Aus der

Klinik für Orthopädie und Unfallchirurgie

Klinikum der Ludwig-Maximilians-Universität München

The Association of Personality Traits with Tertiary Care Outcomes of Elderly Patients with Mobility Impairments

Dissertation

zum Erwerb des Doctor of Philosophy (Ph.D.)

an der Medizinischen Fakultät

der Ludwig-Maximilians-Universität München

vorgelegt von

Sebastian Franz Fuchs

aus

Ebersberg / Deutschland

Jahr

2026

Mit Genehmigung der Medizinischen Fakultät der
Ludwig-Maximilians-Universität München

Erstes Gutachten:	Prof. Dr. Martin Weigl
Zweites Gutachten:	Prof. Dr. Lars Schwettmann
Drittes Gutachten:	Prof. Dr. Clemens Cyran
Viertes Gutachten:	Prof. Dr. Sophia Stöcklein

Dekan: Prof. Dr. med. Thomas Gudermann

Tag der mündlichen Prüfung: 16.06.2026

Affidavit

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

Dean´s Office Medical Faculty
Faculty of Medicine

Affidavit

Fuchs, Sebastian

Surname, first name

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is my own work. I have only used the sources indicated and have not made unauthorised use of services of a third party. Where the work of others has been quoted or reproduced, the source is always given.

I further declare that the dissertation presented here has not been submitted in the same or similar form to any other institution for the purpose of obtaining an academic degree.

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Dean´s Office Medical Faculty
Doctoral Office

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List of abbreviations

ASA Score	American Society of Anesthesiologists (ASA) physical status classification system
ASKU	Allgemeine Selbstwirksamkeit Kurzskala (English: General Self-Efficacy Short Scale)
BE	Behavioral Economics
DAG	Directed Acyclic Graph
DizzyReg	The Patient Registry of the German Center for Vertigo and Balance Disorders
DHI	Dizziness Handicap Inventory
DSGZ	Deutsches Schwindel- und Gleichgewichtszentrum (German Center for Vertigo and Balance Disorders
EQ-index	EQ-5D-5L Utility Index calculated from Utility Values of the German Population
EQ-5D-5L	EuroQol Five-Dimensional Five-Level Questionnaire
EQ-VAS	EuroQol Visual Analogue Scale
HRQoL	Health-Related Quality of Life
H-WTTR	Willingness to Take Risks in the Context of Health
LMU	Ludwig-Maximilians-Universität München (Ludwig Maximilian University of Munich)
LMU clinic	Klinikum der Ludwig-Maximilians-Universität München (University Clinic of the Ludwig Maximilian University of Munich)
MobilE-TRA 2	Auswirkung individueller verhaltens- und sozioökonomischer Aspekte auf patientenrelevante Ergebnisse bei Patienten mit Schwindel und Gleichgewichtsstörungen sowie Gelenkerkrankungen (Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults)
MobilE-NET	Munich Network Health Care Research
MUM	Musculoskeletal University Center Munich
OA	Osteoarthritis
THR	Total Hip Replacement
TKR	Total Knee Replacement
WOMAC	Western Ontario and McMaster Universities Osteoarthritis Index
VDB	Vertigo, Dizziness, and Balance Problems

List of publications

Peer reviewed publications used for this doctoral thesis

- **Paper I:**
  Fuchs S, Schwettmann L, Katzenberger B, Paulus A, Holzapfel B M, Biebl J T, Weigl M (2025).
  Association of self-efficacy, risk attitudes, and time preferences with health-related quality of life and functioning after total hip or knee replacement–Results of the MobilE-TRA 2 cohort.
  Health and Quality of Life Outcomes, 23(1), 44. DOI: 10.1186/s12955-025-02374-y

- **Paper II:**
  Katzenberger B, **Fuchs S**, Schwettmann L, Strobl R, Hauser A, Koller D, Grill E (2023).
  Association of self-efficacy, risk attitudes, and time preferences with functioning in older patients with vertigo, dizziness, and balance disorders in a tertiary care setting – Results from the MobilE-TRA2 cohort.
  Frontiers in Neurology 14: 1316081. DOI: 10.3389/fneur.2023.1316081

Additional peer reviewed publications

- **Paper III:**
  Katzenberger B, Schwettmann L, Weigl M, Paulus A, Pedron S, **Fuchs S**, Koller D, Grill E (2021).
  Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults (MobilE-TRA 2):
  study protocol of an observational cohort study in a tertiary care setting.
  BMJ Open 11(12): e051915. DOI: 10.1136/bmjopen-2021-051915

Conference Contributions

- Katzenberger B, **Fuchs S**, Schwettmann L, Strobl R, Hauser A, Koller D, Grill E (2023).
  Risk attitude and self-efficacy are associated with vertigo-specific functioning in older patients with vertigo, dizziness and balance disorders – results from the longitudinal multicenter study MOBILE-TRA 2.
  18. Jahrestagung DGEpi, oral presentation. Würzburg, Germany

1 My contribution to the publications

1.1 Contribution to publication I (Fuchs et al. 2025)

I, Sebastian Fuchs, contributed to the conceptualization of the study with Lars Schwettmann, Martin Weigl, and Alexander Paulus. I was solely responsible for patient recruitment and data collection, and follow-up assessments. In addition, I managed the datasets and conducted literature research to establish a comprehensive understanding of the current state of knowledge. In collaboration with Benedict Katzenberger, I processed the raw data, performed quality checks, and together we developed the methodological and analytical framework. I carried out the data analysis, visualized the results, prepared the manuscript, and published the final research report. Benedict Katzenberger validated the statistical approach. I drafted the manuscript and was responsible for integrating feedback from co-authors.
Alongside Martin Weigl, I administered the project. Lars Schwettmann, Martin Weigl, and Alexander Paulus secured project funding and supervised its implementation. All authors contributed to the review and editing of the manuscript.

1.2 Contribution to publication II (Katzenberger et al. 2023)

For this publication, I contributed my expertise throughout the project and manuscript creation. I provided feedback on the methodological section, developed by Benedict Katzenberger and Ralf Strobl, as well as on the study's concept, data analysis, and interpretation of the results. Together with Benedict Katzenberger, I supported data quality control of the processed datasets.
In agreement with Ralf Strobl and Ari Hauser, I approved the statistical approach. Benedict Katzenberger led the scientific investigation, conducted the data analysis, and prepared the original draft. Benedict Katzenberger and Ari Hauser created the data visualizations.
The project conceptualization was carried out by Benedict Katzenberger, Lars Schwettman, and Eva Grill. Benedict Katzenberger and Daniela Koller were responsible for project administration, while Lars Schwettmann and Eva Grill obtained funding and supervised the project. Eva Grill additionally managed project resources. All authors contributed to the writing, reviewing, and editing of the manuscript.

1.3 Contribution to publication III (Katzenberger et al. 2021, appendix publication)

Publication III presents the study protocol forming the basis for Publications I and II. It is included to provide a deeper understanding of the planning phase and study framework.
Together with Benedict Katzenberger, Eva Grill, Lars Schwettmann, Martin Weigl, Sara Pedron, and Alexander Paulus, I drafted, revised, and approved the manuscript of the protocol. Eva Grill, Lars Schwettmann, Martin Weigl, Alexander Paulus, and Daniela Koller were responsible for the conceptualization of the cohort and overall project design.

2 Introductory summary

2.1 Background

Mobility impairments are a major health concern in older adults [1]. In the affected population, such impairments are associated with lower health-related quality of life (HRQoL), poorer psychological health, decreased healthcare utilization, worse health outcomes, and a higher probability of falling [2–6]. In particular, joint diseases and vertigo, dizziness, and balance problems (VDB) seem to be the most influential factors for disability in this population [7]. Among musculoskeletal disorders, osteoarthritis is one of the conditions with the highest prevalence [8]. The German healthcare system faces several challenges, including an aging population and rising treatment costs [9]. Additionally, hospitals anticipate a surge in overall case numbers until 2050 [10]. Developing more efficient treatment strategies could help mitigate these pressures. Given their considerable impact on both patient health and the healthcare system, this thesis focuses on OA and the medical conditions encompassed by VDB.

OA is a complex, chronic health condition that affects the structure of joints and is a common cause of physical activity restrictions [11, 12]. It leads to multiple alterations of the joint, resulting in pain, functional limitations, and joint stiffness [13, 14]. Major risk factors are gender, obesity, genetics, diet, injury, abnormal joint loading, and age [15]. Hence, its prevalence is high in the elderly population.

The term VDB covers various medical conditions with multifactorial causes, including vestibular, visual, proprioceptive, cardiovascular, and psychiatric conditions or pathologies [16–20]. VDB affect more than 25% of the population aged 70 years and older [21, 22]. They are accountable for a major share of the burden of disability in elderly populations and severely affect patients' activity, participation, and mobility [7, 19, 23].

2.1.1 Osteoarthritis and total replacement of the Hip or Knee

According to the German S3 treatment guidelines for hip replacement and OA in the knee, conservative approaches, including physical activity, medication, injections, patient education, and the reduction of modifiable risk factors, should be applied before considering surgical intervention [24]. Nevertheless, the high effectiveness of total hip and knee replacement (THR/TKR) in restoring functioning and alleviating pain has been well established by previous research [25–27]. Therefore, when conservative options fail, THR/TKR is recommended as the treatment of choice for severe hip or knee OA [24, 28, 29].

2.1.2 Vertigo, Dizziness, Balance Problems, and Interdisciplinary Assessment

Most of the underlying conditions of VDB can be addressed with effective diagnostic and treatment methods [30–32]. While identifying the underlying condition is crucial for proper treatment and is advised by the German S2k guideline on vestibular functional disorders, differential diagnosis can be challenging and often requires an interdisciplinary approach [33–35]. Available treatment options include repositioning maneuvers, physical therapy, neuro-rehabilitation,

medication, or discontinuation of specific drugs, and surgery, but depend heavily on the specific condition [33, 36]. Despite the varying effectiveness of these treatments, patients with VDB undergoing interdisciplinary rehabilitation can improve their functional status in the long term [37].

2.1.3 Role of the patient in rehabilitation and postoperative outcomes

Physical activity and physical therapy can evidently improve patient health during treatment and rehabilitation of OA and VDB [38–40]. However, the patient's active contribution plays a vital role in managing these chronic health conditions.

After arthroplasty or in patients with OA in general, home exercise programs have been shown to positively affect pain and functional outcomes [41–44].

Nevertheless, the positive effects of exercise therapy diminish over time due to declining patient adherence to the prescribed exercises [42]. Moreover, Picha and Howell provide a framework for how an individual's belief in their capacity to act accordingly and to obtain a specific performance, defined as self-efficacy, amplifies the positive effects of home exercises on treatment success [45, 46]. Findings on self-efficacy in general rehabilitation after THR/TKR remain mixed. Previous evidence from a larger Norwegian cohort suggests that self-efficacy may enhance rehabilitation outcomes following THR [47]. In contrast, a study on an American cohort with a mixed THR/TKR population found no association between self-efficacy and post-treatment outcomes [48].

In individuals with VDB, home exercises were also an effective measure to improve health status and independence [49]. Yet, low adherence to home exercise recommendations appears to pose a risk to the therapeutic success of the treatment [50]. Regarding personality traits, self-efficacy was positively associated with a more confrontational and active approach to fear of heights, or more generally, visual height intolerance - a phobia comprising distress and vertigo when exposed to heights [51]. A qualitative assessment of the influence of VDB patients' self-efficacy in different everyday life activities supports the relevance of this personality trait [52].

These findings show how individuals with OA and VDB can deviate from beneficial health behavior. At the same time, they represent occasions in which patients' individual characteristics could influence the success of their therapy.

2.1.4 Behavioral Economic Perspective

In health economics, behavior aimed at improving or preserving health status is considered an investment in the individual's health [53]. Basic economic theory assumes that rational individuals will select the best investment to maximize their utility. Nevertheless, despite extensive education on adverse health outcomes, human decisions might deviate systematically from optimal behavior [54]. Behavioral economics (BE) explains these deviations from rational behavior by merging several scientific disciplines, including economics, psychology, neurology, and social sciences [55]. Thus, by incorporating the idea of personality traits, BE principles can help to conceive fluctuations in treatment success in empirical settings.

Three often-discussed behavioral economic personality traits will be the focus of this thesis: general self-efficacy, willingness to take risks in the context of health (H-WTTR), and time

preferences, specifically future orientation [54–60]. H-WTTR describes how well individuals deal with risk and uncertainty in health-related matters, while future orientation reflects an individual's discount rate of consequences occurring in a later period [57, 59, 61].

Their status as determinants of health behavior was established in previous works [59, 62–64]. Nevertheless, previous evidence on the actual predictive properties for the effectiveness of treatment in OA and VDB is weak for self-efficacy and lacking for H-WTTR and future orientation.

In hip and knee OA, guidelines for both joints are available on the highest evidence level of the classification system (S3). Additionally, the quality control of rehabilitation following THR/TKR is supported by an agreement of rehabilitation centers [24, 29, 65]. In VDB, the situation is more complex, as each condition requires a tailored approach. The current guideline on vestibular functional disorders is based on expert consensus. Thus, the guideline ranks in the middle of the classification system (S2k) [33]. Due to the higher degree of homogeneity and standardization, patients with OA may find it easier to obtain information and secure adequate rehabilitation than patients with VDB, and personality traits might further affect this coherence.

2.2 Research questions

This thesis aimed to research patients' behavior in real-life clinical settings and apply insights from BE theory. More specifically, it assesses the role of personality traits in rehabilitation in two different mobility-restricted cohorts: after THR/TKR to treat OA and after interdisciplinary assessment to treat VDB. The researched personality traits, self-efficacy, risk attitude, and time preferences, were analyzed regarding their:

- Association with patients' initial health status before the respective treatment.
- Predictive properties for health status three months after the initial treatment.
- Differences in the association with health status relative to one another.
- Associations with health status and potential differences between OA and VDB patient groups.

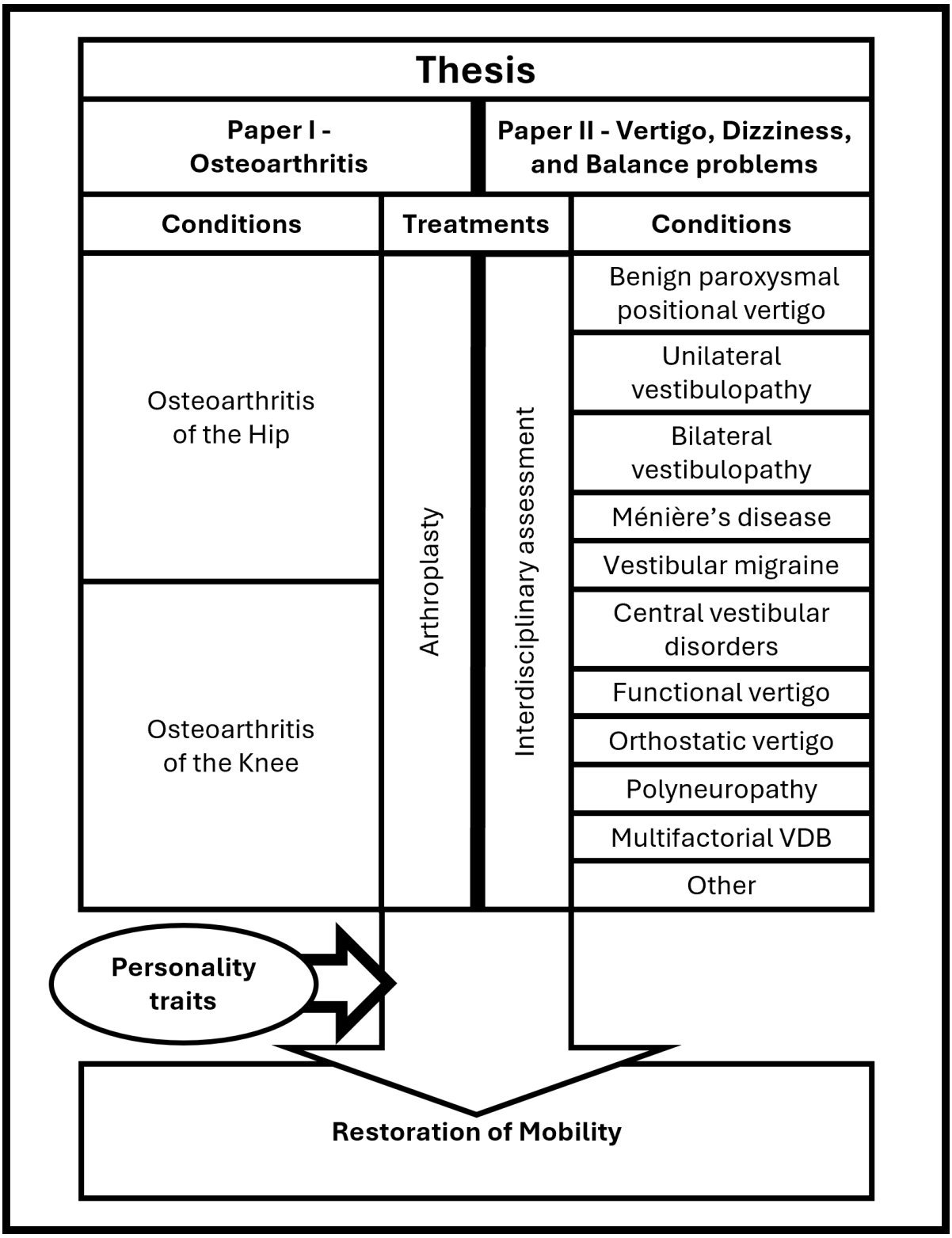

Figure 1: Schematic Overview of the Thesis.

2.3 Overview of articles included in the doctoral thesis

The articles that cumulatively form this doctoral thesis comprise one publication on OA patients and one on VDB patients. For a comprehensive understanding of the structured and well-planned execution of the project, the mutual study protocol for the overall project was included as a third appendix publication.

1. **Original research article:** Fuchs S, Schwettmann L, Katzenberger B, Paulus A, Holzapfel B M, Biebl J T, Weigl M (2025). Association of self-efficacy, risk attitudes, and time preferences with health-related quality of life and functioning after total hip or knee replacement – Results of the MobilE-TRA 2 cohort. Health and Quality of Life Outcomes, 23(1), 44. DOI: 10.1186/s12955-025-02374-y

2. **Original research article:** Katzenberger B, Fuchs S, Schwettmann L, Strobl R, Hauser A, Koller D, Grill E (2023). Association of self-efficacy, risk attitudes, and time preferences with functioning in older patients with vertigo, dizziness, and balance disorders in a tertiary care setting – Results from the MobilE-TRA2 cohort. Frontiers in Neurology 14: 1316081. DOI: 10.3389/fneur.2023.1316081

3. **Study protocol:** Katzenberger B, Schwettmann L, Weigl M, Paulus A, Pedron S, Fuchs S, Koller D, Grill E (2021). Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults (MobilE-TRA 2): study protocol of an observational cohort study in a tertiary care setting. BMJ Open 11(12): e051915. DOI: 10.1136/bmjopen-2021-051915

2.4 Methods

Although two distinct patient groups were included, the basic approach to data collection, management, and analysis remained the same for both cohorts. The processes and methods were adjusted only where necessary to meet specific challenges in a cohort. Thus, unless stated otherwise, the methodological description applies to both cohorts. Within a longitudinal observational study, patients were assessed before and three months after their treatment.

2.4.1 Data sources

This thesis was conducted as part of the project "Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults" (MobilE-TRA 2), a research project of the Munich Network Health Care Research (MobilE-NET) [66–68]. The MobilE-TRA 2 study was explicitly designed to examine determinants of BE associated with improved mobility in a cohort of older adults, aiming to enhance healthcare with its findings. Patients aged 60 years and older were asked to participate before treatment at the clinic of the Ludwig Maximilians University of Munich (LMU; LMU clinic) in Germany. Treatments took place at two divisions of the clinic. OA patients were treated at the Musculoskeletal University Center Munich (MUM), and VDB patients were treated at the German Center for Vertigo and Balance Disorders (DSGZ). Exclusion criteria included insufficient command of the German

language and other barriers that prevented participation in the study, such as visual, auditory, or cognitive impairments.

The treatment of all OA patients included in this study was conducted according to the German guidelines for THR and TKR by the Association of Scientific Medical Societies in Germany, as well as the standard procedures established at the LMU clinic [24, 28]. Baseline recruitment of THR/TKR patients commenced in October 2020 and was completed in July 2022, with follow-up assessments conducted between January 2021 and October 2022.

VDB patients in the study were recruited during their initial interdisciplinary evaluation after being referred to Tertiary care. Their recruitment began in December 2020 and concluded in June 2022, followed by a 3-month follow-up assessment from March 2021 to September 2022.

Patients were introduced to the study via mail or phone during their clinic visit. The paper-based and self-administered questionnaires were then completed at the clinic or at home. In the THR/TKR cohort, completion at the hospital after the inpatient admission was offered as an additional option on the day before surgery. To avoid multiple assessments of the same items, VDB data was combined with complementary patient data from the DizzyReg registry (The Patient Registry of the German Center for Vertigo and Balance Disorders) of the DSGZ [69]. Reminders ensured high participation rates in the three-month follow-up.

Due to considerable disparities in the clinically relevant differences and the number of observed diseases, the baseline sample size was calculated separately, with 131 patients required for the THR/TKR and 324 for the VDB cohort. As 144 THR/TKR and 337 patients answered questionnaires for baseline and follow-up, both study branches surpassed their recruitment aims.

2.4.2 Measures

2.4.2.1 Personality traits

This thesis assessed three personality traits as exposures: self-efficacy, willingness to take risks in the context of health (H-WTTR), and time preferences. Note that, while Publication II uses the term 'health-related risk attitudes,' this also refers to H-WTTR. These traits were selected because they had already been the subject of previous research in behavioral economics [54–60, 70]. The following paragraph provides a detailed description of these personality traits, along with a brief outline of relevant historical articles.

Albert Bandura introduced the concept of self-efficacy in 1977 [56]. It is defined as an individual's belief in successfully executing a skill or plan with their available abilities under specific circumstances and environmental influences [56, 71]. Thus, it is a crucial factor in human behavior that enables successful performance and the overcoming of obstacles. General self-efficacy was assessed using the General Self-Efficacy Short Scale, named "Allgemeine Selbstwirksamkeit Kurzskala" (ASKU) in the original German validation study [72]. Based on three questions ranging from 1 (very low) to 5 (very high), the score of the ASKU is calculated as the mean value of all given answers. The full text of the three questions is "I can rely on my own abilities in difficult situations," "I am able to solve most problems on my own", and "I can usually solve even challenging and complex tasks well" [73].

H-WTTR is the health-domain-specific application of the underlying concept of willingness to take risks in general [59, 61]. The concept of risk compensation was first described in Adam

Smith's *The Wealth of Nations* in 1776, a seminal work in economic theory [74]. While the concept of willingness to take risks in general dates back to the early literature, von Neumann and Morgenstern introduced the "utility of gambling" in 1947 and provided the first mathematical framework [75]. Since then, it has gradually found its way into health economics through its application in health insurance theory [76]. As the initial Grossman model on health demand did not include willingness to take risks [53, 77], there is no designated first publication that applies it directly to medical decisions. A working paper by Breyer and Fuchs in 1982 might represent one of the earliest adaptations [78]. The concept was adapted into a BE framework by Kahneman and Tversky in 1979 [70]. The H-WTTR item applied in this thesis was assessed by an extensively validated single-item question asking for the willingness to take risks in the context of health on an 11-point scale from 0 "not at all willing to take risks" to 10 "very willing to take risks" [59].

The roots of time preferences in economic theory lie in the second volume of the *Grundlagen der Nationalökonomie, Capital and Interest,* by Böhm-Bawerk from 1889 [79]. It discusses the varying time values of goods and how past experiences can alter an individual's perception of these values. The earliest traceable exploration of time preferences, health status, and behaviors in the literature was an article by Fuchs in 1980, which studied the theoretical concept in an empirical setting [80]. Similar to H-WTTR, this thesis applied health-domain-specific measures of time preferences. They were captured by two items based on single questions. The primary question used in all main analyses was "I am ready to sacrifice my well-being in the present to achieve certain results in the future" on a scale from 0 to 10, to assess the patients' future orientation [57]. The secondary time preference question was used in the sensitivity analysis of both publications to determine if the findings on time preferences remained robust with different measures. It inversely assessed present orientation by asking how much patients agreed with the statement "I am only concerned about the present, because I trust that things will work out themselves in the future" on a scale from 0 ("totally disagree") to 5 ("totally agree") [57].

2.4.2.2 Functioning

Specific standardized questionnaires on patients' functioning were applied as outcomes for both disease groups.

In THR/TKR patients, the German version of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) was used to assess OA-specific health status [81, 82]. The WOMAC was developed to evaluate OA in the hip or knee and is structured into three domains: five items ask about pain, 17 on functional limitation, and two on stiffness [81]. All three domains are weighted equally and summed to obtain the WOMAC global score, serving as an overall measure [83]. All WOMAC scores were transformed into a range from 0 (worst) to 100 (best) to facilitate the interpretation and comparison of the scores within the research article. This approach is consistent with methodological recommendations in the literature [84].

For VDB patients, the German version of the Dizziness Handicap Inventory (DHI) was implemented to assess functioning in participating patients [85, 86]. Developed for the assessment of dizziness, the DHI is also structured into three domains: seven items in the physical domain, nine items in the functional domain, and nine items in the emotional domain.

The overall DHI score is calculated by summing the values for each answer across all domains, resulting in a range from 0 (best) to 100 (worst). As outcome measures, the overall score and the separate domains were analyzed.

2.4.2.3 Health-related Quality of Life

Analyses on THR/TKR patients considered HRQoL as an additional outcome. HRQoL was measured by the EuroQol Five-Dimensional Five-Level Questionnaire (EQ-5D-5L) and the EuroQol visual analogue scale (EQ-VAS) [87]. The EQ-5D-5L is based on five questions, ranging from 0 (best) to 5 (worst), and was transformed using the German value set to obtain population-based utility values (EQ-index), ranging from -0.661 (worst) to 1 (best) [88]. The VAS assesses HRQoL from 0 (worst) to 100 (best), by asking: "We would like to know how good or bad your health is TODAY."

2.4.3 Statistical approach

For a general overview of the data, summary statistics were calculated for both cohorts and for each included disease individually. The analysis of THR/TKR also features an unadjusted comparison of outcomes before and after treatment, as well as baseline correlations between outcome measures and personality traits. The test statistics applied for this comparison included the t-test for unpaired samples, ANOVA, the Chi-squared test, and the Kruskal-Wallis test. Additionally, specifically for this thesis, the personality traits of OA and VDB patients before treatment were compared between the overall groups using Welch's t-test, which utilized mean values, standard deviations, and sample sizes from the articles.

Regression models were applied in both cohorts to analyze the prognostic properties of the examined personality traits. These models regressed on overall DHI for VDB and on global WOMAC, EQ-5D index, and EQ VAS for THR/TKR. Regressions were also conducted on the subscales of the disease-specific functioning scores. All analyses of VDB patients were conducted using mixed regression models and time interactions to model the influence of personality traits following treatment. The improvement of health outcomes by THR/TKR is typically limited by a characteristic ceiling effect, well-documented in the literature [89, 90]. This effect required controlling for the outcome at baseline in these regressions, as higher baseline scores would otherwise be associated with worse improvements after the treatment. To address this challenge, linear regression models were implemented on outcome change scores between baseline and follow-up to obtain a methodologically sound model.

For the selection of the covariates, directed acyclic graphs (DAGs) were constructed to analyze the interrelation between all considered measures and to determine the minimal adjustment set. This approach prevents the risk of over-adjustment or collider bias while controlling for confounding adequately [91]. The DAGs were constructed separately for each outcome and informed by an extensive literature review, supplemented by additional reference lists.

The creation and analyses of DAGs were conducted in DAGitty [92]. The data were analyzed in R [93].

2.5 Main results in OA and VDB cohorts

For THR and TKR, OA-specific functioning and HRQoL improved significantly after treatment. Self-efficacy was associated with better outcomes before and three months after the treatment. The pre-surgical associations applied to all HRQoL and functioning outcomes. While positive associations in the THR cohort after surgery were present for the EQ-index and all WOMAC functioning outcomes, they were only observed in EQ-VAS for the TKR cohort.

Preoperative associations with H-WTTR were present in the HRQoL outcomes across both arthroplasty treatments. Associations with future orientation before the surgery were limited to THR and only appeared in EQ-VAS and the WOMAC functioning subscale. Postoperatively, none of the health outcome scores showed any association with H-WTTR and future orientation. Comparing preoperative personality traits between the THR and TKR groups showed similar levels before the surgery.

For VDB, a significant improvement in functioning was found three months after interdisciplinary assessment. Self-efficacy was also associated with a better functional outcome before and three months after interdisciplinary assessment. H-WTTR was associated with functioning before interdisciplinary assessment but showed no associations with functional outcomes three months later. Future orientation did not show any association before or after interdisciplinary assessment. Differences in personality traits prior to treatment were also compared between each condition in the VDB groups. Only future orientation revealed significant differences between the groups, whereas self-efficacy and H-WTTR did not.

Calculating Welch's t-tests for each personality trait at baseline between the overall values of the OA and VDB cohorts did not reveal any significant differences for self-efficacy ($p = 0.42$), H-WTTR ($p = 0.26$), or future orientation ($p = 0.64$).

2.6 Discussion

The following section discusses the findings of the included research articles and concludes with a comparison of their key insights.

2.6.1 Discussion of Findings in OA cohort

Self-efficacy had the highest relevance across all treatment outcomes in patients undergoing THR/TKR, regardless of observation period. The association of H-WTTR was limited to better preoperative health status. Future orientation showed only weak preoperative associations, limited to a fraction of outcomes in THR.

Previous findings on self-efficacy in THR could be reproduced and extended for TKR using updated patient data. These previous examinations comprise a secondary data analysis by Brembo et al., which determined a positive association with health status [47] and a primary analysis by Hartley et al. that did not detect an association after treatment [48]. Hartley et al. included TKR patients in the study. Presumably, this association might not have been detected due to the smaller sample size and shorter follow-up period. Nevertheless, the positive associations before the THR/TKR surgery were confirmed by Hartley et al., and several studies on OA patients without THR/TKR surgery [48, 94–96].

The findings support H-WTTR as a factor influencing the timing of treatment. Uncertainty about the condition, as well as fear of severe diagnoses and surgical intervention, may delay patients from proactively seeking medical consultation. Conversely, a higher presurgical H-WTTR might encourage earlier clinical presentation, enabling the patient to confront their condition and proceed with treatment.

In the context of OA, this relationship might be especially relevant, as fear, particularly of post-surgical pain, appears to be a common concern among patients [97]. In the literature, this cognitive bias of preferring uncertainty over negative, yet relevant, information is referred to as the "ostrich effect" and has been found in other health behaviors [98]. The positive association between H-WTTR and health status before the surgery could therefore be explained if a lower H-WTTR promotes the "ostrich effect," leading to sooner diagnoses in patients with higher H-WTTR. However, previous studies have linked a higher H-WTTR to reduced use of preventive services, although these findings were predominantly not statistically significant [61].

Furthermore, individuals with higher H-WTTR may implement more effective strategies to handle their restrictions, which could also explain a causal relationship with the effectiveness of treatment.

The lack of an association between H-WTTR and health status after arthroplasty could be attributed to opposing effects on health status. While the associations before treatment suggest a positive and activating effect of H-WTTR, previous literature has linked H-WTTR and general willingness to take risks to less healthy behavior [59, 62]. Thus, the positive and negative effects might have canceled each other out, resulting in an overall neutral association after three months.

2.6.2 Discussion of Findings in the VDB cohort

In patients with VDB, self-efficacy also emerged as the most relevant personality trait, with consistently positive associations at both baseline and follow-up. Again, the associations of H-WTTR were confined to pre-treatment status, while no associations with future orientation appeared in any period.

The positive association between self-efficacy and better health status before and after interdisciplinary assessment of VDB patients is a novel finding in the literature. Besides these positive associations, low levels of self-efficacy were even associated with functional decline in VDB patients three months after their assessment. Thus, a specific level of self-efficacy seems to be required to cope with the challenge of diagnosis and pursue successful treatment. While these results quantitatively confirm the importance of self-efficacy in treating VDB, challenges arising from low self-efficacy in VDB were previously explored in a qualitative study [52]. In that study, patients with dizziness were interviewed about different aspects of their everyday lives. Avoidance behavior was a frequent issue found in domains with low self-efficacy. Overall, the positive association between higher self-efficacy and better functioning observed in Publication II aligns with previous research reporting beneficial effects of self-efficacy in VDB patients [51].

Similar to OA, uncertainty may influence patients' decisions on when to seek interdisciplinary assessment in VDB. As hypothesized for OA, the "ostrich effect" may also be relevant for VDB patients. Additionally, fear avoidance behavior could represent a mechanism linking H-WTTR

with disease management. While patients may avoid triggers of their symptoms, such as motion and visual stimuli, exposure to these triggers is known to reduce sensitivity [99]. Therefore, higher H-WTTR might support a more confrontational coping style before treatment initiation. The disappearance of this association three months after the interdisciplinary assessment could be a direct consequence of the treatment. Properly advised patients might become more aware of the benefits of challenging their symptoms, which would reduce the difference in health status between patients with high and low H-WTTR.

2.6.3 Comparison of OA and VDB cohorts

In direct comparison, the THR/TKR and VDB results were consistent overall and seemed to assemble a conclusive picture. The baseline values of self-efficacy, H-WTTR, and future orientation in the OA and VDB cohorts were also at a similar level. There was no evidence that associations between personality traits and health status were influenced by differences in the methodological rigor of the guidelines.

The findings on self-efficacy in both disease groups are consistent with its beneficial association with overall health and health behavior established in the literature [56, 100, 101].

H-WTTR revealed a more complex pattern: while positively associated with health before treatment, it showed no clear relationship afterward. To further investigate the distinctive similarity observed in H-WTTR, it is essential to examine the respective outcomes and subscales in detail. Among patients with VDB, the positive association between H-WTTR and overall DHI scores before treatment was characterized by significant associations in both the functional and emotional domains. In contrast, no such association was found for WOMAC in patients with OA. However, an association was identified prior to surgery for HRQoL. The EQ-5D-5L includes an item assessing emotional status, specifically anxiety and depression, whereas the WOMAC does not capture emotional aspects. This distinction suggests that emotional status may play a key role in the observed positive association prior to the treatment. A detailed analysis of individual EQ-5D-5L items was beyond the scope of Publication I, leaving this as a hypothesis for future research. Additionally, as a generic measure, the EQ-5D-5L may be less sensitive to emotional status in OA, compared to the DHI in VDB.

The associations between health status and future orientation before treatment were either low or absent, resulting in unclear relevance. No group showed associations after the treatment either. Therefore, no detailed assumptions should be made without further supporting data. Even though the missing associations for H-WTTR and future orientation after treatment also reveal a similarity between the two disease groups, this finding should be interpreted cautiously. The three-month time frame after treatment might have been too short to detect associations for both traits. This assumption would be particularly plausible for the question on future orientation, as patients might have referred to a time later than three months.

As OA and VDB comprise disparate health conditions with different characteristics and pathogeneses, the actual reasons for the similarity in personality traits' associations can only be hypothesized at the current research stage. The similarities may stem from mobility impairment as a shared symptom in OA and VDB.

However, testing this theory requires further research on personality traits in other treatments and diseases, as well as on the underlying mechanisms of the findings. Patients' fear of falling could be an example of such a mechanism affecting both assessed disease groups [102–104].

Long-term associations between these personality traits and health status should be investigated in subsequent examinations.

2.7 Strengths and Limitations

The studies included in this thesis, along with the research framework, demonstrate several strengths. The recruitment process and data collection followed a detailed and published study protocol, with a primary focus on personality traits as the subject of research. Validated instruments were applied wherever possible, ensuring high quality and reliability of the results.

Although the COVID-19 pandemic caused unavoidable interruptions in the recruitment of THR/TKR patients, the integrity of the sample was preserved. To further assess potential selection bias, the American Society of Anesthesiologists (ASA) physical status classification was analyzed as an independent indicator of patient health. The analysis revealed a consistent baseline health status across recruitment periods, supporting the robustness of the data.

Because both study arms were conducted under the same research protocol and through close collaboration between the two study teams, the same methodological rigor applies to the VDB publication and cohort. The VDB arm uses the same validated instruments and items to assess personality traits, with analysis adapted to the specific characteristics of this disease group.

Assessments of THR/TKR and VDB patients were conducted at identical intervals, shared the same conceptual design, and questionnaire structure. The close collaboration between the study arms facilitated optimal data quality, as teams exchanged practical experiences on enabling participation, supporting assessments, and follow-ups, to ensure high data completeness in all regards. The close cooperation also led to a joint, multi-step data quality control process.

Beyond data collection, this methodological diligence extended into the analytical process. Comprehensive DAGs informed the causal frameworks and guided the optimization of the main regression models in both publications [91, 92]. Because a validated time preference measure was not available, sensitivity analyses were conducted to support the validity of the applied items. Substituting present orientation for future orientation in the regression models did not alter the main findings in either disease group or across all outcomes.

Nevertheless, there are some noteworthy limitations. This study framework primarily employed self-reported measures to assess outcomes, exposures, and covariates. While most of the applied measures were validated in previous studies, self-assessment can be a source of information or self-report bias. Considering the clinical context and frail patient groups, this risk had to be accepted to keep the focus on straightforward and comprehensible measures. Especially in older patients, difficult questions are at risk of collecting biased, incomplete, or missing answers [105]. The limits of applying complex items in the present thesis were also demonstrated by the patients' low acceptance of a discrete choice experiment based on financial values [106]. This section of the questionnaire aimed to calculate individual intertemporal discount rates based on choices between financial values tied to specific time points. Thus, answering the questions requires diligent gauging of the options presented. Many patients also considered assessing

pecuniary questions in a clinical context, and shortly before treatment, to be unsuitable. This led to an excessively high rate of incomplete and invalid answers or to the complete omission of the discrete choice experiment. Consequently, it was not feasible to consider this instrument in any analysis.

As mentioned above, three months for follow-ups might also be too short to capture long-term associations with the treatments' effectiveness sufficiently. This might have especially influenced the results regarding H-WTTR or future orientation.

Despite the sensitivity analysis targeting the possible influence of COVID-19, the pandemic could have introduced other types of bias into the data, which might not be detectable by statistical means within the dataset.

As a final point, focusing on one tertiary care center per disease group within a single university hospital has both advantages and drawbacks. As every patient is treated under the same protocols, this focus improves comparability within the cohorts. However, this also limits the generalizability to other regions or healthcare facilities.

2.8 Contribution to scientific knowledge

This PhD thesis contributes to the current scientific understanding of how personality traits are associated with the rehabilitation of mobility-restricted elderly patients in tertiary care centers. While the scope of this thesis did not allow for the identification of universal principles in mobility-restricted patient groups, the insights gained are still highly valuable in advancing the understanding within the fields of medicine and BE.

Previous research findings on self-efficacy and rehabilitation after joint replacement could be reproduced and extended by high-quality examinations on up-to-date primary data. Furthermore, the association of self-efficacy and health status after TKR or VDB treatment is a novel finding.

Examining H-WTTR and future orientation regarding treatment is also a novelty in both disease groups. Although the findings on associations three months after the treatments did not show a clear direction, their exploration is an essential first step in understanding the role of personality traits in this rehabilitation context.

Moreover, including all three BE concepts in a single model is necessary to separate the individual influence of each personality trait from the others. From this perspective, the model design also brings additional value to the research on self-efficacy.

2.9 Practical relevance of results and outlook

Beyond its theoretical contributions to science, the insights presented in this doctoral thesis are also applicable to real-world scenarios.

All personality trait measures discussed in this thesis can be assessed in frail populations within five minutes. This quick assessment makes them practical as a screening tool during clinical consultations. Additionally, their suitability for self-assessment presents an opportunity to provide them to patients as a resource for self-evaluation.

Assuming the availability of individual personality trait data, patients at risk could be targeted directly to raise their awareness of their contribution to rehabilitation. Moreover, personality traits could be considered in the medical recommendation of whether the timing or treatment is appropriate. If treatment is unavoidable, interventions can help influence personality traits that may jeopardize the treatment's success. Building on the insights of this thesis, interventions in a clinical context could be particularly relevant for enhancing self-efficacy. This approach can be supported by previous assessments in a general healthy cohort that analyzed the effectiveness of various self-efficacy interventions in enhancing physical activity [107].

If H-WTTR, or future orientation, is found to have a long-term association with better treatment outcomes, interventions can also be adapted accordingly. However, a cautious approach is necessary for implementing interventions. Although the assumption that higher H-WTTR may enhance patients' physical activity in rehabilitation seems plausible, previous research linked it to generally poorer health outcomes [59, 62].

Considering personality traits in rehabilitation has the potential to serve as a cost-effective and efficient method to enhance the effectiveness and efficiency of patient care. Especially with healthcare facing the challenge of aging societies, and thus, increasing health costs and higher numbers of OA and VDB patients, such strategies will become more relevant in the future [108–111]. Further research will be necessary to support the findings of self-efficacy, extend them to other disease groups, clarify the role of H-WTTR and future orientation, and identify novel personality traits with medical relevance.

3 Publication I

Association of self-efficacy, risk attitudes, and time preferences with health-related quality of life and functioning after total hip or knee replacement – Results of the MobilE-TRA 2 cohort.

Sebastian Fuchs, Lars Schwettmann, Benedict Katzenberger, Alexander Paulus, Boris Michael Holzapfel, Johanna Theresia Biebl, Martin Weigl

Health and Quality of Life Outcomes
ACCEPTED 14 April 2025
DOI: 10.1186/s12955-025-02374-y

Fuchs *et al.*
Health and Quality of Life Outcomes (2025) 23:44
https://doi.org/10.1186/s12955-025-02374-y

Health and Quality of Life Outcomes

RESEARCH Open Access

Association of self-efficacy, risk attitudes, and time preferences with health-related quality of life and functioning after total hip or knee replacement – Results of the MobilE-TRA 2 cohort

Sebastian Fuchs[1,2,3*], Lars Schwettmann[4,5], Benedict Katzenberger[2,3], Alexander Paulus[1,6], Boris Michael Holzapfel[1], Johanna Theresia Biebl[1] and Martin Weigl[1]

Abstract

Background While total hip and knee replacement (THR/TKR) surgery are effective measures to restore functioning and reduce pain in patients with severe osteoarthritis (OA), long-term treatment effects vary among patients. Following behavioral economic theory, these differences may be partially attributed to the impact of personality traits on individual strategies to approach post-surgical challenges. This study explored the associations between self-efficacy, willingness to take risk regarding health (H-WTTR), and future orientation, and the 3-month course of health-related quality of life (HRQoL) and OA-specific health status.

Methods As part of the prospective and observational MobilE-TRA 2 cohort study, 147 patients aged 60 years and older were assessed by self-administered questionnaires before and three months after THR/TKR at a single German hospital. As indicators for the surgical outcome, HRQoL was assessed by the EuroQol Five-Dimensional Five-Level Questionnaire (EQ-5D-5L), including the visual analogue scale (EQ-VAS), and functioning was assessed by the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) using the global score, function score, and pain score. All WOMAC scores were transformed into scales with 0 = worst health and 100 = best health. Self-efficacy was measured using the General Self-Efficacy Short Scale. H-WTTR and future orientation were assessed by single-item questions on 11-point Likert scales. The associations between these personality traits and the 3-month change in the outcome scores were analyzed using linear regression models for THR and TKR respectively.

Results In THR patients a one-point-increase in self-efficacy was associated with improvements in EQ-5D-5L (β=0.0704; p=0.0099), WOMAC global (β=6.6337; p=0.0139), WOMAC function (β=8.2557; p=0.0046), and WOMAC pain (β=5.9994; p=0.0232). For TKR, only the association of self-efficacy with the EQ-VAS change-score was significant (β=5.8252; p=0.0482). Self-efficacy demonstrated weak positive, but not significant associations with all WOMAC scores and a negative association close to zero with the EQ-Index. H-WTTR and future orientation showed no significant associations to changes of the outcome scores.

*Correspondence:
Sebastian Fuchs
Sebastian.Fuchs@med.uni-muenchen.de
Full list of author information is available at the end of the article

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Conclusions Self-efficacy appears to be a prognostic factor for better THR/TKR outcomes after three months. If these findings can be confirmed in further research, strategies to improve self-efficacy should be considered in prehabilitation programs.

Trial registration Not applicable.

Keywords Self-efficacy, Risk attitudes, Time preferences, Arthroplasty, Health-related quality of life, Functioning

Background

Total hip and knee replacement (THR/TKR) combined are the most frequent surgeries in German hospitals [1]. The positive effects of THR/TKR for patients with severe osteoarthritis (OA) are well documented [2–4]. In all age groups, THR/TKR improve physical functioning and health-related quality of life (HRQoL) and reduce pain [5]. However, long-term treatment effects vary considerably among patients [6]. The reasons are still incompletely understood.

Previous literature highlights the importance of early rehabilitation in THR/TKR for the long-term improvement of HRQoL and functioning [7, 8]. Physical therapy and home exercises after surgery improve mobility and physical functioning and reduce pain [9, 10]. Better adherence to recommended exercise improves the long-term outcomes in patients with knee and/or hip OA [11]. Accordingly, personality traits associated with adherence to treatment recommendations may contribute to variations in HRQoL and functioning after THR/TKR.

Economic theory considers beneficial health behavior as an investment in good health [12]. However, individuals tend to deviate from favorable healthy behaviors despite ample knowledge about the consequences [13]. Behavioral economics integrates concepts from various other scientific fields including psychology, anthropology, and neuroscience to address and explain these deviations. This analysis focuses on self-efficacy, willingness to take risk in the context of health (H-WTTR), and time preferences, captured by future orientation, three often discussed personality traits in behavioral economics [13–17] and established determinants of health behavior [18–21]. Consequently, they might influence OA patients' strategies to approach challenges after THR/TKR and thus affect HRQoL and functioning.

Prior research on personality traits as prognostic factors for THR/TKR outcomes produced mixed findings. Whereas higher preoperative self-efficacy predicted improvements in OA-specific health status three months after THR [22], another examination of THR/TKR patients six weeks after surgery could not find evidence for this association [23]. A pilot study on a self-efficacy intervention before THR/TKR delivered inconclusive results [24].

Direct evidence linking future orientation or H-WTTR with THR/TKR is still missing. However, studies conducted in other populations have identified future orientation as a determinant of a more physically active lifestyle and greater adherence to physical activity advice and dietary recommendations [25–27]. Given that physical activity and avoiding obesity are associated with favorable outcomes following THR/TKR, it is plausible that future orientation may likewise contribute to improved postoperative results in this patient group. Risk preferences were linked to unhealthy behaviors such as smoking, but also to health-promoting behaviors such as physical activity [21, 27].

The aim of this study was to examine preoperative self-efficacy, H-WTTR, and future orientation as determinants of changes in different domains of HRQoL and OA-specific health status from the time of surgery to the three-month follow-up in patients with hip or knee OA undergoing THR/TKR.

Methods

Study design

This analysis is part of the longitudinal observational cohort study MobilE-TRA 2, conducted at the LMU University Hospital Munich in Germany. MobilE-TRA 2 examines determinants of patient outcomes using insights from behavioral economics to inform care practices and improve mobility and participation in older adults. The study comprises two subprojects targeting distinct disease groups: OA – the focus of this publication – and vertigo, dizziness, and balance disorders. The OA subproject was carried out at the Musculoskeletal University Center Munich (MUM), a division of the LMU University Hospital Munich [28, 29].

This subproject involved OA patients aged 60 and older presenting for THR/TKR at the MUM. Exclusion criteria were insufficient command of the German language or other insufficient skills to participate and fill out the questionnaire, such as impaired visual or hearing function. Eligibility was checked by a member of the study team.

The sample size was calculated based on the EuroQol visual analogue scale (EQ-VAS) assuming a minimum important change (MIC) of 9 for THR patients, 8 for TKR, and a SD of 18 for both groups [30]. The MIC

represents the minimal mean within-person change that is perceived by patients as important [31]. 38 THR and 47 TKR patients were necessary to estimate the mean with a power of 0.85 (α= 0.05). Two follow-ups and 20% loss to follow-up, derived from previous projects, required 132 (59 THR, 73 TKR) patients at baseline.

The study design was published beforehand [28] and approved by the ethics committee of the medical faculty at the Ludwig Maximilian University Munich. All participants provided written informed consent. This manuscript adheres to the STROBE Statement [32].

Setting, participants, and data collection

Assessments before (baseline) and three months after THR/TKR (follow-up) were conducted between November 2020 and October 2022. The study was introduced during clinic visits, at the ward, or by telephone. No participation incentive was offered. During recruitment, all eligible and available patients were contacted at the MUM for a complete survey. Interested patients received baseline study materials either personally or by mail. The baseline questionnaire completion period was within the last 14 days before THR/TKR. All questionnaires were paper-based and designed for self-administration, allowing participants to complete them independently at home or the MUM if their hospital stay commenced one day before their scheduled THR/TKR.

Follow-ups were sent by postal mail. Two reminders, by mail and telephone, followed in 9-day intervals. Reasons for premature withdrawal were obtained during these telephone calls. Throughout all assessments, participants could contact the study team if they required clarification on the questionnaires. Upon return, all questionnaires were checked for completeness and plausibility. In cases of missing or unclear responses, patients were contacted again. These extensive quality control procedures and comprehensive participant support contributed to high response rates and optimal data quality.

Intervention

THR/TKR were performed according to the German guidelines for THR/TKR indications of the Association of the Scientific Medical Societies in Germany and the hospital standard procedures [33, 34]. Physiotherapy started on the day of surgery or the following day. Further physiotherapeutic treatments were scheduled daily on weekdays and once per weekend.

Median hospital stay was 8 days for THR and TKR, respectively. Afterward, patients underwent approximately three weeks of multimodal inpatient rehabilitation, the typical postoperative care provided in Germany after THR/TKR [33, 34].

Measures

Outcomes

HRQoL was measured using the EuroQol Five-Dimensional Five-Level Questionnaire (EQ-5D-5L), its dimensions range from 0 (best) to 5 (worst), and the EuroQol visual analogue scale (EQ-VAS) ranging from 0 (worst) to 100 (best) [35]. The EQ-5D-5L utility index (EQ-index) ranging from − 0.661 (worst) to 1 (best) was calculated with the German value set for population-based utilities [36]. To facilitate the interpretation of the results, the MIC was included as a reference value for each outcome. According to previous literature, the MIC for the EQ-index was reported as 0.106 for improvements after THR and 0.090 after TKR [37]. On the EQ-VAS, the MIC was defined as a 9-point change for THR and an 8-point change for TKR [30].

OA-specific health status was assessed using the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) in Likert scale format [38, 39]. Based on 24 questions, separated into 3 different scales (pain, stiffness, physical function) the WOMAC was specifically developed to evaluate hip and knee OA [38]. The WOMAC global score was implemented by adding up all three equally weighted subscales [40]. Following methodological recommendations, WOMAC scores were transformed to a range from 0 (worst) to 100 (best) to facilitate interpretation and comparison between the scales [41]. As recommended in the literature, the MIC based on a change from their respective mean baseline values is 14% for the WOMAC global score, 13.9% for the functioning scale and 15.5% for the pain scale [42]. The respective values will be reported in the results section.

Personality traits

General self-efficacy was measured by the validated General Self-Efficacy Short Scale, ranging from 1 (very low) to 5 (very high) as the mean of three items on self-efficacy [43]. H-WTTR was assessed by a single validated question on an 11-point Likert Scale regarding willingness to take risk in the context of health from 0 ('not at all ready to take risks') to 10 ('very likely to take risks') [21]. Two single-question items captured time preferences. Future orientation was assessed by 'I am ready to sacrifice my well-being in the present to achieve certain results in the future' on an 11-point Likert scale [44], where higher values represent a stronger focus on the future. Present orientation was surveyed by 'I am only concerned about the present, because I trust that things will work themselves out in the future' from 1 (totally disagree) to 5 (totally agree) [44].

Covariables

Clinical data on body mass index (BMI), prior THR/TKR surgeries, and the American Society of Anesthesiologists (ASA) score [45] was collected from the clinical information system. The ASA score classifies preoperative physical health into five groups based on medical history, physical examination, and diagnostic tests: healthy, mild systemic disease, severe systemic disease, incapacitating disease constantly threatening life, and moribund (life expectancy < 24 hours). The ASA score is associated with perioperative risks.

Questionnaires assessed age, sex, education, marital status, and chronic comorbidities. Education was categorized by years of formal education: lower secondary (up to 9 years), intermediate secondary (10 - 11 years), upper secondary (12–13 years), and tertiary education (college/university degree) [29]. The prespecified list in Supplementary File 1 - Table S1 assessed the number of comorbidities. Free text on further diseases was classified according to the International Statistical Classification of Diseases and Related Health Problems 10th revision (ICD-10) [46]. The number of comorbidities was categorized into 0, 1, 2, 3, and 4 or more conditions.

Based on three directed acyclic graphs (DAGs), a confirmatory covariate selection identified the minimal sufficient adjustment sets for HRQoL and OA-specific functioning and pain. A separate literature review informed the model's interrelations and effect directions. Hence, regressions control sufficiently for potential confounding while avoiding over-adjustment or collider bias [47]. Supplementary File 2 - Figures 1 - 3 provide all DAG models with references. The DAG identified sex, age, and number of diseases as essential co-variates in all regression models and additionally education in estimations of HRQoL.

Statistical methods

Summary statistics were calculated separately for the total, THR, and TKR samples. Preoperative differences between THR and TKR patients were tested for significance using t-test, χ^2-test, and Kruskal–Wallis test, within-group between the assessments using t-tests, and Wilcoxon signed-rank tests. Baseline associations between personality traits were calculated by the Pearson correlation coefficient.

To examine the association between the personality traits self-efficacy, H-WTTR, and future orientation at baseline and change scores of HRQoL and OA-specific health status from baseline to follow-up, linear regression models were computed for EQ-5D index, EQ-VAS, WOMAC global, WOMAC function, and WOMAC pain. Analyses were separated by THR/TKR and outcome. A sensitivity analysis replaced future orientation with present orientation to check the robustness of results regarding time preferences. The models were adjusted for the baseline values of the outcome measure [22, 23, 48].

Only complete cases were analyzed, as missing data only affected three values in three different patients. According to Jakobsen et al., multiple imputation was deemed unnecessary, due to the low impact of missing data [49]. Supplementary File 3 - Table S2 provides an overview of missing data for all key variables.

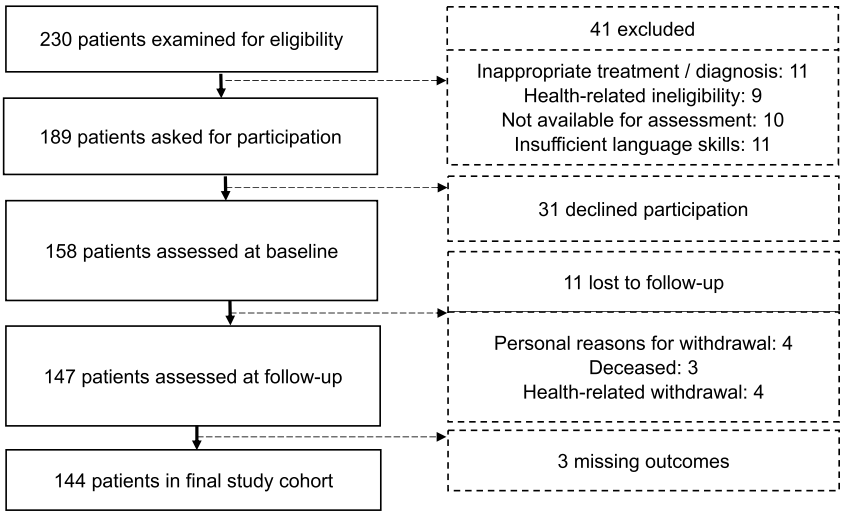

Fig. 1 Patient Flow Diagram

Sensitivity analysis addressed potential selection bias of healthier patients during the SARS-CoV- 2 pandemic due to limited availability of respirators and ICU beds. Univariate linear regression was used to analyze changes in the ASA score over time. The significance level was set at 5%.

Analyses were conducted in R version 4.2.2 [50]. DAGs were created and analyzed using DAGitty [51].

Results

Participants

During the recruitment period, 230 consecutive patients with THR/TKR were assessed for eligibility. 41 patients were ineligible and 31 declined participation. Of the remaining 158, 147 patients (93%) replied at follow-up. 11 patients were lost to follow-up. Missing outcome data required the exclusion of 3 more patients. Figure 1 gives detailed information on the patient flow.

Patient characteristics

Table 1 shows baseline patient characteristics. The study population was composed of 75 patients with THR and 69 with TKR. THR/TKR cohorts did not differ significantly, except for the worse ASA score before THR.

Treatment outcome

Table 2 presents HRQoL and WOMAC scores at baseline and follow-up. Both THR and TKR patients improved significantly, with greater improvements in THR patients.

Based on the respective baseline values and recommended thresholds from the literature, the calculated MICs for THR were 5.87 for the WOMAC global, 5.96 for the WOMAC functioning, and 6.88 for the WOMAC pain. For TKR, the corresponding MICs were 7.61 for the WOMAC global, 8.14 for the WOMAC functioning, and 8.31 for the WOMAC pain [42].

EQ-5D-5L dimensions

THR patients improved in all dimensions, particularly mobility and pain (Table 3). TKR also improved in mobility and pain, but the follow-up scores in self-care, usual activities, and anxiety/depression were similar to baseline.

Table 1 Preoperative patient characteristics

Measure	Value	Overall	Hip	Knee	*p*-value
n		144	75	69	
Age median [IQR]		72 [67, 79]	72 [67, 78]	72 [66, 79]	0.898[c]
Female, n (%)		81 (56.2)	45 (60.0)	36 (52.2)	0.437[a]
Self-efficacy (mean (SD))		4.03 (0.87)	4.03 (0.83)	4.01 (0.93)	0.935[a]
Health-related willingness to take risk (mean (SD))		4.90 (2.40)	4.72 (2.36)	5.10 (2.43)	0.342[a]
Future orientation (mean (SD))		6.30 (2.46)	6.28 (2.50)	6.32 (2.44)	0.924[c]
Number of diseases, n (%)	0	25 (17.4)	13 (17.3)	12 (17.4)	0.135[b]
	1	38 (26.4)	15 (20.0)	23 (33.3)	
	2	31 (21.5)	15 (20.0)	16 (23.2)	
	3	19 (13.2)	10 (13.3)	9 (13.0)	
	> 4	32 (21.5)	22 (29.3)	9 (13.0)	
BMI median [IQR]		26.9 [23.2, 30.1]	26.4 [22.0, 29.7]	27.5 [24.6, 30.4]	0.059[c]
ASA score, n (%)	1	4 (2.8)	3 (4.0)	1 (1.4)	0.028[b]
	2	52 (36.1)	19 (25.3)	33 (47.8)	
	3	85 (59.0)	52 (69.3)	33 (47.8)	
	4	3 (2.1)	1 (1.3)	2 (2.9)	
Previous THR/TKR, n (%)	Yes	52 (36.1)	24 (32.0)	28 (40.6)	0.370[b]
Years of education, n (%)	≤ 9	60 (41.7)	31 (41.3)	29 (42.0)	0.296[b]
	10 - 11	35 (24.3)	14 (18.7)	21 (30.4)	
	12 - 13	10 (6.9)	6 (8.0)	4 (5.8)	
	> 13	39 (27.1)	24 (32.0)	15 (21.7)	

IQR Interquartile range, *SD* Standard deviation, general self-efficacy (1–5) higher scores indicate higher self-efficacy, health-related willingness to take risk (0–10) lower values represent more risk aversion, future orientation (0–10) higher values indicate a stronger orientation on the future, *BMI* body mass index, *ASA score (1–5)* American Society of Anesthesiologists score assessing the physical status of a patient before surgery with values representing (1) healthy, (2) mild systemic disease, (3) severe systemic disease, (4) life-threatening severe systemic disease, (5) moribund patient respectively, *THR/TKR: (0, 1)* Total hip or knee replacement, indicates if a patient already had a total hip or knee replacement surgery at baseline assessment

P-values calculated using: [a] t-test for unpaired samples, [b] Chi-squared test, [c] Kruskal–Wallis test

Table 2 Quality of life and WOMAC scores at baseline and after three months

		THR			TKR	
Measure	**Baseline**	**Follow-up**	***p*-value**	**Baseline**	**Follow-up**	***p*-value**
n	75	75		69	69	
EQ-5D-5L utility index (median [IQR])	0.48 [0.33, 0.77]	0.88 [0.76, 0.94]	< 0.001[b]	0.67 [0.46, 0.85]	0.88 [0.74, 0.94]	< 0.001[b]
EQ-VAS (mean (SD))	56.80 (21.95)	69.44 (21.65)	< 0.001[a]	60.64 (19.81)	71.04 (18.82)	0.002[a]
WOMAC global (mean (SD))	41.93 (17.94)	74.22 (18.45)	< 0.001[a]	54.36 (19.90)	70.46 (19.05)	< 0.001[a]
WOMAC functioning (mean (SD))	42.90 (18.52)	76.02 (19.99)	< 0.001[a]	58.55 (20.20)	74.10 (20.16)	< 0.001[a]
WOMAC pain (mean (SD))	44.40 (19.85)	80.82 (18.83)	< 0.001[a]	53.62 (21.28)	74.24 (18.02)	< 0.001[a]
WOMAC stiffness (mean (SD))	38.50 (24.64)	65.83 (23.01)	< 0.001[a]	50.91 (27.06)	63.04 (24.86)	0.007[a]

All WOMAC scores were rescaled to 0–100 and inverted where high values represent a better health status; WOMAC global: aggregated score of all three WOMAC subscales equally weighted

THR Total hip replacement, *TKR* Total knee replacement, *EQ-5D-5L* EuroQol Five-Dimensional Five-Level Questionnaire, *EQ-VAS* EuroQol visual analogue scale, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index, *IQR* Interquartile range, *SD* Standard deviation

P-values for differences between baseline and follow-up within groups of THR and TKR were calculated using: [a] t-test for paired samples, [b] Wilcoxon signed-rank test

Table 3 Comparison of EQ-5D-5L at baseline and after three months between THR and TKR

		Baseline	**Follow-up**	**Change**	**T2 vs. T1**	**Differences in change scores**
	Group	**Mean (SD)**	**Mean (SD)**		***p*-value**	***p*-value**
Mobility	THR	3.28 (0.97)	2.00 (1.08)	− 1.28	< 0.001[a]	0.053[b]
	TKR	3.03 (1.04)	2.14 (1.06)	− 0.88	< 0.001[a]	
Self-care	THR	1.67 (0.96)	1.35 (0.60)	− 0.32	0.016[a]	0.038[b]
	TKR	1.35 (0.76)	1.32 (0.65)	− 0.03	0.811[a]	
Usual activity	THR	2.56 (1.19)	1.89 (1.02)	− 0.67	< 0.001[a]	< 0.001[b]
	TKR	1.91 (1.07)	2.00 (1.03)	0.09	0.627[a]	
Pain	THR	3.67 (0.68)	2.13 (0.86)	− 1.53	< 0.001[a]	0.001[b]
	TKR	3.30 (0.85)	2.36 (0.92)	− 0.94	< 0.001[a]	
Anxiety/depression	THR	1.60 (0.85)	1.39 (0.68)	− 0.21	0.092[a]	0.363[b]
	TKR	1.51 (0.83)	1.42 (0.69)	− 0.09	0.507[a]	

Higher values represent greater restrictions of HRQoL, negative change-scores imply improvement of symptoms

THR Total hip replacement, *TKR* Total knee replacement, *EQ-5D-5L dimensions* EuroQol Five-Dimensional Five-Level Questionnaire dimensions (1 - 5)

P-values for differences between baseline and follow-up within groups of THR and TKR were calculated using [a] t-test for paired samples. *P*-values for differences in change scores were calculated using [b] t-test for unpaired samples

Correlations of personality traits with HRQoL and WOMAC at baseline

Table 4 presents the baseline correlations of personality traits with the EQ and WOMAC scores.

In THR patients, the correlations were consistently positive, with self-efficacy significantly associated with EQ-index (r= 0.435; p= 0.000), EQ-VAS (r= 0.385; p= 0.001), WOMAC global (r= 0.232; p= 0.045), WOMAC functioning (r= 0.306; p= 0.008) and WOMAC pain (r= 0.237; p= 0.041). For H-WTTR only EQ-index (r= 0.228; p= 0.0496) correlated significantly. Future orientation was significantly associated with EQ-VAS (r= 0.385; p= 0.002) and WOMAC functioning (r= 0.325; p= 0.005).

Regarding TKR, positive correlations also prevailed. Self-efficacy had significant associations with EQ-index (r= 0.471; p= 0.000), EQ-VAS (r= 0.344; p= 0.004), WOMAC global score (r= 0.412; p= 0.000), WOMAC functioning (r= 0.491; p= 0.000) and WOMAC pain (r= 0.332; p= 0.005). H-WTTR correlated significantly with EQ-index (r= 0.296; p= 0.014) and EQ-VAS (r= 0.352; p= 0.003), but not with the WOMAC scales. Future orientation did not correlate significantly with any outcome.

Associations of personality traits with changes in HRQoL and WOMAC scores

Multivariate regression models on outcome change scores are presented in Table 5. For patients with THR, a higher baseline self-efficacy was associated with improvement in the EQ-index (β= 0.0704; p= 0.0099), the WOMAC global score (β= 6.6337; p= 0.0139),

Table 4 Correlations of personality traits with HRQoL and WOMAC scores at baseline

		EQ-Index	EQ-VAS	WOMAC global	WOMAC function	WOMAC pain
THR patients	Self-efficacy	**0.435 *** **	**0.385 *** **	**0.232 ***	**0.306 ** **	**0.237 ***
	Health-related willingness to take risk	**0.228 ***	0.213	0.034	0.118	0.077
	Future orientation	0.207	**0.358 ** **	0.188	**0.325 ** **	0.153
TKR patients	Self-efficacy	**0.471 *** **	**0.344 ** **	**0.412 *** **	**0.491 *** **	**0.332 ** **
	Health-related willingness to take risk	**0.296 ***	**0.352 ** **	0.065	0.067	0.052
	Future orientation	− 0.070	0.188	0.067	0.116	0.119

Pearson correlations between personality traits and all outcomes

THR Total hip replacement, *TKR* Total knee replacement, *EQ-5D-5L* EuroQol Five-Dimensional Five-Level Questionnaire, *EQ-VAS* EuroQol visual analogue scale, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index, General self-efficacy (1–5) higher scores indicate higher self-efficacy, health-related willingness to take risk (0–10) lower values represent risk aversion, future orientation (0–10) higher values indicate a stronger orientation on the future

Significance: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; in bold if the result was at least significant at $p < 0.05$ level

WOMAC functioning (β= 8.2557; p= 0.0046), and WOMAC pain (β= 5.9994; p= 0.0232). The association between self-efficacy and EQ-VAS was positive, but not significant (β= 3.0619; p= 0.3402).

For TKR, only the association of self-efficacy with the EQ-VAS change-score was statistically significant (β= 5.8252; p= 0.0482). Self-efficacy demonstrated weak positive, but not significant associations with the WOMAC global score (β= 1.1519; p= 0.6998), WOMAC functioning (β= 0.0120; p= 0.9972), and WOMAC pain (β= 1.1571; p= 0.6843). The association between self-efficacy and EQ-index was close to zero (β=− 0.0070; p= 0.8465).

When comparing these changes with the respective MIC values, the associations between self-efficacy and the WOMAC global (β= 6.6337; MIC= 5.87), and WOMAC functioning (β= 8.2557; MIC= 5.96) in the THR cohort exceeded the defined thresholds. The results for TKR overall and other combinations of associations between personality traits and outcomes for THR remained below their respective MIC thresholds.

Supplementary File 4 - Figure S4 depicts the linear associations between self-efficacy and EQ-Index, EQ-VAS, and WOMAC global separately for THR/TKR.

The supplementary files 5 and 6 include the figures S5 and S6 which show linear associations between H-WTTR and future orientation and the outcomes.

H-WTTR was positively, but not significantly associated with all WOMAC scores in THR/TKR patients. Associations with HRQoL outcomes showed no clear positive or negative tendency.

No associations between future orientation and outcome scores were significant. Whereas strictly negative for THR, they were positive for TKR.

Good baseline scores of all outcome measures were associated with smaller improvement in these scores.

Sensitivity analyses

Replacing future orientation with present orientation led to minor changes in significances and effect sizes (Supplementary File 7 - Table S3). Nevertheless, the implications remained consistent, indicating the robustness of the main analyses.

Neither the linear modeled regression nor the scatter plot implies a distinctive trend of ASA scores over time (Supplementary File 8 - Figure S7). This suggests that the SARS-Cov- 2 pandemic did not create selection bias.

Discussion

This study provides comprehensive insights into personality traits and their association with outcomes three months after THR/TKR. In patients undergoing THR, higher self-efficacy was associated statistically significant improvements in general OA-specific health status and physical functioning, surpassing the threshold for MIC. Associations of self-efficacy with HRQoL and pain after THR were also statistically significant, but below threshold for MIC.

In contrast, for TKR, higher self-efficacy was associated with improvements in HRQoL; however, these changes did not reach the threshold for MIC. Neither H-WTTR nor future orientation were associated with outcomes after THR or TKR.

Personality traits were also associated with preoperative health status. In THR/TKR, self-efficacy was associated with better HRQoL, physical functioning, and lower pain. H-WTTR was associated with better HRQoL, but not with better functioning or pain. Future orientation was only associated with better HRQoL and physical functioning in THR patients.

Comparison of the results on self-efficacy with previous research

In THR patients, the association between self-efficacy and improved WOMAC scores corresponds with

Table 5 Regression results for associations of personality traits with changes in EQ-5D, EQ-VAS, and WOMAC scores

	EQ-5D-5L utility index		EQ-VAS		WOMAC global		WOMAC function		WOMAC pain	
	β THR	β TKR	β THR	β TKR	β THR	β TKR	β THR	β TKR	β THR	β TKR
Intercept	**0.3174 ***	**0.6567 ****	**41.0049 ***	27.3463	**43.2794 ****	**39.1233 ***	**31.2369 ***	**52.0817 ****	**52.7320 *****	**45.7655 ****
Self-efficacy	**0.0704 ****	− 0.0070	3.0619	**5.8252 ***	**6.6337 ***	1.1519	**8.2557 ****	0.0120	**5.9994 ***	1.1571
Health-related willingness to take risk	− 0.0027	0.0085	− 1.1304	− 0.6109	0.4557	0.9599	0.1420	1.1277	0.1435	1.0180
Future orientation	− 0.0059	0.0007	− 0.7295	1.5918	− 1.1166	0.8937	− 0.8987	0.7182	− 0.9882	0.9310
Male	0.0340	− 0.0553	5.0454	− 2.9442	8.2014	− 5.5233	7.3096	− 5.6967	**10.5608 ***	1.1747
Age	0.0032	− 0.0017	0.5271	0.0653	0.3433	− 0.2404	0.3184	− 0.2951	0.4970	− 0.1769
Diseases = 1	0.1217	− 0.0105	− 1.5850	1.9280	− 1.2393	10.1159	5.1482	6.0711	− 5.1682	5.1092
= 2	0.0498	− 0.0354	− 2.0378	− 6.9599	− 0.6789	10.6210	3.5706	6.2477	− 4.9668	7.4529
= 3	0.1185	− 0.0181	− 3.2699	− 7.8033	− 2.7762	10.8547	3.9172	5.4063	− 14.7960	5.7977
>= 4	0.0377	− 0.1509	− 6.2499	− 5.1642	− 8.2861	− 7.3776	− 3.7319	− 11.5961	− 11.7986	− 8.4547
Years of Education = 10–11	0.0508	0.0127	**17.3616 ***	7.9742	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
= 12–13	**− 0.1867 ***	− 0.0132	− 7.5909	− 2.3857	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
> 13	0.0050	− 0.0590	6.5668	− 6.1218	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]	NA[a]
Outcome at baseline	**− 0.6667 *****	**− 0.6629 *****	**− 0.7208 *****	**− 0.7337 *****	**− 0.8830 *****	**− 0.7158 *****	**− 0.7998 *****	**− 0.7393 *****	**− 0.8515 *****	**− 0.7912 *****

Each column shows the influence of all included independent variables on the change score of one specific outcome measure (follow-up - baseline)

THR Total hip replacement, *TKR* Total knee replacement, *EQ-5D-5L* EuroQol Five-Dimensional Five-Level Questionnaire, *EQ-VAS* EuroQol visual analogue scale, *WOMAC* Western Ontario and McMaster Universities Osteoarthritis Index, general self-efficacy (1–5) higher scores indicate higher self-efficacy, health-related willingness to take risk (0–10) lower values represent risk aversion, future orientation (0–10) higher values indicate a stronger orientation on the future, male 0 = female, 1 = male, diseases present at baseline (0–4) number of diseases present at baseline assessment with 4 aggregating counts of 4 diseases and above, outcome at baseline adjustment for baseline value of the specific outcome

[a]: In estimations with WOMAC as the outcome, education was not part of the minimal sufficient adjustment set, not included as a covariate, and thus appears as NA in the table

Significance: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$; in bold if the result was at least significant at $p < 0.05$ level

findings by Brembo et al. [22]. In a secondary analysis of 223 Norwegian patients assessed in 2003 - 2004, they surveyed the impact of social support and self-efficacy, measured by the General Self-Efficacy scale, on the WOMAC global score three months after THR. The significant but weaker association than in the present study may be attributed to different measures to assess self-efficacy. Cultural differences in German and Norwegian patients or health care [52, 53] or innovations in surgical techniques could also explain these differences.

In TKR, the associations between self-efficacy and improved outcome measures were mainly positive, but mostly not significant. Thus, as with THR, self-efficacy may also be beneficial in TKR, but to a lower extent. Furthermore, the smaller improvements in TKR patients may partly explain the lower association and lack of significance between self-efficacy and the outcome.

The non-significant association of self-efficacy with functioning after TKR is comparable to findings by Hartley et al. [23]. Surveying 62 patients on the effect of hope and self-efficacy, on the Self-Efficacy for Rehabilitation Outcome Scale, they observed no significant association with functioning six weeks after THR/TKR. The lack of significance in that study may be due to the short follow-up and the inclusion of patients with TKR with smaller improvements.

However, Hartley et al. [23] also detected an association between self-efficacy and better functioning in patients before undergoing THR/TKR. The same association was found in studies of non-surgical OA patients [54–56]. This suggests that self-efficacy is generally associated with better functioning in patients with OA, regardless of whether they decide to undergo surgery or not.

The MobilE-TRA 2 subproject on patients with vertigo, dizziness, or balance disorders also examined the associations between self-efficacy and treatment outcomes [29]. Consistent with the findings from the OA subproject, higher self-efficacy was associated with treatment success, while H-WTTR and future orientation showed no significant associations. These results suggest that self-efficacy could be a determinant for better treatment outcomes for several conditions that lead to mobility impairment in later life.

Comparison of the results for H-WTTR and future orientation with previous research

This is the first clinical study assessing the association between H-WTTR, future orientation, and outcomes after THR/TKR and controlling for these two characteristics in a single model with self-efficacy. Notably, H-WTTR was thoroughly validated as an instrument in a large general population study in Germany n≈22,000) [21]. Even though the instrument has not yet been applied in a cohort of THR/TKR patients, the extensive sample size of the validation study and the emphasis on representative results with sufficient statistical power support its validity and transferability to various clinical populations [21].

The absence of associations between H-WTTR or future orientation and outcomes contrasts with initial expectations. Due to the results of previous research linking lower H-WTTR and higher future orientation to better adherence, we expected a positive influence on the outcome [21, 25, 57]. The lack of association between H-WTTR and outcome at follow-up might be explained by patients with higher H-WTTR scores surpassing the recommended workload, potentially accelerating functional improvement in some cases. This may compensate for possible health risks due to lower compliance, thereby preventing a deterioration in functioning. In addition, due to the short observation period characterized by intensive postoperative supervision, behavioral consequences of H-WTTR and future orientation on the outcome might have been mitigated. Furthermore, the assessed concept of future orientation may capture a more distant future.

Further interpretation of results

As expected, the mobility and pain dimensions of the EQ-5D-5L improved the most, as these are the most commonly affected domains in patients with hip and knee OA [58]. Notably, THR was not only associated with improvements in physical function but also with reductions in anxiety and depression, suggesting potential additional benefits of the intervention.

Focusing on preoperative outcomes, the positive association between H-WTTR and HRQoL may reflect a potential link between risk-taking health behaviors and a greater willingness to accept the potential risks of surgery. Consequently, patients with higher H-WTTR might have decided to undergo surgery at an earlier stage of their disease when their quality of life was still relatively less impaired compared to individuals with lower H-WTTR scores.

Similarly, the positive association between future orientation and baseline outcomes in THR suggests that a stronger focus on long-term health improvements may influence the timing of surgery. More future-oriented patients might decide to undergo THR earlier despite initial discomfort or less severe impairment. The predominantly positive associations between future orientation and outcomes before TKR point to a comparable decision-making.

Higher baseline scores in functioning and quality of life were strongly associated with less improvement, which is a well-known phenomenon in studies on

prognostic factors for outcomes following THR/TKR [6, 59]. These associations may result from a ceiling effect of patient-assessed outcomes in THR/TKR [52].

Strengths and Limitations

A key strength of this study is its design based on primary data, whereas comparable previous studies relied on secondary data [22] or a smaller sample size [23]. Furthermore, the differentiation between THR and TKR revealed distinct sample-specific results. High participation and follow-up rates, a high level of data completeness, and a careful and well-informed development of the regression model further underline this study's robustness and methodological quality.

However, some limitations should be acknowledged. First, the monocentric design at a university hospital may limit the generalizability of the findings to other healthcare settings. Second, the three-month follow-up period might have been too short to fully capture potential associations between H-WTTR or future orientation and long-term health outcomes. Third, the applied self-reported measures may have been subject to self-report bias. Despite the selection of validated measures, self-report bias could not be completely excluded.

Conclusion

This study clarifies how selected personality traits are associated with the outcome in HRQoL and functioning after THR/TKR. Further research is necessary to confirm the prognostic properties of self-efficacy. If confirmed, pre-operative strategies that foster self-efficacy should be integrated into prehabilitation programs [24, 60–62]. Our findings do not support the implementation of H-WTTR and future orientation interventions before THR/TKR. However, these traits might be relevant for long-term treatment success. Subsequent studies should consider extended follow-up periods.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s12955-025-02374-y.

Supplementary Material 1
Supplementary Material 2
Supplementary Material 3
Supplementary Material 4
Supplementary Material 5
Supplementary Material 6
Supplementary Material 7
Supplementary Material 8

Acknowledgments

The authors greatly appreciate the effort and commitment of all participants in this study. We want to acknowledge Ralf Strobl for his statistical advice and the staff of the orthopedic department of the Musculoskeletal University Center Munich (MUM) at the LMU University Hospital Munich for their support during the patient recruitment.

Authors' contributions

SF: Conceptualization, data curation, methodology, data analysis, project administration, visualization, original drafting, reviewing & editing. LS: Conceptualization, funding acquisition, supervision, reviewing & editing. BK: Data curation, methodology, validation, reviewing & editing. AP: Conceptualization, supervision, reviewing & editing. BH: Reviewing & editing. JB: Reviewing & editing. MW: Conceptualization, funding acquisition, project administration, supervision, reviewing & editing.

Funding

Open Access funding enabled and organized by Projekt DEAL. This work was funded by the German Federal Ministry of Education and Research under the research grant number 01GY1913 A.
It was conducted as a part of the project "Munich Network Healthcare Research – MobilE-Net" and the study "MobilE-TRA 2".

Data availability

Data is available upon reasonable request. The collected data cannot be shared publicly because the patients did not consent to the deposit of their data in a public repository. Access to any individual-level patient data is not available.

Declarations

Ethics approval and consent to participate

This study was conducted according to the Declaration of Helsinki and received approval from the ethics committee of the medical faculty of the Ludwig Maximilian University Munich under the number 20 - 727.

Competing interests

The authors declare no competing interests.

Author details

[1]Department of Orthopaedics and Trauma Surgery, LMU University Hospital, LMU Munich, Munich, Germany. [2]Institute for Medical Information Processing, Biometry and Epidemiology (IBE), Faculty of Medicine, LMU Munich, Munich, Germany. [3]Pettenkofer School of Public Health, Munich, Germany. [4]Department of Health Services Research, Faculty VI - School of Medicine and Health Sciences, Carl von Ossietzky Universität Oldenburg, Oldenburg, Germany. [5]Institute of Health Economics and Health Care Management (IGM), Helmholtz Zentrum München (GmbH) – German Research Center for Environmental Health, Neuherberg, Germany. [6]Orthopaedisches Fachzentrum Weilheim-Garmisch-Starnberg-Penzberg, Weilheim, Germany.

Received: 9 April 2024 Accepted: 14 April 2025
Published online: 23 April 2025

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4 Publication II

Association of self-efficacy, risk attitudes, and time preferences with functioning in older patients with vertigo, dizziness, and balance disorders in a tertiary care setting – Results from the MobilE-TRA2 cohort.

Benedict Katzenberger, Sebastian Fuchs, Lars Schwettmann, Ralf Strobl, Ari Hauser, Daniela Koller, Eva Grill

Frontiers in Neurology
ACCEPTED 20 November 2023
DOI: 10.3389/fneur.2023.1316081

frontiers | Frontiers in Neurology

TYPE Original Research
PUBLISHED 15 December 2023
DOI 10.3389/fneur.2023.1316081

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OPEN ACCESS

EDITED BY
Tjasse Bruintjes,
Gelre Hospitals, Netherlands

REVIEWED BY
Luc Vereeck,
University of Antwerp, Belgium
Courtney D. Hall,
East Tennessee State University, United States

*CORRESPONDENCE
Benedict Katzenberger
benedict.katzenberger@med.uni-muenchen.de

RECEIVED 10 October 2023
ACCEPTED 20 November 2023
PUBLISHED 15 December 2023

CITATION
Katzenberger B, Fuchs S, Schwettmann L, Strobl R, Hauser A, Koller D and Grill E (2023) Association of self-efficacy, risk attitudes, and time preferences with functioning in older patients with vertigo, dizziness, and balance disorders in a tertiary care setting—Results from the MobilE-TRA2 cohort.
Front. Neurol. 14:1316081.
doi: 10.3389/fneur.2023.1316081

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Association of self-efficacy, risk attitudes, and time preferences with functioning in older patients with vertigo, dizziness, and balance disorders in a tertiary care setting—Results from the MobilE-TRA2 cohort

Benedict Katzenberger[1,2]*, Sebastian Fuchs[1,2,3], Lars Schwettmann[4,5], Ralf Strobl[1,6], Ari Hauser[1], Daniela Koller[1] and Eva Grill[1,6]

[1]Institute for Medical Information Processing, Biometry and Epidemiology (IBE), Faculty of Medicine, LMU Munich, Munich, Germany, [2]Pettenkofer School of Public Health, Munich, Germany, [3]Department of Orthopaedics and Trauma Surgery, LMU University Hospital, LMU Munich, Munich, Germany, [4]Department of Health Services Research, School of Medicine and Health Sciences, Carl Von Ossietzky University of Oldenburg, Oldenburg, Germany, [5]Institute of Health Economics and Health Care Management (IGM), Helmholtz Zentrum München (GmbH) – German Research Center for Environmental Health, Neuherberg, Germany, [6]German Center for Vertigo and Balance Disorders, LMU University Hospital, LMU Munich, Munich, Germany

Introduction: The functional burden of vertigo, dizziness, and balance problems (VDB) might depend on the personality traits of the patients affected. The aim of this study thus was to investigate the impact of self-efficacy, risk attitudes, and time preferences on functioning in older patients with VDB before and after treatment in a specialized tertiary care center.

Methods: Data for this study was obtained from the MobilE-TRA2 cohort study, conducted at a specialized tertiary care center in Germany. Patients aged 60 and older were assessed during their initial stay at the care center and 3 months later, using self-administered questionnaires. Self-efficacy was measured on a scale from 1 (very low) to 5 (very high). Health-related risk attitudes were inquired using an 11-point scale. Time preferences were measured by evaluating patients' willingness to postpone a reward in favor of a greater benefit on an 11-point Likert scale. Functioning was evaluated using the Dizziness Handicap Inventory, representing functional, emotional, and physical aspects of functional disability caused by VDB. Mixed-effects regression models were used to analyze the association between the selected personality traits and functioning over time. Interaction terms with time were incorporated for each personality trait, enabling the assessment of their influence on functioning 3 months following the initial observation period.

Results: An overall of 337 patients (53% women, median age at baseline = 70 years) were included. Patients with higher self-efficacy (Beta = −3.82, 95%-CI [−6.56; −1.08]) and higher willingness to take risks (Beta = −1.31, 95%-CI [−2.31; −0.31]) reported better functioning during their initial visit at the care center. Self-efficacy significantly predicted functioning after 3 months for overall functioning (Beta = −4.21, 95%-CI [−6.57; −1.84]) and all three domains.

Conclusion: Our findings suggest that patients with high self-efficacy and high willingness to take risks may exhibit better coping mechanisms when faced with the challenges of VDB. Promoting self-efficacy may help patients to better manage the duties accompanying their treatment, leading to improved functioning. These insights may inform the development of personalized treatment aimed at reducing the functional burden of VDB in older patients.

KEYWORDS

vertigo, dizziness, balance disorders, functioning, self-efficacy, risk attitudes, time preferences

1 Introduction

Vertigo, dizziness, and balance problems (VDB) are common and challenging syndromes, especially in older adults. They affect over 30% of the population over the age of 60 (1–3) and result in relevant and often persistent functional decline (4). While VDB commonly are a result of disorders of the vestibular system, they also can be provoked by other diseases, such as orthostatic hypotension or polyneuropathy. People with VDB are often faced with a wide range of problems in carrying out tasks of their daily lives (5, 6), including work-related and social activities (7). Household chores and grocery shopping, traveling, reading, and even walking, bending over or dressing can become challenging (8, 9). Depression and anxiety are common comorbidities (10, 11), arguably provoked by feelings of reduced self-esteem, fear, vulnerability, frustration, and isolation (12).

Earlier research suggests that people with certain personality structures are particularly susceptible to VDB and its effects (13, 14) and that individuals differ in their ways of coping with functional restrictions caused by VDB (15). In the context of highly specialized tertiary care, personality traits might influence the patients' ability to navigate the challenges inherent in their care process, as observed in the management of chronic diseases (16). As such, it is conceivable that personality traits may hold predictive value in determining treatment outcomes to some extent. Nevertheless, the current state of research on the impact of personality traits on functional restrictions in patients with VDB remains sparse.

Further insights may come from the field of behavioral economics, which is a branch of economics that combines approaches and methods from economics and psychology to understand how and why individuals make decisions and choices (17). Concepts from behavioral economics recognize that patients may not consistently conform to the expected rationality when coping with their disease and the associated restrictions. This deviation can be attributed to variations in underlying personality traits, including but not limited to the patient's confidence in their ability to overcome a health problem, their risk-taking propensity, and the way they assess the benefits or harms that lie in the distant future (18). Such insights could be helpful to better understand and predict functional restrictions in patients with VDB. The present work focuses on three prominent personality traits, namely self-efficacy, individual risk attitudes, and time preferences, as three selected BE concepts in the realm of health-related decision-making, which are known to be major determinants of health behavior (16, 19–21).

Self-efficacy denotes the belief in one's ability to organize and execute the courses of action required to successfully achieve set goals (22). The positive influence of self-efficacy on various health outcomes is well-known in the literature (16, 23–25). With regard to VDB, it may indicate patients' willingness to actively confront their problems. This has been shown, e.g., for visual height intolerance (26), a condition characterized by discomfort or anxiety when individuals are exposed to heights or elevated places, even if they are safe and enclosed. Likewise, patients with high levels of self-efficacy and resilience were less likely to develop secondary somatoform dizziness and vertigo (27). Also, internal health locus of control, i.e., the belief that individuals themselves are in control of managing their health condition (28), was found to support coping in VDB (29). Although internal locus of control encompasses a broader belief in the control over one's health condition, while self-efficacy is more focused on task-specific confidence, these findings underline the importance of patients' perceptions of control.

Health-related risk attitudes refer to an individual's general propensity to take or avoid risks in health-related decision situations (21). They hold significance in understanding coping styles within VDB, where individuals regularly face risk-related decisions linked to daily activities, involving certain actions or environments that may exacerbate symptoms. Moreover, individuals with VDB have to consider their elevated propensity for falls (30, 31). Patients with VDB thus must carefully assess the level of engagement in health-related activities, such as performing physical exercise, that pose some risk of triggering symptoms or falls but may contribute to maintaining overall functioning. Some individuals may be very risk-averse, resulting in excessive caution (11, 32), exaggerated self-restriction, or even complete avoidance of environments they perceive as safe (33). Such self-imposed restriction could then result in adverse consequences, including diminished core stability and restricted participation in various activities. Conversely, those more willing to take risks may not be as susceptible to fear and exaggerated self-restriction possibly mitigating the negative impact of VDB on functioning.

Finally, time preferences, reflecting the patient's valuation of the present over the future when deciding between immediate health

benefits or harms and potential benefits or harms in the future (34–36), can influence health behavior. It has been demonstrated that more present-oriented individuals tend to be less likely to adopt healthy lifestyles than future-oriented individuals (20, 37) and engage in fewer self-management activities (38, 39). On the other hand, individuals with a stronger present orientation reported lower levels of concern about future illness (40). Consequently, they might be more optimistic about the future and therefore experience lower levels of self-imposed restrictions (33) than their future-oriented counterparts.

It is widely recognized that patients with VDB derive substantial benefit from evidence-based and interdisciplinary rehabilitation programs in many different underlying pathologies (41–45). The effects of such rehabilitation programs seem to be even larger when the interventions are tailored to the patients' specific needs (46). In this context, gaining a better understanding of how the selected personality traits influence functioning and recovery in patients with VDB before and after their visit to a highly specialized tertiary care center may help to adapt and further improve existing therapeutic approaches.

The objective of this article thus was to investigate the impact of self-efficacy, risk attitudes, and time preferences on the development of functioning in older patients with VDB before and after treatment in a specialized tertiary care setting.

2 Materials and methods

2.1 Study design and study population

Data for this research project was collected in the prospective cohort study MobilE-TRA2 ("Behavioral and patient-individual determinants of quality of life, functioning and physical activity in older adults") at the interdisciplinary outpatient clinic of the German Center for Vertigo and Balance Disorders (DSGZ) at the Munich University Hospital. The DSGZ is one of the world's leading centers for diagnosis, treatment, and research of vertigo. Patients usually present at the clinic after referral from primary care. The study included patients aged 60 and older with VDB who presented for their initial interdisciplinary evaluation at the DSGZ. Patients with terminal diseases, cognitive impairment, or insufficient command of the German language were excluded. A more detailed description of the study is given elsewhere (47).

The sample size calculation for MobilE-TRA 2 was guided by a clinically significant difference of 10.0 points on the DHI, assuming a standard deviation of 25. Targeting a power of 0.8 (alpha = 0.05) necessitated a sample size of 52 patients. Given the longitudinal nature of MobilE-TRA 2, spanning three waves, and anticipating a 20% loss to follow-up between each wave, we established a minimum sample size of 81 patients. As different underlying pathologies had to be considered in order to control for their impact on our estimates, we quadrupled this figure, arriving at a target sample size of 324 patients.

The MobilE-TRA-2 study received ethics approval from the Ethics Committee at the medical faculty of Ludwig Maximilian University of Munich (#20-727). Written informed consent was obtained from all participants and the study was performed in accordance with the Declaration of Helsinki principles.

2.2 Data collection procedures

Baseline assessment was conducted between December 2020 and June 2022 and consisted of a self-administered questionnaire which patients either completed during their stay at the DSGZ or sent back via postal mail. Information from the patient registry DizzyReg of the DSGZ (48) was used to complement the baseline assessment. In brief, DizzyReg is an ongoing prospective clinical patient registry that collects and combines information stored in electronic health records and medical discharge letters with patient-reported information gathered by self-administered questionnaires. For the follow-up of the MobilE-TRA2 cohort, patients were mailed a questionnaire 3 months after the individual baseline assessment. Patients who did not respond to the initial follow-up questionnaire within 1 month received a reminder and were supplied with an identical duplicate of the initial follow-up questionnaire.

2.3 Personality traits

Self-efficacy was rated based on the three items of the General Self-Efficacy Short Scale (49). Patients report their confidence that they (1) can rely on their abilities in difficult situations, (2) can handle most problems well on their own, and (3) can usually solve even demanding and complex tasks effectively. The level of confidence is rated on a scale from 1 ("doesn't apply at all") to 5 ("applies completely"). The level of self-efficacy was calculated as the arithmetic mean of all three answers, resulting in a scale from 1 (very low self-efficacy) to 5 (very high self-efficacy). To measure health-related risk attitudes, a single item with an 11-point scale was used, ranging from 0 ("not at all willing to take risks") to 10 ("very willing to take risks") (21). The concept of time preferences used in this analysis was assessed by two items. One item measures the willingness to postpone a reward (0 = not willing at all, 10 = very willing) for the sake of a greater benefit in the future (36) and one item assesses the patient's orientation toward the present rather than in the future ("I am only concerned about the present, because I trust that things will work themselves out in the future," 1 = totally disagree, 5 = "totally agree") (34).

2.4 Functioning

Functioning was assessed using the German version of the Dizziness Handicap Inventory (DHI) (8, 50). The DHI is the most commonly used instrument to assess functioning loss caused by dizziness in everyday activities, including activity limitation, participation restrictions, and experienced difficulties. It incorporates 25 single items that can be summarized into three domains, representing functional (range 0–36), physical (range 0–28), and emotional (range 0 – 36) aspects of functioning, as well as a total score (range 0–100). Higher scores indicate more severe limitation or restriction.

2.5 Covariables

The selection of covariables for this study was based on the directed acyclic graph (DAG) presented in Supplementary Figure S1. This approach allowed us to identify the minimal sufficient adjustment set necessary to control for potential confounding while simultaneously avoiding bias from over-adjustment or collider bias (51). The construction of the DAG was informed by a review of the literature and experts' knowledge at the DSGZ. The resulting minimal adjustment set contained the specific VDB diagnosis, multimorbidity, a history of falls prior to the visit at the DSGZ, as well as information on the age, gender, education, and marital status of the participants.

The specific diagnosis of VDB was based on an extensive neurootological workup performed at the DSGZ, conforming to current guidelines (52–57). This workup includes a comprehensive battery of bedside tests, audiologic and vestibular function tests, as well as imaging if necessary. We focused on the most frequent diagnoses at the DSGZ, namely benign paroxysmal positional vertigo (BPPV), unilateral vestibulopathy, bilateral vestibulopathy, Menière's disease, vestibular migraine, central vestibular disorders, functional vertigo, orthostatic vertigo, and vertigo caused by polyneuropathy. Less frequent diagnoses were assigned to "Other" to facilitate statistical analysis. If no single leading cause was identifiable by the experts at the DSGZ, patients were classified as having multifactorial VDB.

Additional information was provided by patients regarding existing comorbidities related to the heart, lungs, liver, kidneys, neurological conditions, high blood pressure, inflammatory joint diseases, and further diseases specifically indicated by the participants. This approach yielded a compilation of 13 potential comorbidities, which can be found in Supplementary Table S1. We used this information to identify multimorbid patients, i.e., patients that suffered from at least two chronic conditions in addition to VDB. Multi-morbidity was added as binary information (yes/no) in the analysis.

During baseline assessment, patients reported whether they had fallen within the last 12 months prior to their visit at the DSGZ using a single yes-or-no question. Information on age and gender (male/female) was based on patients' self-report. Education levels were categorized based on the German educational system into: no graduation, lower secondary education 1 (equals 9 years of school), lower secondary education 2 (equals 10 years of school), upper secondary education (equals 12 or 13 years of school), and tertiary education (university, university of applied sciences). Marital status was self-reported (single, married, divorced, or widowed).

2.6 Statistical analysis

Summary statistics were calculated for the overall sample and separately for each diagnosis of VDB. Mean and standard deviation were reported for normally distributed continuous variables, median and the interquartile range for non-normally distributed variables, and relative and absolute frequencies for categorical variables. Potential differences in the observed variables between different diagnoses of VDB were examined using one-way ANOVA for normally distributed continuous variables, Kruskal-Wallis test for non-normally distributed continuous variables, and Chi-squared test for categorical variables.

Longitudinal linear mixed models with random intercept and fixed slopes were applied to assess the association between the selected personality traits and the level of functioning over time. We computed four distinct models: one for the overall DHI to estimate overall functioning and separate models for each of the three DHI sub-scales. Each beta coefficient obtained from the models represents the estimated change in the respective DHI score associated with a one-unit change in the corresponding predictor variable while controlling for the influence of all other variables in the model. Within each model, we simultaneously integrated the variables indicating self-efficacy, risk attitudes, and time preferences. This approach allowed us to accurately estimate the impact of each personality trait while simultaneously controlling for the influence of the other two traits. To assess potential multicollinearity issues among the personality traits and other covariates, we computed variance inflation factors (VIF) (58) using a predetermined threshold of 5 points. Furthermore, we introduced interaction terms involving time for each personality trait within each model, enabling us to investigate whether changes in functioning over time were predicted by the patients' respective personality traits.

In the regression analyses, we adopted a strategy of centering the measures of self-efficacy, risk attitudes, and time preferences around their respective means. This decision was informed by the observed concentration of values around the mid-range, with comparatively few instances of extremely low or high values. By employing centered models, we derived estimators for the intercept and overall change over time that are representative for individuals with moderate levels of these personality traits. These estimators directly capture a significantly larger portion of our study cohort compared to non-centered models. Given the minimum age criterion established in the inclusion criteria, we also subtracted the minimum age of 60 from the patients' age in years. Consequently, the reported estimates for the intercepts and the overall change over time in the centered models apply to patients at the age of 60 with mean personality traits.

Time preferences were represented by patients' willingness to postpone a reward within the primary analysis. To assess the robustness of our findings, we performed sensitivity analyses in which we re-evaluated the identical longitudinal linear mixed models. However, in these analyses, we measured time preferences based on patients' present-time orientation ("I am only concerned about the present, because I trust that things will work themselves out in the future"). This was done to examine whether the specific assessment of time preferences has an impact on the results.

The significance level was set to 5%. All computational analyses were carried out with R Version 4.1.2, including the usage of the *nlme* library (59). Regression assumptions were tested visually. We employed DAGitty, a browser-based, open-source tool to construct, edit, and analyze the DAG central to our study (60). In essence, users utilize a graphical interface to create the DAG, and the tool automatically identifies and highlights causal and biasing paths using distinct colors. This dynamic feature allows researchers to promptly and interactively assess the impact of

DAG modifications, such as adding new arrows or variables or inverting arrows with unclear causal direction. Additionally, DAGitty identifies the minimal adjustment set by and underlying algorithm, providing real-time feedback to the user along with the underlying assumptions.

3 Results

A total of 337 patients (53 % women, median age at baseline = 70 years, IQR = [64, 78]) were included in the baseline assessment. Of these, 299 (89%) returned the follow-up questionnaires, which were sent out 3 months after their respective baseline assessment. The most frequent diagnoses at baseline were BPPV [$n = 48$, (21%)] and functional vertigo ($n = 48$), followed by balance problems caused by polyneuropathy ($n = 43$). Thirty patients were classified as having multifactorial VDB. A third ($n = 112$, 33%) of the patients reported to have experienced at least one fall within the last 12 months prior to their visit. Additional details can be found in Table 1.

The mean overall DHI score across all patients at baseline was 41 points, indicating a moderate level of handicap due to VDB, with 62 (18%) patients reaching an overall DHI of more than 60 points (severe handicap) (61). The overall DHI score as well as all three sub-scores differed significantly across the diagnoses of VDB. Patients with bilateral vestibulopathy and patients with functional vertigo reported the highest level of impairment with DHI scores of 48.57 and 47.70, respectively. Conversely, patients with orthostatic vertigo and patients with other forms of VDB presented with better functioning (DHI = 29.21, resp. DHI = 28.10). The patients' willingness to postpone a reward (mean = 6.19, SD = 2.16) differed significantly across VDB diagnoses. Patients with functional vertigo exhibited the lowest willingness to delay gratification (mean = 5.42, SD = 2.19). The measures related to self-efficacy (mean = 3.96, SD = 0.85) and willingness to take risks (mean = 4.63, SD = 2.33) did not significantly differ across the various VDB diagnoses.

The mean overall DHI score at the follow-up assessment was 39 points across all patients. The overall DHI score again varied across the diagnoses of VDB, with corresponding differences in the functional and physical sub-scales of the DHI. A comprehensive list of the overall DHI scores and the three distinct DHI sub-scales for each diagnosis at follow-up is provided in Supplementary Table S2.

Adjusted for all covariates, the overall functional status increased on average by 2.56 points (95%-CI [−4.47; −0.65]) over the course of 3 months. Patients with higher self-efficacy reported better overall functioning at baseline (Beta = −3.82, 95%-CI [−6.56; −1.08]) and experienced greater improvement after 3 months (Beta = −4.21, 95%-CI [−6.57; −1.84]). While patients displaying a greater willingness to take risks reported slightly better overall functioning at baseline (Beta = −1.31, 95%-CI [−2.31; −0.31]), there were no statistically significant differences in their rate of improvement over time compared to risk-averse patients. Time preferences were neither significantly associated with baseline functioning nor with improvement over time. More detailed results of the mixed models for the DHI overall scales and the DHI subscales are presented in Table 2.

The performed sensitivity analysis revealed that using the patient's orientation toward the present as an alternative operationalization of time preferences did not change the association found in the main model (Supplementary Table S3). This consistency underscores the robustness of our findings.

Figure 1 displays a graphical representation of the predicted values from our models. It illustrates the overall functioning at the baseline assessment and the three-month follow-up for various values of the selected personality traits. Based on these predictions, a threshold of 3.29 points on the self-efficacy scale was identified as necessary for patients to experience an improvement in functioning over the course of 3 months. Patients below this threshold had lower functioning compared to their baseline assessment.

4 Discussion

We analyzed the impact of self-efficacy, risk attitudes, and time preferences on functioning in older patients with vertigo, dizziness, and balance disorders (VDB) using cohort data from a specialized tertiary academic care clinic. Patients with higher self-efficacy and more willingness to take risks reported higher levels of functioning when presenting at the clinic. Higher self-efficacy was also found to be an independent predictor of a better recovery at 3 months after initial assessment.

Overall, patients showed a small but significant improvement in functioning over time which might in part be due to the standardized diagnostic workup at the DSGZ and the long-standing experience of the clinic with management of VDB. These findings are in good agreement with previous research, highlighting the potential benefits of evidence-based and interdisciplinary assessment and vestibular rehabilitation therapy (42, 44) for patients with VDB.

Our analysis showed that patients with higher levels of self-efficacy were less restricted by their symptoms. These findings align with previous studies that have emphasized the positive influence of self-efficacy on various health outcomes, both within VDB (26, 27) and in general (16, 23, 25). Our results suggest that individuals who have a greater belief in their abilities to handle difficult situations, solve problems, and rely on their skills might have already developed effective coping mechanisms and adopted them in their daily life, thereby mitigating the impact of VDB on their functioning.

Our most striking observation was that self-efficacy predicted functional status of the patients 3 months after their initial visit. This indicates that patients may require a certain level of self-efficacy to experience functional improvement over time. Patients with very high self-efficacy demonstrated remarkable improvements, while those with low self-efficacy displayed an even lower functioning status after 3 months than during their first visit at the DSGZ. This suggests that self-efficacy may have a dual role in VDB diagnostics, serving as both a prerequisite and a catalyst for functional improvement after visiting a specialized care center. One possible explanation for this observation lies in the challenges

TABLE 1 Unadjusted summary statistics stratified by diagnosis at baseline assessment ($n = 337$).

	Diagnosis												
	Overall	BPPV	Unilateral vestibulopathy	Bilateral vestibulopathy	Ménière's disease	Vestibular migraine	Central vestibular	Functional vertigo	Orthostatic vertigo	Polyneuropathy	Multifactorial	Other	*p*-value[a]
N (%)	337	48	18	14	33	29	22	48	29	43	30	23	
Socio-economic information and medical background													
Age (median, IQR)	70.00 [64.00, 78.00]	69.00 [65.00, 77.25]	67.00 [60.50, 70.50]	69.00 [64.75, 77.75]	72.00 [67.00, 77.00]	64.00 [61.00, 71.00]	68.50 [63.00, 75.75]	64.50 [61.75, 70.25]	75.00 [62.00, 78.00]	78.00 [73.00, 81.50]	77.50 [73.25, 82.00]	65.00 [62.50, 71.50]	<0.001
Gender (*n*, %)													
Female	179 (53.1)	29 (60.4)	8 (44.4)	6 (42.9)	21 (63.6)	20 (69.0)	9 (40.9)	39 (81.2)	13 (44.8)	15 (34.9)	11 (36.7)	8 (34.8)	<0.001
Male	158 (46.9)	19 (39.6)	10 (55.6)	8 (57.1)	12 (36.4)	9 (31.0)	13 (59.1)	9 (18.8)	16 (55.2)	28 (65.1)	19 (63.3)	15 (65.2)	
Fall within last 12 months (*n*, %)													
No	220 (66.3)	30 (63.8)	12 (66.7)	8 (57.1)	26 (78.8)	25 (86.2)	14 (66.7)	34 (72.3)	16 (55.2)	26 (61.9)	16 (53.3)	13 (59.1)	0.192
Yes	112 (33.7)	17 (36.2)	6 (33.3)	6 (42.9)	7 (21.2)	4 (13.8)	7 (33.3)	13 (27.7)	13 (44.8)	16 (38.1)	14 (46.7)	9 (40.9)	
Multimorbidity (≥2 Comorbidities) (*n*, %)													
No	142 (42.1)	16 (33.3)	8 (44.4)	6 (42.9)	19 (57.6)	13 (44.8)	10 (45.5)	23 (47.9)	12 (41.4)	12 (27.9)	9 (30.0)	14 (60.9)	0.158
Yes	195 (57.9)	32 (66.7)	10 (55.6)	8 (57.1)	14 (42.4)	16 (55.2)	12 (54.5)	25 (52.1)	17 (58.6)	31 (72.1)	21 (70.0)	9 (39.1)	
Education[b] (*n*, %)													
Lower secondary education 1	119 (36.3)	18 (37.5)	6 (35.3)	5 (35.7)	12 (37.5)	9 (32.1)	6 (27.3)	13 (28.3)	14 (51.9)	17 (39.5)	12 (41.4)	7 (31.8)	0.981
Lower secondary education 2	81 (24.7)	14 (29.2)	5 (29.4)	4 (28.6)	5 (15.6)	5 (17.9)	10 (45.5)	14 (30.4)	4 (14.8)	10 (23.3)	6 (20.7)	4 (18.2)	
Upper secondary education	40 (12.2)	4 (8.3)	2 (11.8)	2 (14.3)	5 (15.6)	5 (17.9)	2 (9.1)	6 (13.0)	3 (11.1)	6 (14.0)	2 (6.9)	3 (13.6)	
Tertiary education	87 (26.5)	11 (22.9)	4 (23.5)	3 (21.4)	10 (31.2)	9 (32.1)	4 (18.2)	13 (28.3)	6 (22.2)	10 (23.3)	9 (31.0)	8 (36.4)	
No graduation	1 (0.3)	1 (2.1)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Marital status (*n*, %)													
Single	22 (6.5)	6 (12.5)	3 (16.7)	1 (7.1)	1 (3.0)	1 (3.4)	2 (9.1)	2 (4.2)	3 (10.3)	0 (0.0)	2 (6.7)	1 (4.3)	0.727

(Continued)

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TABLE 1 (Continued)

	Diagnosis												
	Overall	BPPV	Unilateral vestibulopathy	Bilateral vestibulopathy	Ménière's disease	Vestibular migraine	Central vestibular	Functional vertigo	Orthostatic vertigo	Polyneuropathy	Multifactorial	Other	*p*-value[a]
Married	227 (67.4)	31 (64.6)	13 (72.2)	9 (64.3)	22 (66.7)	18 (62.1)	17 (77.3)	33 (68.8)	20 (69.0)	28 (65.1)	20 (66.7)	16 (69.6)	
Divorced	49 (14.5)	7 (14.6)	2 (11.1)	2 (14.3)	4 (12.1)	6 (20.7)	3 (13.6)	9 (18.8)	2 (6.9)	6 (14.0)	4 (13.3)	4 (17.4)	
Widowed	39 (11.6)	4 (8.3)	0 (0.0)	2 (14.3)	6 (18.2)	4 (13.8)	0 (0.0)	4 (8.3)	4 (13.8)	9 (20.9)	4 (13.3)	2 (8.7)	
Personality traits													
Self-efficacy (mean, SD)	3.96 (0.85)	3.85 (0.74)	4.02 (0.77)	4.03 (0.75)	4.00 (0.69)	4.25 (0.89)	3.83 (0.91)	4.02 (0.93)	4.00 (1.10)	3.75 (0.85)	3.94 (0.74)	4.03 (1.01)	0.562
Health-related risk attitudes (mean, SD)	4.63 (2.33)	4.34 (2.42)	4.59 (2.58)	5.21 (2.58)	5.36 (2.25)	3.68 (2.13)	4.59 (2.61)	4.19 (2.21)	5.14 (2.22)	4.76 (2.01)	4.80 (2.12)	4.83 (2.82)	0.217
Time preferences—willingness to postpone a reward (mean, SD)	6.19 (2.16)	6.15 (2.04)	7.50 (1.95)	6.79 (2.26)	7.03 (2.01)	6.44 (2.34)	5.86 (2.05)	5.42 (2.19)	5.86 (2.21)	5.62 (1.93)	6.50 (1.85)	6.39 (2.48)	0.007
Time preferences—present-orientation (mean, SD)	2.53 (1.03)	2.37 (0.97)	2.41 (1.06)	2.57 (1.09)	2.68 (1.08)	2.42 (1.06)	2.62 (0.86)	2.71 (0.92)	2.82 (1.09)	2.54 (1.10)	2.34 (1.11)	2.18 (1.10)	0.490
Functioning													
DHI overall score (mean, SD)	40.93 (21.40)	43.83 (22.39)	45.00 (23.09)	48.57 (20.58)	43.67 (19.92)	32.83 (24.41)	44.00 (22.35)	47.70 (17.87)	29.21 (14.89)	38.70 (21.05)	44.64 (20.87)	28.10 (21.59)	0.001
DHI functional score (mean, SD)	16.53 (9.80)	17.17 (10.50)	17.75 (9.49)	19.29 (8.69)	17.74 (8.34)	13.23 (10.73)	18.00 (10.32)	19.62 (8.99)	13.21 (7.88)	15.35 (9.08)	18.50 (10.99)	10.19 (9.59)	0.007
DHI physical score (mean, SD)	11.41 (6.95)	13.87 (6.03)	14.25 (7.41)	15.00 (7.72)	10.13 (7.78)	7.67 (6.66)	12.57 (6.85)	11.67 (6.34)	7.50 (4.95)	11.68 (7.98)	12.69 (5.81)	9.00 (6.26)	<0.001
DHI emotional score (mean, SD)	13.04 (8.14)	12.78 (8.78)	13.00 (8.36)	14.29 (7.68)	16.00 (8.27)	11.62 (8.73)	13.43 (8.51)	16.38 (6.66)	8.50 (6.41)	11.68 (7.17)	13.50 (8.28)	10.27 (8.93)	0.003

BPPV, Benign paroxysmal positional vertigo; DHI, Dizziness Handicap Inventory; IQR, Interquartile range; SD, Standard deviation. [a]ANOVA, Kruskal-Wallis test, Chi-squared test. [b]Lower secondary education 1 equals 9 years of school, Lower secondary education 2 equals 10 years of school, upper secondary education equals 12 or 13 years of school.

TABLE 2 Longitudinal linear mixed models to assess the association between personality traits and functioning.

	Dizziness handicap inventory (95%−CI)			
	M1: overall score	M2: functional score	M3: physical score	M4: emotional score
Observations (n)	557 (305)	559 (305)	560 (306)	562 (306)
(Intercept)[a]	44.53 (33.07; 56.00)	18.38 (13.13; 23.62)	11.75 (7.95; 15.55)	14.49 (10.20; 18.79)
Wave[a]				
Baseline	Reference	Reference	Reference	Reference
Follow-up (3 months later)	**−2.56 (−4.47; −0.65)**	**−1.17 (−2.03; −0.32)**	−0.04 (−0.75; 0.67)	**−1.44 (−2.17; −0.71)**
Personality traits (centered to the respective mean)				
Self-efficacy[b]				
Self-efficacy	**−3.82 (−6.56; −1.08)**	**−1.76 (−3.01; −0.52)**	−0.60 (−1.51; 0.31)	**−1.49 (−2.51; −0.48)**
Self-efficacy* time	**−4.21 (−6.57; −1.84)**	**−1.65 (−2.71; −0.59)**	**−1.03 (−1.89; −0.17)**	**−1.43 (−2.32; −0.55)**
Health-related risk attitudes[c]				
Risk attitudes	**−1.31 (−2.31; −0.31)**	**−0.54 (−0.99; −0.09)**	−0.07 (−0.40; 0.27)	**−0.71 (−1.09; −0.34)**
Risk attitudes* time	0.29 (−0.56; 1.14)	0.16 (−0.22; 0.54)	−0.01 (−0.32; 0.31)	0.13 (−0.20; 0.45)
Time preferences—willingness to postpone a reward (WPR)[d]				
WPR	−0.38 (−1.48; 0.73)	−0.21 (−0.72; 0.29)	0.11 (−0.25; 0.48)	−0.28 (−0.69; 0.13)
WPR* time	−0.12 (−1.05; 0.81)	0.03 (−0.39; 0.44)	−0.21 (−0.55; 0.13)	0.01 (−0.34; 0.36)
Random effects				
Intercept (SD)	15.49	7.13	4.89	5.75

Higher scores indicate worse functioning. Significant findings are printed in bold. All models are controlled for the diagnosis, present falls within the last 12 months, multimorbidity, age, gender, education, and marital status. CI, Confidence interval; M1–M4, Models 1 to 4, one model per score; SD, Standard deviation. [a]Applies for patients aged 60 with mean self-efficacy of 3.96, mean risk attitudes of 4.63, and mean willingness to postpone a reward of 6.19. [b]Centered to mean self-efficacy of 3.96. [c]Centered to mean risk attitudes of 4.63. [d]Centered to mean willingness to postpone a reward of 6.19.

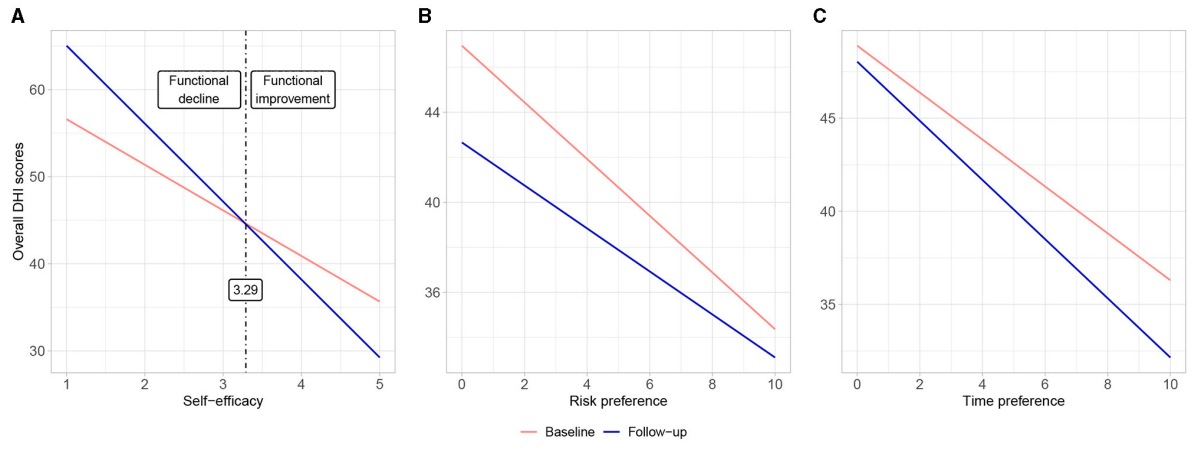

FIGURE 1
Comparison of predicted values for the overall functioning during baseline and follow-up assessment (3 months later) for different values of **(A)** self-efficacy, **(B)** risk attitudes, and **(C)** time preferences (willingness to postpone a reward). Higher values in the DHI scores indicate worse functioning.

that patients may find themselves confronted with when leaving the care center after their initial visit. Recommendations for future treatment options which, depending on the underlying pathology, may involve exercises, consultations with specialists, or additional diagnostic procedures, often require patients to take on new responsibilities and learn new skills. Consistent with this, previous research on self-efficacy in the management of chronic diseases suggests that patients with high self-efficacy are better able to cope with these challenges (16). This likely applies to patients with VDB leaving the care center as well. Therefore, empowering patients

to develop confidence in their abilities to actively participate in their treatment should be an important pillar of future treatment strategies. Self-efficacy enhancing interventions, which have proven to be of use in many other diseases (62–64), should be adapted and tested to meet the personal needs of patients with VDB (65).

Interestingly, our study revealed that patients with higher willingness to take risks demonstrated better functioning during their initial visit to the care center. This finding might appear surprising at first sight, considering that higher willingness to take risks is generally associated with a less healthy lifestyle (19, 21). However, in the case of VDB, patients with higher risk-taking tendencies may have developed strategies that contribute to maintaining their functioning. Individuals who are more inclined to take risks might more vigorously engage in activities that challenge their balance and mobility, leading to better adaptation and improved functioning. Additionally, they may be less affected by fears and uncertainties associated with the disease (5, 32). It is important to note that the results of this study should not be interpreted as a recommendation to promote risk-taking behavior in general, given the negative side effects of higher risk-taking found in other studies (19, 21). Instead, future research should focus on unraveling the specific strategies employed by patients with higher risk-taking tendencies to promote functioning.

Several limitations of this study have to be considered. First, most of the data gathered within this study relied on self-reported measures, which may be susceptible to potential information bias. Although we cannot exclude the possibility of such bias being present in our data, we want to emphasize that validated instruments were used, wherever available, and data collection and processing was accompanied by constant quality controls. The assessment of the personality traits relied on a set of self-assessment questions, rather than more extensive choice experiments. Usually, in the economic literature risk attitudes are elicited by a series of hypothetical or even monetarily incentivized lotteries, whereas setting to measure time preferences describe intertemporal trade-offs. However, our sample comprised a considerable portion of frail study participants, many of whom were older and in poor health. These participants might have been overwhelmed by the often-demanding choice experiments, resulting in biased, inaccurate, or incomplete data. Preference modules involving such comparably simple questions used within this study are well established and yielded good and comparable results in the past (66). Second, while personality traits had long been considered to be mostly stable over time (67), recent studies have questioned this traditional assumption, especially in the cases of health shocks (68, 69). This might also be of relevance in our field of application. Though it may be possible that self-efficacy, risk attitudes, or time preferences have changed between the baseline assessment and the follow-up, especially in the case of (very) successful or (very) unsuccessful treatments, a follow-up time of 3 months likely was too short for profound changes in the personality structure. Third, the data collection of this study took place during the COVID-19 pandemic, which might have influenced participants' experiences, perceptions, and behaviors, thus potentially entailing systematic differences in their personality traits. These pandemic-related factors could have affected the generalizability of our findings to non-pandemic periods. One indication for such an effect could be a systematic difference in the personality traits between time points of high incidence rates and rigorous restrictions and time points of low incidence rates and more loosened restrictions through the course of the baseline assessment. Though this was not the focus of this article, a performed descriptive sensitivity analysis showed that the personality traits remained somewhat stable over the course of the baseline assessment and did not reveal any indication of temporal trends.

Patients with vertigo, dizziness, or balance disorders often face considerable limitations and restrictions in functioning. In conclusion, our study contributes to the understanding of the influence of selected personality traits on functioning in older patients with VDB. Further research is warranted to elucidate the underlying mechanisms driving the observed associations found in this study. Adaptations to current treatment strategies are necessary to improve functioning as some patient groups, especially those with low self-efficacy, don't seem to benefit from current care pathways. Our findings provide an initial foundation for the development of tailored interventions that address personality traits, thereby contributing to the optimization of VDB management strategies. Promoting self-efficacy through clinical interventions and thoughtful communication can empower patients to play an active part in their treatment and thus holds promise for improving functioning and overall wellbeing in individuals with VDB.

Data availability statement

The datasets presented in this article are not readily available because of data privacy regulations that apply in the country of data collection. Requests to access the datasets should be directed to BK, benedict.katzenberger@med.uni-muenchen.de.

Ethics statement

The studies involving humans were approved by the Ethics Committee at the Medical Faculty of Ludwig Maximilian University of Munich (#20-727). The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

BK: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing—original draft, Writing—review & editing. SF: Methodology, Validation, Writing—review & editing, Data curation. LS: Conceptualization, Funding acquisition, Supervision, Writing—review & editing. RS: Methodology, Validation, Writing—review & editing. AH: Validation, Visualization, Writing—review & editing. DK: Project administration, Writing—review & editing. EG: Conceptualization, Funding

acquisition, Resources, Supervision, Writing—review & editing.

Funding

The author(s) declare financial support was received for the research, authorship, and/or publication of this article. This study is part of the project "Munich Network Health Care Research—MobilE-Net" and was funded by the German Federal Ministry of Education and Research (grant number 01GY1913A).

Acknowledgments

The MobilE-TRA 2 cohort study was conducted under the consortium leadership of the Institute for Medical Information Processing, Biometry, and Epidemiology at the Ludwig Maximilian University of Munich. The authors acknowledge the patients' willingness to participate, their appreciated support, and their valuable feedback in the pilot testing of the questionnaire. The authors thank Michael Klein, Karoline Bögle, and Fiona Brosch for their valuable contribution to the data collection of this study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fneur.2023.1316081/full#supplementary-material

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Appendix: Publication III

Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults (MobilE-TRA 2): study protocol of an observational cohort study in a tertiary care setting.

Benedict Katzenberger, Lars Schwettmann, Martin Weigl, Alexander Paulus, Sara Pedron, Sebastian Fuchs, Daniela Koller, Eva Grill

BMJ Open
ACCEPTED 12 November 2021
DOI: 10.1136/bmjopen-2021-051915

Open access Protocol

BMJ Open

Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults (MobilE-TRA 2): study protocol of an observational cohort study in a tertiary care setting

Benedict Katzenberger ,[1,2,3] Lars Schwettmann,[4,5] Martin Weigl,[6] Alexander Paulus,[6] Sara Pedron,[4,7] Sebastian Fuchs,[1,3,6] Daniela Koller,[1,2] Eva Grill[1,8]

To cite: Katzenberger B, Schwettmann L, Weigl M, *et al*. Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults (MobilE-TRA 2): study protocol of an observational cohort study in a tertiary care setting. *BMJ Open* 2021;**11**:e051915. doi:10.1136/bmjopen-2021-051915

► Prepublication history for this paper is available online. To view these files, please visit the journal online (http://dx.doi.org/10.1136/bmjopen-2021-051915).

Received 31 March 2021
Accepted 12 November 2021

Check for updates

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For numbered affiliations see end of article.

Correspondence to
Mr Benedict Katzenberger; benedict.katzenberger@med.uni-muenchen.de

ABSTRACT

Introduction Vertigo, dizziness and balance problems (VDB) as well as osteoarthritis (OA) are among the health conditions with the greatest impact on mobility and social participation in older adults. Patients with VDB and OA were shown to benefit from specialised care such as vestibular rehabilitation therapy or joint replacement. However, these effects are not permanent and seem to disappear over time. One important reason might be a decreasing adherence to therapy recommendations. Findings from behavioural economics (BE) can help to shed light on individual effects on adherence behaviour and long-term outcomes of VDB and OA.

Objective Based on insights from BE concepts (ie, self-efficacy, intention, and time and risk preferences), MobilE-TRA 2 investigates the determinants of functioning and health-related quality of life (HRQoL) 3 and 12 months after discharge from total hip replacement (THR)/total knee replacement (TKR) in patients with OA and after interdisciplinary evaluation for VDB.

Methods and analysis MobilE-TRA 2 is a longitudinal observational study with data collection in two specialised tertiary care centres at the university hospital in Munich, Germany between 2020 and 2023. Patients aged 60 and older presenting for their first THR/TKR or interdisciplinary evaluation of VDB at Ludwig Maximilians University (LMU) hospital will be recruited for study participation. Three and twelve months after baseline assessment, all patients will receive a follow-up questionnaire. Mixed-effect regression models will be used to examine BE concepts as determinants of adherence, HRQoL and functioning.

Ethics and dissemination The study was approved by the ethics committee at the medical faculty of the LMU Munich under the number 20-727. Results will be published in scientific, peer-reviewed journals and at national and international conferences. Findings will also be disseminated via newsletters, the project website and a regional conference for representatives of local and national authorities.

Strengths and limitations of this study

- This observational prospective cohort study will provide comprehensive data of behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults at multiple time points.
- This study uses validated and well-established outcome measures.
- We investigate patients with vertigo, dizziness and balance problems or with osteoarthritis because these health conditions might have major impact on mobility and social participation in older adults.
- Data originate from one university hospital in Germany, so generalisability of the results is limited to this setting.

INTRODUCTION

Following economic modelling, adherence to therapy recommendations and other health behaviours, such as physical activity or a healthy diet, can be viewed as investments in one's own health.[1] However, despite long-term advantages of these investments, individuals tend to deviate from these behaviours, even after educational efforts to provide information regarding their positive effects. Behavioural economics (BE) is a field of research that helps to explain such harmful deviations.[2 3] Corresponding studies reveal that departures appear systematically and therefore can be predicted and explained using specific concepts, such as individual risk and time preferences.[4]

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In the context of specialised hospital care, BE can help explaining patient-relevant outcomes after treatment, but also non-adherence to therapy recommendations. MobilE-TRA 2 uses insights from BE to shed light on individual effects on outcomes in patients with vertigo, dizziness and balance problems (VDB) as well as osteoarthritis (OA). These health conditions were chosen as they are among the health conditions with the greatest impact on mobility and social participation in older adults.[5] The current project focuses on the investigation of the determinants of quality of life, functioning and physical activity, after a definite diagnosis has been made, and after therapy and rehabilitation have been initiated. Furthermore, adherence to recommendations may play a prominent role as a process variable, which could also be influenced by self-efficacy and risk or time preferences of patients.

With a prevalence of up to 50 %, VDB are frequent problems of patients aged 60 and older. The causes of VDB are often multifactorial. Distinct treatable vestibular disease entities, dizziness caused by medication, cardiovascular diseases or diabetes may align with symptoms of the ageing of vestibular, proprioceptive or somatosensory systems. By increasing postural instability, VDB are among the most apparent and prevalent causes for falls in aged adults.[6] Furthermore, they significantly limit mobility and activities of daily life[5] and restrict social participation.[5 7] It is well established that aged adults with VDB benefit from vestibular rehabilitation therapy, regardless of the underlying pathology. However, it has been noted that old age is an independent predictor for unfavourable long-term outcomes, even after evidence-based and interdisciplinary treatment.[8]

With respect to VDB, only a limited number of BE concepts have been investigated to date. Patients showing resilience and high self-efficacy were less likely to develop secondary, chronic forms of functional vertigo.[9] Likewise, persons with high general self-efficacy reported more confronting, active behaviour to address their visual height intolerance.[10]

Likewise, OA is a major cause of mobility restrictions in older adults.[11] Persons with OA have an increased risk for cardiovascular and dementia associated mortality, with low levels of physical activity contributing to this excess mortality.[12] Several evidence-based recommendations and guidelines are available for the management of OA.[13] Specifically, after joint replacement, physical therapy, home exercises and increased physical activity are effective methods to reduce limitations of patients' functioning and mobility.[14 15] However, these effects are not permanent and seem to disappear over time. One major aspect contributing to this decline is non-adherence to physical activity recommendations,[16] which concerns up to 50% of OA patients and might be one decisive factor jeopardising positive surgery outcomes.[17] This may lead to reduced mobility and low physical functioning levels after joint replacement and increase the likelihood for subsequent revision.[18] Besides non-adherence to physical activity recommendations, there might be several other factors, which play a role in determining long-term outcomes after major treatment decisions, for example, after total hip or knee replacement (THR/TKR), but their role has yet to be acknowledged and understood.

In general, attitudes and motivation of patients are among the determinants for therapeutic success after THR/TKR.[19 20] Physical, social and socioeconomic factors, but also psychological aspects including self-efficacy, intentions, or expectancies for the future, serve as potential barriers to better outcomes.[21–25] Regarding BE, stronger orientation to the present appears to be associated with less healthy behaviour.[4 26 27] However, it is unclear if increased risk tolerance promotes or inhibits adherence to recommended exercise.[4 27]

In summary, too little attention has been paid to the role of BE concepts for long-term outcomes of OA and VDB. In fact, these factors may need to be considered not only in the preoperative phase, but also during discharge and rehabilitation planning and aftercare. Corresponding knowledge can be used to refine care pathways and to inform healthcare practice, potentially identifying persons at higher risk for adverse outcomes and tailoring specific interventions to improve adherence.

MobilE-TRA 2 is part of the second phase of MobilE-Net (Enabling participation by enabling MOBILity in older adults—Evidence-based health care research Network). MobilE-Net 2 is composed of three projects, which aim to develop multiprofessional care pathways targeted at older adults to reduce the burden of disability and to promote healthy ageing, mobility and participation. Based on insights from BE, the second phase of the subproject MobilE-TRA 2 investigates the determinants of functioning and HRQoL for patients with OA at 3 and 12 months after discharge from THR/TKR and for patients with VDB at 3 and 12 months after interdisciplinary evidence-based evaluation. In addition, adherence to recommendations will be considered as a major process variable. Results are of particular importance for the other projects of MobilE-Net to explain unwanted variations in outcomes of an implementation process. We expect to deliver insights that can directly be applied in ambulatory care and in discharge and rehabilitation planning.

Specifically, we want

1. to examine BE concepts as determinants of adherence,
2. to examine BE concepts as determinants of HRQoL and functioning, and
3. to investigate the moderation effect of BE concepts on associations between physical activity and individual factors such as body mass index (BMI) or pain.

METHODS AND ANALYSIS

Study design

MobilE-TRA 2 is a prospective observational cohort study among patients with OA after THR/TKR and patients with VDB after interdisciplinary evidence-based evaluation

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in two specialised tertiary care centres at the university hospital in Munich, Germany. The patient recruitment will take place from November 2020 until March 2022 and the data collection will end in March 2023 with the last patient completing the twelve months follow-up. The longitudinal design of the study captures changes in relevant outcomes. The study is monocentric to avoid variations in case ascertainment as well as surgical and medical treatment standards.

Participants and recruitment

Patient recruitment for MobilE-TRA 2 will take place at the Department of Orthopaedics, Physical Medicine and Rehabilitation (OPMR) and the German Centre for Vertigo and Balance Disorders (DSGZ) at the Ludwig Maximilians University (LMU) hospital in Munich. About 300 patients per year are admitted for first THR/TKR surgery at the Department OPMR. The DSGZ treats over 3000 ambulatory patients per year. Patients at OPMR and DSGZ obtain a rigorous clinical workup in line with current guidelines.[13 28] Typically, in the German system, patients after THR/TKR will undergo 3 weeks of postacute inpatient musculoskeletal rehabilitation and will be discharged from rehabilitation with a recommendation for physical therapy and physical activity. Patients with VDB will receive a recommendation for further measures in line with the recommendations of the Bárány Society[29] to be initiated by their primary care physician, potentially including physical therapy, physical activity or medication.

Patients aged 60 and older presenting at the participating centres for first THR/TKR or first interdisciplinary evaluation of VDB at the LMU hospital will be recruited for study participation. Patients with terminal disease, cognitive impairment, insufficient command of the German language or physical problems preventing participation, such as sensory impairments (bad sight or hearing) or a very low energy level, will be excluded. Patients will be recruited from both departments during their first consultations, that is, prior to surgery for patients with OA and during the first visit at the DSGZ for patients with VDB. Additionally, OA inpatients are recruited at the hospital 1 day ahead of their surgery. The recruitment is performed by trained members of the study team.

Patients participating in the MobilE-TRA 2 study will receive the patient information, the informed consent documents and the baseline questionnaire from the tertiary care centre. The patients in the study do not receive an incentive for study participation. In case of consent, they fill out these forms and hand them back to the study centre. Patients can also choose to complete the questionnaire at home and send it back to the respective study centre. The data collection in this study will be done with the help of pseudonymised identification keys during study conduct. For further information, refer to the section ethics and dissemination of this study protocol.

For the follow-up surveys after 3 and 12 months, a cover letter with instructions and the questionnaires will be sent via postal mail from the study teams to the patients' addresses. If no questionnaire is sent back within a month after the original follow-up invitation, one reminder will be sent. If the participant does not respond to the reminder, the data will be considered missing for the first follow-up. In the second follow-up, 1 month after an unanswered reminder, a non-responder questionnaire will be provided to explore the reasons for withdrawal and to obtain a crude estimate on health status based on a small set of questions.

The recruitment of the study is taking place during the SARS-CoV-2 pandemic. This emergency forced hospitals to take measures to prevent a patient overload and to grant back-up capacities for patients in need of intensive care, for example, by cancelling all routine operations that are not immediately indispensable. This may lead to a potential preselection of the study participants based on their constitution and the severity of the underlying disease. These challenges will be addressed by a careful documentation of the recruitment process and the specifications in force.

Patient and public involvement

Before starting the actual data collection, the questionnaires were pretested on a total of 11 patients at both the OPMR and the DSGZ at the LMU hospital in Munich from October to November 2020, using a think-out-loud approach. Patients did not indicate any major problems, such as ambiguous instructions, when filling out the questionnaire. The results of this pretest then were then used to revise and finalise the questionnaires. Results of the main study will be disseminated to study participants via the project website.

Measures

The primary outcomes of the study are generic quality of life, OA-specific physical functioning in patients with OA and vertigo-specific physical and psychosocial functioning in patients with VDB after 3 and 12 months, measured using validated instruments. Generic quality of life is measured through the EuroQol Five-Dimensional Five-Level Questionnaire (EQ-5D-5L) of the EuroQol Group.[30] For summary valuation, patients' report on the visual analogue scale and the German value set for utilities based on EQ-5D-5L[31] will be used.

OA-specific physical functioning in persons with hip and/or knee OA is assessed using the German version of the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC).[32 33] The WOMAC is an OA-specific tridimensional patient relevant outcome measure with 24 questions (5 on pain, 2 on stiffness and 17 on physical functioning). The main focus of the WOMAC is on the domain mobility that is addressed by 15 of the 24 questions.[34] This study applies the Likert scaled format with 5 response categories (0=none, 1=mild, 2=moderate, 3=severe, 4=extreme). The sum of the assigned values

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results in the score of each scale. The WOMAC has been proven valid, reliable and responsive[32] and is arguably the most frequently used OA-specific patient relevant outcome measure.

Patients with VDB will be asked to fill out the German version of Dizziness Handicap Inventory (DHI),[35] which assesses disability caused by dizziness and unsteadiness on everyday activities, including activity limitation, participation restrictions, and experienced difficulties.

Adherence behaviour to therapy recommendations, physical activity, pain and satisfaction is used as secondary outcome measure. Adherence behaviour to therapy recommendations is addressed with three items dealing with adherence to disease-specific exercises and physical activity (sporting activities and general regular exercise)[16] and one item dealing with weight control. OA specific pain is assessed using the pain scale of the WOMAC.[36] Pain and satisfaction in patients with OA were further assessed by single-item measures following Rolfson *et al* (2016).[37] The pain question asks: 'During the past 4 weeks, how would you describe the pain you usually have in your affected hip/knee?'. Response options are none, very mild, mild, moderate and severe. The satisfaction question asks: 'How satisfied are you with the results of your joint replacement that you received 3 months (12 months) ago?', with the response options very dissatisfied, dissatisfied, neutral, satisfied and very satisfied.

Physical activity for patients with OA or VDB is measured using the self-administered Global Physical Activity Questionnaire (GPAQ).[38 39] The WHO developed the GPAQ for physical activity surveillance. Fifteen questions collect information in the three domains activity at work, travel to and from places, and recreational activities. In addition, one single question asks for sedentary behaviour. The weekly energy expenditure in Metabolic Equivalents is estimated using the frequencies and durations of moderate and vigorous physical activity in each domain in a usual week. The GPAQ is validated in Germany and many other countries[40] and has been applied to various populations including patients with OA.[41]

Concepts of BE are used as exposure. Risk attitudes are measured via two questions including an 11-point Likert scale, where individuals can state their attitude to risk in general and in the health domain from (0) 'not at all ready to take risks' to (10) 'very likely to take risks'.[42] Self-efficacy is rated using the validated Allgemeine Selbstwirksamkeit Kurzskala questionnaire, where individuals are asked to answer three questions on general self-efficacy.[43] Additionally, a further question focuses on self-efficacy concerning physical activity supplemented by an item addressing intention to carry out physical activities.[44]

Time preferences are measured by using three distinct instruments. First, a questionnaire instrument with six items is applied creating a series of binary choices between hypothetical amounts of money now or in the closer future and alternative amounts in the further future. From these choices, individual discount rates can be derived.[45] Second, a qualitative item based on Borghans and Golsteyn (2006)[46] asks respondents to indicate their present-future tradeoff on a 5-point Likert scale. Third, respondents' self-assessed willingness to wait has to be stated on an 11-point Likert scale.[47]

In order to consider potential confounding, information on age, sex, education, occupation, marital status, living conditions, alcohol consumption and smoking behaviour is collected in the questionnaire. We further gathered information about comorbidities of the heart, lung, liver and kidneys as well as neurological diseases, high blood pressure, inflammatory joint diseases and further diseases specifically indicated by the participants. Depression will be assessed using the Patient Health Questionnaire.[48]The exact diagnosis of VDB will be obtained from the patient documentation at the DSGZ. In patients with OA, weight and height are measured routinely as a part of the premedical examination prior to the surgery at the OPMR and are used to calculate the BMI.

German translations were not available for the concepts of BE, the pain and satisfaction in patients with OA, and the adherence behaviour to therapy recommendations. These items thus were independently translated by at least two members of the study team. Discrepancies between the translations were discussed and resolved between the translators. The translated versions then were examined by the respective expert within the study team for each item in order to ensure that the translation did not change the construct of interest.

An overview of research outcomes and instruments used, including the number of items and corresponding references, is shown in table 1.

Sample size

Sample size calculation for THR/TKR is based on a minimally important difference (MID) of 8 for TKR and 9 for THR and a SD of 18 of the EQ-5D-5L.[49] Thus, 37 THR and 47 TKR patients are needed to estimate the mean with a power of 0.8 (alpha=0.05). Assuming a loss to follow-up of 20% between baseline and follow-ups, we need to include 131 (58+73) patients at baseline. Attrition rate is reasonable, based on our previous experiences with primary care patients where we found that 88% of patients of this age group had responded to the first postal follow-up. MID for the EQ-5D-5L are not available for VDB, so based on previous work,[50] we assume 10.0 points on the DHI[35] as a clinically relevant difference for patients with VDB. Assuming an SD of 25, a sample size of 52 will allow estimating the mean with a power of 0.8 (alpha=0.05). Assuming a loss to follow-up of 20%, we need to include 81 patients at baseline. For patients with VDB, different underlying pathologies will have to be considered. Thus, we plan to sample 81 patients from each of the four main somatic aetiologies of VDB, namely Benign Paroxysmal Positional Vertigo, Menière's disease, vestibular migraine, and functional vertigo, yielding a target sample size of 324.

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Table 1 Research outcomes and instruments used, including the number of items

	Instrument, items	Baseline		Follow-ups	
		Patients with THR/TKR	Patients with VDB	Patients with THR/TKR	Patients with VDB
Primary outcome measures					
HRQoL	EQ-5D-5L,[30] 5 items and VAS	x	x	x	x
Specific functioning (OA)	WOMAC functioning scale,[32 33] 17 items	x		x	
Dizziness-specific functioning (VDB)	DHI,[35] 25 items		x		x
Secondary outcome measures					
Pain, satisfaction (OA)	As recommended by Rolfson *et al*,[37] 1 item each	x		x	
OA-specific pain	WOMAC pain scale,[32 33] 5 items	x		x	
Physical activity (OA and VDB)	Global Physical Activity Questionnaire (GPAQ)[38]	x	x	x	x
Adherence behaviour	3 items on exercises and physical activity,[16] 1 item on weight control			x	x
Exposures					
Risk attitude	2 items: general and health specific risk attitude[42]	x	x		
Self-efficacy (general)	3 items[43]	x	x		
Self-efficacy (physical activity)	1 item[44]	x	x		
Intention (physical activity)	1 item[44]	x	x		
Time preferences	8 items[45–47]	x	x		
Confounding variables					
Age, sex, education, occupation, marital status, living conditions, alcohol consumption, smoking behaviour, and comorbidities		x	x	x	x
BMI, diagnosis of VDB	Assessed at the OPMR /DSGZ	x	x		
Depression	PHQ-9[48]	x	x	x	x

BMI, body mass index; DHI, Dizziness Handicap Inventory; DSGZ, German Centre for Vertigo and Balance Disorders; EQ-5D-5L, EuroQol Five-Dimensional Five-Level Questionnaire; HRQoL, health-related quality of life; OA, osteoarthritis; OPMR, Department of Orthopaedics, Physical Medicine and Rehabilitation; THR/TKR, total hip or knee replacement; VAS, visual analogue scale; VDB, vertigo, dizziness and balance problems; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

Data analysis

In a first step, BE concepts, HRQoL and functioning will be analysed descriptively. Differences will be compared using χ^2 tests for categorical variables and analysis of variance for metric variables, which are log transformed if necessary.

Second, mixed-effect regression models will be used in the sample with patients with OA and VDB to examine BE concepts as determinants of adherence, HRQoL and functioning. This method is appropriate to investigate longitudinal data with more than one wave of data.[51] Third, to investigate the impact of BE and psychological concepts as confounders for the association between physical activity and other factors, we will conduct stratified analyses and incorporate interaction terms in the regression models.

ETHICS AND DISSEMINATION

The study was approved by the ethics committee at the medical faculty of the Ludwig Maximilian University Munich under the number 20-727. Patients are supplied

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with sufficient information about their participation in the study and are only included if written informed consent is present. Participants will not be exposed to any medical risk due to study participation. The study is conducted in accordance with the Declaration of Helsinki. Data collection in this study will be done with the help of pseudonymised identification keys during study conduct. All links between the pseudonymised keys and person identifying information such as name or address will be destroyed after study completion. Conclusion about the actual patient will then no longer be possible and data will be de facto anonymised. Data will be double pseudonymised before being forwarded for data analysis to project partners only.

Results will be published in scientific, peer-reviewed journals and at national and international conferences. Results will be disseminated via newsletters, the project website and a regional conference for representatives of local and national authorities. The data set will be available for project researchers on request.

Author affiliations
[1]Institute for Medical Information Processing, Biometry and Epidemiology, Ludwig Maximilians University Munich, Munich, Germany
[2]Munich Center of Health Sciences, Ludwig Maximilians University Munich, Munich, Germany
[3]Pettenkofer School of Public Health, Ludwig Maximilians University Munich, Munich, Germany
[4]Institute of Health Economics and Health Care Management, Helmholtz Center Munich German Research Center for Environmental Health, Neuherberg, Germany
[5]Department of Economics, Martin Luther University Halle Wittenberg, Halle, Germany
[6]Department of Orthopaedics and Trauma Surgery, Musculoskeletal University Center Munich (MUM), University Hospital Munich, Munich, Germany
[7]Professorship of Public Health and Prevention, Faculty of Sport and Health Science, Technical University of Munich, Munich, Germany
[8]German Centre for Vertigo and Balance Disorders, University Hospital Munich, Munich, Germany

Acknowledgements The authors acknowledge the patients' willingness to participate, their appreciated support and their valuable feedback in the pilot testing of the questionnaire. The authors thank Michael Klein and Karoline Bögle for their valuable contribution to the data collection of this study.

Contributors EG, LS, MW and AP are the principal investigators. They conceived and supervised the project. BK coordinated the study. EG, LS, MW, AP and DK contributed to the conception of the cohort and design of the project. DK, BK and EG are responsible for the study's quality assessment. SF is responsible for the data management at the OPMR and preliminary analysis of the osteoarthritis data. LS and SP are responsible for secondary data management, preliminary analysis and preparation and contribute expertise on behavioural economics. BK, EG, LS, MW SP, SF and AP drafted the manuscript. All authors approved and critically revised the final manuscript.

Funding This work is part of the project "Munich Network Healthcare Research—MobilE-Net" and was supported by the German Federal Ministry of Education and Research grant number 01GY1913A.

Competing interests None declared.

Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not applicable.

Ethics approval The study was approved by the ethics committee at the medical faculty of the Ludwig Maximilian University Munich under the number 20–-727.

Provenance and peer review Not commissioned; externally peer reviewed.

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ORCID iD
Benedict Katzenberger http://orcid.org/0000-0003-1043-4104

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Acknowledgements

I am sincerely grateful to my first supervisor, Martin Weigl, for entrusting me with the work on this study, for his strong support throughout the project, and for his expertise and invaluable advice. This journey would not have been possible without him, and this opportunity has enabled me to discover my path in research and develop my potential.

I would also like to express my gratitude to my entire TAC team: to Lars Schwettmann, who mentored me during my master's degree internship and thesis, and kindly accepted the role of second TAC member during my PhD. And to Alexander Paulus, who supported me as the third TAC member, especially during patient recruitment, and provided technical insights into the surgical aspects of this thesis.

Furthermore, I would like to thank all my co-authors. Our collaboration and their valuable feedback have shaped these research reports into comprehensive publications that were smoothly accepted by reviewers.

A special thanks goes to Benedict Katzenberger, not only as a colleague but also as a comrade-in-arms and a friend. His structured approach and kind attitude created a working atmosphere that was both successful and joyful.

Another special thanks goes to Sara Pedron, who, together with Lars Schwettmann, supported me during my master's internship and thesis. During my PhD, I was able to apply many of the things I learned from her in practice.

I would like to express my gratitude to Boris Holzapfel and my colleagues from all professions at MUM, who supported my research in the department and offered their help whenever I needed it. I also wish to thank my colleagues at IBE for our excellent collaboration throughout the project.

Many thanks as well to my colleagues from the PhD program and fellow students. I firmly believe that working together and supporting one another is key to success during challenging times as a PhD student.

At this point, I would like to thank all the patients who contributed to the success of this project. Despite the comprehensive questionnaires and their own challenging circumstances, they found the time and energy to contribute to scientific knowledge and to help improve future patient care.

Finally, I am deeply grateful to my family and friends, who have supported me in every possible way throughout this sometimes challenging journey.

List of all scientific publications to date

Publications in peer-reviewed journals:

- Katzenberger B, **Fuchs S**, Schwettmann L, Strobl R, Hauser A, Koller D, Grill E (2023).
  Association of self-efficacy, risk attitudes, and time preferences with functioning in older patients with vertigo, dizziness, and balance disorders in a tertiary care setting – Results from the MobilE-TRA2 cohort.
  Frontiers in Neurology 14: 1316081. DOI: 10.3389/fneur.2023.1316081

- **Fuchs S**, Schwettmann L, Katzenberger B, Paulus A, Holzapfel B M, Biebl J T, Weigl M (2025).
  Association of self-efficacy, risk attitudes, and time preferences with health-related quality of life and functioning after total hip or knee replacement – Results of the MobilE-TRA 2 cohort.
  Health and Quality of Life Outcomes, 23(1), 44. DOI: 10.1186/s12955-025-02374-y

Study protocols in peer-reviewed journals:

- Katzenberger B, Schwettmann L, Weigl M, Paulus A, Pedron S, **Fuchs S**, Koller D, Grill E (2021).
  Behavioural and patient-individual determinants of quality of life, functioning and physical activity in older adults (MobilE-TRA 2):
  study protocol of an observational cohort study in a tertiary care setting.
  BMJ Open 11(12): e051915. DOI: 10.1136/bmjopen-2021-051915

Medical Guidelines

- Deutsche Gesellschaft für Orthopädie und Unfallchirurgie (DGOU), currently in Consultation version – final release expected in 2026.
  German S3 Guideline "Pertrochantäre Oberschenkelfraktur",
  AWMF-Registernummer 187-009.
  Link: https://register.awmf.org/de/leitlinien/detail/187-009

Conference Contributions

- Katzenberger B, **Fuchs S**, Schwettmann L, Strobl R, Hauser A, Koller D, Grill E (2023). Risk attitude and self-efficacy are associated with vertigo-specific functioning in older patients with vertigo, dizziness and balance disorders – results from the longitudinal multicenter study MobilE-TRA 2.
  18. Jahrestagung DGEpi, oral presentation. Würzburg, Germany

- Harada S, Boehm E, **Fuchs S**, Weigl M, Mansmann U, Feist-Pagenstert I (2024).
  The effects of Denosumab on vertebral trabecular and cortical bone mineral density measured by Quantitative Computed Tomography.
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