Feel positive about monitoring own progress of health actions and health goals in mHealth app.	SN.7.7.a. Notice that health-conscious individuals monitor their progress in health actions and health goals, many of them via mHealth apps. SN.7.7.b. Notice that monitoring own progress of health actions and health goals in mHealth app does not need approval by others. SN.7.7.c. Find role models or supporters in social network who monitor own progress in health actions and goals via mHealth.	SIH.7.7.a. Maintain monitoring own progress of health actions and health goals in mHealth app until habitual. SIH.7.7.b. Identify as a health-conscious person who monitors own progress of health actions and health goals in mHealth app. SIH.7.7.c. Identify as a healthy homemaker and role model who guides own children and partner to monitor own progress of health actions and health goals.	ER.7.7.a. Expect initial discomfort when not used to monitoring own progress of health actions and health goals in mHealth app. ER.7.7.b. Notice that monitoring own progress of health actions and health goals in mHealth app is enjoyable. ER.7.7.c. Feel great about having monitored own progress of health actions and health goals in mHealth app on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.8.

PO.7.8. Reschedule missed or skipped health actions. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.8.a. Get informed about the benefits and importance of rescheduling missed or skipped health actions, and learn to do so. CKR.7.8.b. Acknowledge the habitual character of missing or skipping unfamiliar health actions and the need to change environmental cues to reschedule missed or skipped health actions. CKR.7.8.c. Decide to commit to rescheduling of missed or skipped health actions.	PB.7.8.a. Get informed about possible perceived barriers rescheduling missed or skipped health actions and identify personal barriers. PB.7.8.b. Get informed about possible solutions to overcome perceived barriers rescheduling missed or skipped health actions and implement the most suitable solutions.	SSE.7.8.a. Feel confident about rescheduling missed or skipped health actions. SSE.7.8.b. Express confidence in ability to reschedule missed or skipped health actions, or to learn to do so.	OEA.7.8.a. Expect that rescheduling missed or skipped health actions especially in repeated contexts enhances the likelihood to automate new health behaviors long-term and to ultimately decrease own cardiometabolic risk. OEA.7.8.b Notice the advantages of rescheduling missed or skipped health actions. OEA.7.8.c. Feel positive about rescheduling missed or skipped health actions.	SN.7.8.a. Notice that health-conscious individuals reschedule missed or skipped health actions. SN.7.8.b. Notice that rescheduling missed or skipped health actions does not need approval by others. SN.7.8.c. Notice own social resources and find role models or supporters in own or extended social network who reschedule missed or skipped health actions.	SIH.7.8.a. Maintain rescheduling missed or skipped health actions until habitual. SIH.7.8.b. Identify as a health-conscious person who reschedules missed or skipped health actions. SIH.7.8.c. Identify as a healthy homemaker and role model who guides own children and partner to reschedule missed or skipped health actions.	ER.7.8.a. Expect initial discomfort when not used to rescheduling missed or skipped health actions. ER.7.8.b. Notice that rescheduling missed or skipped health actions is enjoyable. ER.7.8.c. Feel great about having rescheduled a missed or skipped health action on a given day.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.9.

PO.7.9. Evaluate own performance in chosen health actions and health goals in mHealth app when recommended. ***Woman post-GDM will:***						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.9.a. Get informed about the benefits and importance of evaluating own performance in chosen health actions and health goals in mHealth app, and learn to do so. CKR.7.9.b. Acknowledge the habitual character of self-evaluation and the need to change environmental cues to evaluate own performance in mHealth app. CKR.7.9.c. Decide to evaluate own performance in chosen health actions and health goals in mHealth app.	PB.7.9.a. Get informed about possible perceived barriers evaluating own performance in chosen health actions and health goals in mHealth app and identify personal barriers. PB.7.9.b. Get informed about possible solutions to overcome perceived barriers evaluating own performance in chosen health actions and health goals in mHealth app and implement the most suitable solutions.	SSE.7.9.a. Feel confident about evaluating own performance in chosen health actions and health goals in mHealth app. SSE.7.9.b. Express confidence in ability to evaluate own performance in chosen health actions and health goals in mHealth app, or to learn to do so.	OEA.7.9.a. Expect that evaluating own performance in chosen health actions and health goals in mHealth app enhances the likelihood to progress and ultimately decrease own cardiometabolic risk. OEA.7.9.b Notice the advantages of evaluating own performance in chosen health actions and health goals in mHealth app. OEA.7.9.c. Feel positive about evaluating own performance in chosen health actions and health goals in mHealth app.	SN.7.9.a. Notice that health-conscious individuals evaluate own performance in chosen health actions and health goals, many of them via mHealth apps. SN.7.9.b. Notice that evaluating own performance in chosen health actions and health goals in mHealth app does not need approval by others. SN.7.9.c. Notice own social resources and find role models or supporters in own or extended social network who evaluate own performance in chosen health actions and health goals (via mHealth).	SIH.7.9.a. Maintain evaluating own performance in chosen health actions and health goals in mHealth app until habitual. SIH.7.9.b. Identify as a health-conscious person who evaluates own performance in chosen health actions and health goals in mHealth app. SIH.7.9.c. Identify as a healthy homemaker and role model who guides own children and partner to usually evaluate own performance in chosen health actions and health goals.	ER.7.9.a. Expect initial discomfort when not used to evaluating own performance in chosen health actions and health goals in mHealth app. ER.7.9.b. Notice that evaluating own performance in chosen health actions and health goals in mHealth app is enjoyable. ER.7.9.c. Feel great about having evaluated own performance in chosen health actions and health goals in mHealth app.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 3 (continued): Change objectives for performance objective 7.10.

PO.7.10. Adapt chosen health goals and health actions when necessary. *Woman post-GDM will:*						
Commitment, behavioral knowledge, and perceived risk (CKR)	**Perceived barriers (PB)**	**Perceived skills and self-efficacy (SSE)**	**Outcome expectations and attitudes (OEA)**	**Perceived social norms (SN)**	**Self-image and habits (SIH)**	**Emotional reaction to behavior (ER)**
CKR.7.10.a. Get informed about the benefits and importance of adapting chosen health goals and health actions when necessary, and learn to do so. CKR.7.10.b. Acknowledge the habitual character of adapting goals when necessary and the need to change environmental cues to do so for own health goals and health actions. CKR.7.10.c. Decide to commit to the strategies for adapting chosen health goals and health actions when necessary.	PB.7.10.a. Get informed about possible barriers adapting chosen health goals and health actions and identify personal barriers. PB.7.10.b. Get informed about possible solutions to overcome perceived barriers adapting chosen health goals and health actions when necessary and implement the most suitable solutions. PB.7.10.c. Expect and resist hindering social pressure by family members or the wider social network when adapting chosen health goals and health actions.	SSE.7.10.a. Feel confident about adapting chosen health goals and health actions when necessary. SSE.7.10.b. Express confidence in ability to adapt chosen health goals and health actions when necessary, or to learn to do so.	OEA.7.10.a. Expect that adapting chosen health goals and health actions when necessary enhances the likelihood for long-term success in health behavior change and cardiometabolic risk reduction. OEA.7.10.b Notice the advantages of adapting chosen health goals and health actions when necessary. OEA.7.10.c. Feel positive about adapting chosen health goals and health actions when necessary.	SN.7.10.a. Notice that health-conscious individuals adapt their health goals and health actions when necessary. SN.7.10.b. Notice that adapting chosen health goals and health actions when necessary does not need approval by others. SN.7.10.c. Find role models or supporters in own or extended social network who adapt their health goals and health actions when necessary.	SIH.7.10.a. Maintain adapting chosen health goals and health actions when necessary until habitual. SIH.7.10.b. Identify as a health-conscious person who adapts chosen health goals and health actions when necessary. SIH.7.10.c. Identify as a healthy homemaker and role model who guides own children and partner to adapt chosen health goals and health actions when necessary.	ER.7.10.a. Expect initial discomfort when not used to adapting chosen health goals and health actions when necessary. ER.7.10.b. Notice that adapting chosen health goals and health actions when necessary is enjoyable. ER.7.10.c. Feel great about having adapted chosen health goals and health actions when necessary.

CKR = commitment, behavioral knowledge, and perceived risk, ER = emotional reaction to behavior, OEA = outcome expectations and attitudes, PB = perceived barriers, PO = performance objective, SIH = self-image and habit, SN = perceived social norms, SSE = skills and self-efficacy

Supplementary Table 4: Types of questions for the TRIANGLE in-app questionnaires

Question type	Motion data
Open-ended question	• Question: text • Answer: text
Numerical question	• Question: text • Answer: numeric characters
Single choice question	• Question: text • Answer: one to n options to select from, only one selection possible
Multiple choice question	• Question: text • Answer: one to n options to select from, multiple selections possible
Scale question	• Question: text • Answer: Choice of a value on the pre-defined scale
Branching question	• Question: text • Answer: two to four options to select from, only one selection possible

Supplementary Table 5: List of TRIANGLE in-app questionnaires

Questionnaire theme	Questionnaire sub-theme	Condition
Personal *TRIANGLE* goals	Outcome goals	
	Physical activity goals	
	Nutrition goals	
	Psychosocial wellbeing goals	
	Initial *TRIANGLE* achievements	After two months of intervention
	Progressive *TRIANGLE* achievements	After four months of intervention
Food composition questionnaires	Muesli composition	If habitual muesli
	Bread meal composition	If habitual bread meal
	Hot meal composition	If habitual hot meal
	Cold meal composition	If habitual cold meal
Physical activity questionnaires	Fitness self-test	If fitness self-test completed
	Duration of sports activities in the past seven days	

Supplementary Table 6: Initial paper and pencil assessments for the TRIANGLE intervention

Lifestyle area	Assessment items
Physical activity	• Current weekly sporting habits during the past month: frequency, intensity, time, type • Preferred current type of sports • Two preferred pre-pregnancy sporting habits: frequency, intensity, time, and type • Outcome expectations and attitudes towards sports • Sporting preferences • Self-efficacy and motivation to engage into sports • Tracking of training units • Social norms and own sporting behavior during childhood and youth • Stage of change for physical activity and sports • Selection of personal goals for physical activity in the scope of the intervention
Nutrition	• Habitual diet • Self-efficacy and motivation for a healthy nutrition • Own nutrition preferences and expectations • Social norms and own nutrition behavior during childhood and youth • Food group-based eating habits • Habitual meal types, frequency, and timing • Habitual beverages and total amount of liquids per day • Habitual meal planning, meal preparation types, use of sweeteners, and home food supplies • Eating priorities • Outcome expectations and attitudes towards nutrition • Stage of change for healthy nutrition behaviors • Selection of personal goals for healthy nutrition in the scope of the intervention
Psychology	• Habitual mindfulness, positive emotions, gratitude, optimism, relaxation activities, and prioritization • Sleep quality and quantity • Infant's sleep quality and quantity • Awareness for personal strengths • Problem-solving capacities • Stress-eating relation • Stage of change for mental health behaviors • Selection of personal psychological goals in the scope of the intervention

Supplementary Table 7: Overview of the TRIANGLE app content per lifestyle area as tested in the TRIANGLE user study. Part 1. Physical activity.

Questionnaire	Challenge	Library articles
	Challenge 1.1 “Monitor daily step count”, automatically followed by challenge 1.2 “Calculate the average daily step count of this week “	
In-app question on daily average step count of one week by personal coach	*If walking less than 2,500 steps a day:* Challenge 1.4.1 “Walk at least 3,000 steps”, automatically followed by challenges 1.4.2, 1.4.3, and 1.4.4 *If walking between 2,500 and 5,000 steps a day:* Challenge 1.4.2 “Walk at least 5,500 steps”, automatically followed by challenges 1.4.3, and 1.4.4 *If walking between 5,000 and 7,500 steps a day:* Challenge 1.4.3 “Walk at least 8,000 steps”, automatically followed by challenge 1.4.4 *If walking between 7,500 and 9,500 steps a day:* Challenge 1.4.4 “Walk at least 10,000 steps”	Daily physical activity basics Daily biking basics (video tutorial) Tips on posture in daily life and sports (4 video tutorials) Walking basics (video tutorial) Jogging basics (video tutorial)
	Challenge 1.7 “Conduct the fitness self-test” (5 guided practice videos)	Physical fitness basics Cardio training basics
	Challenge 1.10 “Daily 10-minute training” (12 guided practice videos, including warmup and cooldown)	Resistance training basics Ideal training intensity Individual adaptation of training intensity (4 video tutorials) Muscle ache (2 video tutorials) The need for active regeneration (2 video tutorials) Warmup and cooldown basics (3 video tutorials) Breathing support during resistance training (video tutorial) The right technique for basic resistance exercises (7 video tutorials)

Supplementary Table 7 (continued): Part 2. Nutrition

Questionnaire	Challenge	Library articles
If habitual breakfast cereal eater (as assessed in initial paper and pencil lifestyle questionnaire): **In-app questionnaire about habitual muesli composition**	*If less than one quarter of whole grain:* Challenge 2.11.1 "Have your muesli with one quarter of whole grain" *If less than one quarter of lean protein:* Challenge 2.11.2 "Have your muesli with one quarter of lean protein" *If less than one half of fresh fruit:* Challenge 2.11.3 "Have your muesli with one half of fresh fruit" *If one or two components are not met:* Challenge 2.11.4 "Have your ideal muesli" *If none of the components are met:* Challenge 2.11.1, automatically followed by 2.11.2, 2.11.3, and 2.11.4	Nutrition basics Eating basics Basic grocery shopping list
	Challenge 2.11.5 "Have your bread meal with one quarter of whole grain" Challenge 2.11.6 "Have your bread meal with one quarter of lean protein" Challenge 2.11.7 "Have your bread meal with one half of fresh fruit or vegetable" Challenge 2.11.8 "Have your ideal bread meal" Challenge 2.11.5, automatically followed by 2.11.6, 2.11.7, and 2.11.8	Tips for an optimal meal preparation Cooking basics Healthy snacking
Initial paper and pencil lifestyle questions include drinking behavior	*If less than 1.5 l of pure water OR predominantly drinks other than water, black coffee or plain tea:* Challenge 5.12.1 "Find your perfect thirst quencher" Challenge 5.12.2 "Drink at least 1.5 l of pure water a day" Challenge 5.12.3 "Drink at least 1.5 l of pure water or plain herbal tea a day and limit other drinks"	Beverage basics Optimal drinking Beverages – the exceptions

Supplementary Table 7 (continued): Part 3. Psychology/sleep

Questionnaire	Challenge	Library articles
In-app sleep questionnaire	*If current sleep problems are caused by infant's sleep problems:* Challenge 6.4 "Implement sleep enhancing recommendations for infants." *If current sleep problems independent from infant:* Challenge 6.5.1 "Keep a sleep diary", automatically followed by challenge 6.5.2 "Analyze your sleep diary", and by challenge 6.5.3 "Implement sleep enhancing recommendations for own sleep."	Basics for inner balance Sleep tips for me Sleep tips for my child Relaxation basics Four types of relaxation and suitable experiences of relaxation
Initial paper and pencil lifestyle questions include mindfulness	Challenge 6.1 "Eight minutes of mindfulness", automatically followed by challenge 6.2 "Five minutes of mindfulness", challenge 6.3 "Three minutes of mindfulness", and challenge 6.4 "Three mindful moments per day"	Mindfulness basics Tips for mindfulness practice Mindfulness exercises (6 guided practice audios) Optimism basics Five pessimistic and optimistic thinking patterns Self-efficacy basics

Supplementary Table 8: Adaptations of the initial paper and pencil questionnaire following the TRIANGLE user study

Removed items	Added items
• **Seven-item Physical Activity Readiness Questionnaire (PAR-Q) and postpartum sporting abilities** • **Emotional reaction to sports** • **History of incidents or injuries related to sports** • **13-item resiliency questionnaire**	• Two preferred pre-pregnancy sporting habits: frequency, intensity, time, type • Stage of change for engaging in physical activity and sports • Personal goals for physical activity during the intervention • Self-efficacy and motivation for a healthy nutrition • Own nutrition preferences and expectations • Social norms and own nutrition behavior during childhood and youth • Habitual meal planning, meal preparation types, use of sweeteners, and home food supplies • Nutritional priorities • Outcome expectations and attitudes towards nutrition • Stage of change for healthy nutrition behaviors • Personal goals for a healthy nutrition during the intervention • Child’s sleep quality and quantity • Stress-eating relation • Stage of change for mental health behavior • Personal mental health goals during the intervention

Supplementary Table 9: Blood parameters for laboratory assessments in the Test TRIANGLE Pilot Study

Blood parameter	Material	Time point
Creatinine	S-Monovette® Serum	Fasted blood sample (0 min)
Glutamate pyruvate transaminase	S-Monovette® Serum	Fasted blood sample (0 min)
γ-glutamyl transferase	S-Monovette® Serum	Fasted blood sample (0 min)
C-reactive protein	S-Monovette® Serum	Fasted blood sample (0 min)
Ferritin	S-Monovette® Serum	Fasted blood sample (0 min)
Triglycerides	S-Monovette® Serum	Fasted blood sample (0 min)
LDL-C	S-Monovette® Serum	Fasted blood sample (0 min)
HDL-C	S-Monovette® Serum	Fasted blood sample (0 min)
HbA1c	S-Monovette® K_3 EDTA	Fasted blood sample (0 min)
Small blood count	S-Monovette® K_3 EDTA	Fasted blood sample (0 min)
Differential blood count	S-Monovette® K_3 EDTA	Fasted blood sample (0 min)
Plasma blood glucose	S-Monovette® Fluoride	0 min, 30 min, 60 min, 90 min, 120 min
Insulin	S-Monovette® Serum	0 min, 30 min, 60 min, 90 min, 120 min
Thyroid-stimulating hormone	S-Monovette® Serum	Fasted blood sample (0 min) If thyroid-stimulating hormone anomaly, then additional free triiodothyronine (T3) and free thyroxin (T4) measurements

LDL-C = Low-Density Lipoprotein Cholesterol, HDL-C = High-Density Lipoprotein Cholesterol, HbA1c = glycated hemoglobin

Supplementary Table 10: Baseline characteristics at V1 for the control, intervention, and per protocol group in the Test TRIANGLE Pilot Study

		Control	Intervention	p-value [a)]	Per protocol	p-value [b)]
n		27	27		14	
DPP score (max. 4 points at baseline) missing = 1	0	1 (3.9%)	1 (3.7%)	0.74	1 (7.1%)	0.72
	1	20 (76.9%)	18 (66.7%)		7 (50.0%)	
	2	3 (11.5%)	5 (18.5%)		4 (28.6%)	
	3	1 (3.9%)	3 (11.1%)		2 (14.2%)	
	4	1 (3.9%)	0		0	
Physical activity [min/week]		803 (580-1,620)	855 (530-1,530)	0.79	670 (435-1,455)	0.36
Energy intake per day [kcal/day] missing = 1		2,213 (2,055-2,524)	2,246 (2,150-2,815)	0.56	2,217 (1,767-2,473)	0.84
Fiber intake [g/1,000 kcal] missing = 1		8 (7-12)	8 (7-11)	0.63	8 (7-11)	0.78
Fat intake [% of total kcal/day] missing = 1		39 (34-44)	38 (32-43)	0.49	38 (29-42)	0.63
Saturated fat intake [% of total kcal/day] missing = 1		13 (11-16)	12 (11-15)	0.55	12 (10-15)	0.46

Supplementary Table 10 (continued)

		Control	Intervention	p-value a)	Per protocol	p-value b)
Body weight [kg]		72.5 (66.3-84.4)	72.6 (61.9-83.2)	0.53	66.9 (61.9 -76.5)	0.28
BMI [kg/m²]		26.3 (23.2-30.3)	25.4 (22.1-30.5)	0.66	23.8 (21.3-27.2)	0.24
BMI category	≥ 23	21 (77.8%)	19 (70.4%)	0.76	8 (57.1%)	0.28
	< 23	6 (22.2%)	8 (29.6%)		6 (42.9%)	
AUC glucose [mg/dl*min] missing = 1		36,196 ± 7,704	33,185 ± 6,794	0.13	33,092 ± 7,406	0.13
Plasma glucose oGTT 60' [mg/dl] missing = 1		172 ± 49	157 ± 42	0.27	158 ± 46	0.32
Disposition index (DI) missing = 5		209 (122-282)	248 (180-312)	0.13	253 (180-312)	0.16
Insulin sensitivity index (ISI) missing = 5		4.3 (1.9-6.6)	4.9 (3.1-6.2)	0.45	4.7 (3.8-5.5)	0.55
VO_2peak [ml/min] missing = 11		1926 ± 439	1,889 ± 351	0.83	1,966 ± 369	0.84
Body fat mass [kg]		28 (20-36)	22 (18-31)	0.41	20.8 (16.8-27.2)	0.23
WHO-5 total score		14.4 ± 3.4	14.4 ± 3.1	0.89	13.8 ± 3.2	0.60
WHO-5 total score < 13		10 (37.0%)	6 (22.2%)	0.23	4 (28.6%)	0.73
PSS-10 total score		15.3 ± 5.8	14.2 ± 5.3	0.34	15.5 ± 5.1	0.88
Glucose tolerance status	Normal	14 (51.8%)	16 (59.2%)	0.43	9 (64.3%)	0.94
	IFG	2 (7.4%)	5 (18.5%)		1 (7.1%)	
	IGT	8 (29.6%)	5 (18.5%)		3 (21.4%)	
	IFG+IGT	3 (11.1%)	1 (3.7%)		1 (7.1%)	
Waist circumference [cm] missing = 1		88 (77-94)	82 (77-89)	0.27	81 (77-85)	0.19
Systolic blood pressure [mmHg] missing = 1		119 ±12	119 ±9	0.78	119 ±8	0.78
Diastolic blood pressure [mmHg] missing = 1		79 ±11	79 ±8	0.82	82 ±8	0.28

n (percent) for categorial variables, mean ± standard deviation for normally distributed metric variables, median (first and third quartile) for other metric variables; a, b) Chi-Square or Fisher-Exact Test for categorial and Mann-Whitney-U Test for metric variables; p-value a) for comparison of control and intervention subjects (modified intention-to-treat group); p-value b) for comparison of control and per protocol subjects. The per protocol group is a subset of participants of the intervention group who used the core features of the app regularly throughout the study. DPP = Diabetes Prevention Program,
BMI = body mass index, AUC glucose = area under the glucose curve, IFG = impaired fasting glucose, IGT = impaired glucose tolerance, oGTT = oral glucose tolerance test, VO_2peak = peak oxygen uptake, WHO-5 = World Health Organization-5 Well-Being Index, PSS-10 = Perceived Stress Scale-10 item

Supplementary Table 11: Percentage of perceived habit change in the control vs. the intervention group and in the control vs. the per protocol group in the Test TRIANGLE Pilot Study

		Control	Intervention	p-value a)	Per protocol	p-value b)
n		27	27		14	
Did you change health-related habits during the study? missing = 2	Def. not	6 (22.2%)	1 (4.0%)	***< 0.0001***	1 (7.7%)	***0.002***
	Rather not	11 (40.7%)	0 (0.0%)		0 (0.0%)	
	Rather yes	8 (29.6%)	13 (52.0%)		7 (53.9%)	
	Def. yes	2 (7.4%)	11 (44.0%)		5 (38.5%)	

n (percent), [a, b] Chi-Square or Fisher-Exact Test; p-value [a)] for comparison of control and intervention subjects (modified intention-to-treat group); p-value [b)] for comparison of control and per protocol subjects. The per protocol group is a subset of participants of the intervention group who used the core features of the app regularly throughout the study.