Aus der

Klinik und Poliklinik für Frauenheilkunde und Geburtshilfe

Klinikum der Ludwig-Maximilians-Universität München

Impact of gestational diabetes on maternal labour outcomes:

A comparative analysis of induction duration, prolonged labour and caesarean delivery rates

zum Erwerb des Doktorgrades der Medizin

an der Medizinischen Fakultät der

Ludwig-Maximilians-Universität München

vorgelegt von

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Amarante, Portugal

Jahr

2025

Mit Genehmigung der Medizinischen Fakultät der

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Tag der mündlichen Prüfung: 31.07.2025

Acknowledgements

I would like to express my deepest gratitude to my family for their unwavering support and encouragement throughout the course of this research. Their understanding and patience have been invaluable in helping me complete this work.

I am also immensely grateful to Joshua for his constant motivation, love, and belief in my abilities. His support has been a cornerstone in my academic journey.

Additionally, I would like to thank my friends for their friendship and encouragement. Their support and understanding have provided me with the balance needed to persevere through this challenging process.

A special thanks to my revisors, whose expertise and insightful feedback have been invaluable in shaping this work. Your guidance and constructive criticism have significantly enhanced the quality of this research. I would also like to extend my sincere gratitude to PD Dr. med Maria Delius for her valuable support and encouragement throughout this project. Her expertise and thoughtful input have greatly contributed to the development of this study.

Lastly, I extend my appreciation to all the participants and the Obstetric Department of the LMU University Hospital (Campus Innenstadt) for their cooperation and support, without which this study would not have been possible.

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List of abbreviations

ADA: American Diabetes Association

BMI: body mass index

CS: Caesarean section

CTG: cardiotocography

GCT: glucose challenge test

GDM: gestational diabetes mellitus

IADPSG: International Association of Diabetes and Pregnancy Study Groups

IL-6: interleukin-6

NICU: neonatal intensive care unit

oGTT: oral glucose tolerance test

PIH: pregnancy-induced hypertension

PPH: postpartum hemorrhage

TNF-α: tumor necrosis factor-alpha

WHO: World Health Organization

Summary

This research explores the effects of gestational diabetes mellitus on maternal and labour outcomes, with a particular emphasis on the duration of induction, overall labour progression, and the frequency of non-elective caesarean sections. A cohort of 128 pregnant women was examined, consisting of 93 in a control group and 35 diagnosed with GDM. While maternal age and parity were similar between both groups, a notable distinction was the significantly higher pre-pregnancy BMI in the GDM group (29.7 kg/m² compared to 23.56 kg/m²). Interestingly, despite the elevated BMI, women with GDM experienced less weight gain during pregnancy, likely due to enhanced dietary regulation and closer clinical monitoring.

Labour outcomes indicated that women in the GDM group had a shorter induction phase, but their overall labour was longer, particularly during the first stage. This aligns with previous research suggesting that metabolic changes in GDM pregnancies may impact uterine contractility. However, no significant differences were observed in the duration of the second stage of labour between the two groups.

Regarding the mode of delivery, the GDM group had a significantly higher rate of caesarean sections, mainly due to an increase in planned procedures. Although the rate of unplanned caesarean sections did not differ significantly, GDM was linked to a greater likelihood of labour interventions overall. In terms of neonatal outcomes, there were no substantial differences in birth weight or Apgar scores between the groups, and the risk of macrosomia did not appear to increase in GDM pregnancies.

These findings highlight the importance of careful maternal weight management and vigilant monitoring of labour in GDM-affected pregnancies. While effective management of GDM can reduce certain neonatal risks, the longer labour durations and increased rate of caesarean sections suggest that more research is needed to optimize delivery outcomes for this population.

Zusammenfassung

Die vorliegende Dissertation untersucht den Einfluss von Gestationsdiabetes mellitus (GDM) auf maternale und geburtshilfliche Komplikationen, mit besonderem Fokus auf die Dauer der Einleitung, den gesamten Geburtsverlauf und die Häufigkeit von sekundären Sectiones. In die Analyse wurden 128 schwangere Frauen einbezogen, davon 93 in die gesunde Kontrollgruppe und 35 mit Gestationsdiabetes mellitus. Die Basischarakteristika wie Alter und Parität waren in beiden Gruppen ähnlich, jedoch hatten Frauen in der GDM-Gruppe einen signifikant höheren prägraviden BMI (29,7 kg/m² vs. 23,56 kg/m²). Trotz des höheren BMI nahmen die Frauen in der GDM-Gruppe während der Schwangerschaft weniger Gewicht zu, was vermutlich auf eine diätetische Anpassung und engmaschigere Überwachung zurückzuführen ist.

Die Ergebnisse der Geburt legen nahe, dass die Einleitungsdauer in der GDM-Gruppe kürzer war; die Gesamtdauer der Geburt war jedoch im Vergleich zu der Kontrollgruppe länger, insbesondere in der ersten Phase der Geburt. Diese Befunde stehen im Einklang mit früheren Studien, die darauf hinweisen, dass Stoffwechselfaktoren in GDM-Schwangerschaften die Uteruskontraktilität beeinflussen können. In der zweiten Phase der Geburt gab es jedoch keine signifikanten Unterschiede zwischen den beiden Gruppen.

In Bezug auf den Geburtsmodus zeigte sich in der GDM-Gruppe eine signifikant höhere Rate an Sectiones, hauptsächlich aufgrund von geplanten Eingriffen. Obwohl keine signifikanten Unterschiede bei ungeplanten Sectiones beobachtet wurden, war GDM insgesamt mit einem erhöhten Risiko für geburtshilfliche Interventionen verbunden. Die neonatalen Parameter, einschließlich des Geburtsgewichts und der Apgar-Werte, waren in beiden Gruppen vergleichbar, ohne signifikant erhöhtes Risiko für Makrosomie in der GDM-Gruppe nachweisen zu können.

Diese Studie betont die Bedeutung des Gewichtsmanagements und der Überwachung des Geburtsverlaufs bei Schwangerschaften mit GDM. Während eine effektive GDM-Therapie einige neonatale Risiken abmildert, erfordert die Assoziation mit längeren Geburten und einer höheren Kaiserschnittrate weitere Untersuchungen, um optimale Geburtsergebnisse für diese Patientinnen zu gewährleisten.

1. Introduction

In obstetrics induction of labour is broadly discussed under various aspects. Induction of labour represents one of the most common interventions in pregnant women and is carried out in about 20-25% of all pregnancies. Some of the most frequent medical indications for induction of labour include premature rupture of membranes, gestational diabetes, postterm pregnancy and increased maternal age (1, 2).

Gestational diabetes (GDM) is defined as a variable severity glucose intolerance that either emerges or is first recognized during pregnancy. Understanding the pathogenesis of GDM is crucial for comprehending its impact on pregnancy. The principal metabolic disorders associated with GDM arise from insulin resistance and/or β-cell dysfunction (3).

GDM is associated with significant maternal and fetal morbidity and mortality, including stillbirth, perinatal death, neonatal death and infant mortality in both live and stillborn infants. GDM is also linked to adverse perinatal outcomes (4). According to Bell et al. (4), who conducted a regional population-based survey involving 1258 women in Northern England between 1996 and 2004, the frequency of birth complications increases by 50% in women with pre-existing diabetes.

Over the past few decades, several studies have investigated the delivery process in women with GDM, yielding some indirect findings. For women undergoing labour induction with prostaglandins, various baseline characteristics have been associated with successful outcomes. These characteristics include younger age, non-Black race, lower body mass index (BMI), multiparity, a later gestational age at delivery, ruptured membrane status, higher cervical dilation, and a higher Bishop Score (5). Conversely, diabetes has been identified as a risk factor for the failure of labour induction. In 2013, Sak et al. (6) reported that hyperglycemia was linked to a longer induction-to-abortion interval in women undergoing second-trimester termination with misoprostol. Furthermore, in 2017, Hawkins et al. (5) supported the findings of Timofeev et al. (7), suggesting that the labour curves for active labour were similar for pregnancies with and without diabetes undergoing labour induction with prostaglandins. The difference lay in the duration of the latent phase, implying that diabetic women experience a prolonged latent phase of labour.

In 2004, Ehrenberg et al. (8) conducted a study to evaluate whether pregravid obesity and diabetes (both gestational and pregestational) are independent risk factors for increasing the likelihood of caesarean delivery. They concluded that diabetes mellitus is indeed an independent risk factor for caesarean section. The study suggests that

women with GDM face specific challenges such as poor myometrial contractility and an increased risk of fetal distress, both of which raise the probability of caesarean sections. These complications occur even when controlling for other risk factors like obesity, showing that GDM directly influences the need for caesarean delivery, independent of other conditions.

Dunne et al. showed that post-partum haemorrhage is six times more common in diabetic women probably because of poor myometrial contractility (9). Other studies related post-partum haemorrhage to altered oxytocin response or altered uterine smooth muscle function. Already in 1985 McMurtrie et al. (10) described in rats that a diabetic state alters estradiol-stimulated changes in myometrial ultrastructure leading to alterations in contractility.

In 2012, Al-Qahtani et al. (11) compared spontaneous contractions, high K^+ depolarization, and oxytocin-induced contractions in diabetic patients and matched control subjects scheduled for elective caesarean section (CS). Their findings indicated that in diabetic patients, uterine contractions were significantly reduced, whether occurring spontaneously, in response to oxytocin, or under high K^+ conditions, attributed to diminished calcium channel expression and signalling, even when patients were being treated with insulin. Furthermore, they observed a small but significant reduction in myometrial mass in diabetic patients, which contributed to the decreased contractility. Notably, oxytocin was found to increase myometrial force and calcium transients to a similar extent in both non-diabetic and diabetic patients.

2. Overview of gestational diabetes

GDM is defined as glucose intolerance that is first identified or begins during pregnancy. It is classified based on the timing of diagnosis and the need for treatment. Specifically, Class A1 gestational diabetes is managed with diet and exercise alone, whereas Class A2 requires insulin or oral hypoglycemic agents for glycemic control (12).

GDM is a significant public health concern, affecting a substantial proportion of pregnancies worldwide. The prevalence of GDM varies widely due to differences in diagnostic criteria, population characteristics, and screening practices. Globally, approximately 7% of pregnancies are complicated by GDM, although rates can range from 1-14% depending on the population and diagnostic criteria used (13). Additionally, geographic regions with higher obesity rates tend to report higher prevalence of GDM. Over recent decades, the incidence of GDM has been increasing, likely due to rising rates of obesity and changes in diagnostic criteria that allow for earlier and more frequent detection (14).

Several factors increase the risk of developing gestational diabetes, which can be broadly categorized into non-modifiable and modifiable risk factors. Non-modifiable risk factors include age, ethnicity, family history, and previous history of GDM or delivery of a macrosomic newborn. Women over the age of 25 have as well a higher risk of developing GDM, with risk increasing further in women older than 35 years. Certain ethnic backgrounds, including Australia, Middle Eastern (Lebanese, Syrian, Iranian, Iraqi or Afghanistan) women and Pacific Islanders, are associated with a higher risk of GDM. A family history of diabetes, particularly in first-degree relatives, also increases the likelihood of developing GDM. Additionally, women who have previously had GDM or delivered a newborn weighing more than four kilograms are at higher risk for developing the condition in subsequent pregnancies (15, 14, 16).

Modifiable risk factors include overweight and obesity, sedentary lifestyle, and poor dietary habits. Pre-pregnancy overweight and obesity are significant risk factors for GDM, with higher BMI ≥ 30 kg/m² directly correlated with increased risk. A sedentary lifestyle plays a significant role in the development of insulin resistance, which is a key factor in GDM. Sedentarism increases the workload on pancreatic islets and decreases their efficiency through multiple pathways, including endoplasmic reticulum stress, mitochondrial dysfunction, oxidative stress, and inflammation. These pathways collectively contribute to the apoptosis and death of beta cells, further exacerbating insulin resistance (17). Poor dietary habits, particularly high intake of

processed and high-sugar foods, further increase the risk of developing GDM (15, 14, 18, 19).

Understanding these risk factors is crucial for early identification and intervention, which are essential to improve maternal and fetal outcomes, emphasizing the importance of routine screening and preventive measures in at-risk populations.

2.1. Pathophysiology

GDM arises from complex interactions between hormonal changes in pregnancy and underlies genetic and environmental factors. The pathophysiology of GDM primarily involves insulin resistance and pancreatic β-cell dysfunction, which occur due to the following mechanisms:

2.1.1. Hormonal changes and insulin resistance

During pregnancy, several hormones are produced in increased quantities to support fetal growth and development. These hormones include placental lactogen, progesterone, cortisol, and human placental growth hormone. While essential for maintaining pregnancy, they have anti-insulin effects that can lead to increased insulin resistance. This physiological insulin resistance ensures an adequate supply of glucose to the fetus by reducing maternal glucose uptake and increasing glucose production by the liver (20, 21).

2.1.2. Pancreatic β-cell dysfunction

In a normal pregnancy, the maternal pancreas compensates for insulin resistance by increasing insulin secretion. However, in women who develop GDM, there is an inadequate β-cell response. This insufficiency can be attributed to both genetic predisposition and acquired factors. The exact mechanisms are not fully understood, but it is believed that genetic factors predispose certain women to β-cell dysfunction, which is then exacerbated by the metabolic demands during pregnancy (22).

2.1.3. Genetic and environmental factors

Genetic predisposition plays a significant role in the development of GDM. Women with a family history of type 2 diabetes are at higher risk, indicating a hereditary component to β-cell dysfunction and insulin resistance. Additionally, various gene polymorphisms associated with insulin signaling and β-cell function have been identified as risk factors for GDM (23, 24).

Environmental factors, such as obesity, poor diet, and sedentary lifestyle, contribute significantly to the development of GDM. Obesity, in particular, exacerbates insulin resistance through the release of adipokines and inflammatory cytokines from adipose tissue. These substances interfere with insulin signaling pathways, further impairing glucose metabolism (20, 19).

2.1.4. Inflammatory and metabolic pathways

Chronic low-grade inflammation, commonly observed in obesity, also contributes to the pathophysiology of GDM. Adipose tissue in obese individuals releases pro-inflammatory cytokines such as tumor necrosis factor-alpha (TNF-α) and interleukin-6 (IL-6). These cytokines interfere with insulin signaling and exacerbate insulin resistance (21).

Moreover, lipid metabolism alterations in pregnancy can lead to an increase in free fatty acids, which impair insulin signaling and β-cell function. This lipotoxicity adds another layer of metabolic stress, contributing to the development of GDM (24).

2.1.5. Epigenetic changes

Recent research suggests that epigenetic modifications may also play a role in the pathogenesis of GDM. Epigenetic changes, such as DNA methylation and histone modification, can affect gene expression involved in insulin secretion and action. These changes can be influenced by environmental factors, such as diet and physical activity, during pregnancy (25).

2.2. Diagnosis

The diagnosis of GDM is a critical component of prenatal care, as timely identification and management can significantly improve maternal and fetal outcomes. The diagnostic process typically involves the screening of pregnant women for glucose intolerance, followed by confirmatory testing for those who screen positive. Various guidelines exist, but common practices are based on recommendations from organizations such as the American Diabetes Association (ADA) (26), the International Association of Diabetes and Pregnancy Study Groups (IADPSG) (27), and the World Health Organization (WHO) (28). In Germany, the guidelines are primarily based on the recommendations of the German Diabetes Association (Deutsche Diabetes Gesellschaft, DDG) and are consistent with those cited before (2).

At the first visit to the gynecologist, pregnant women are assessed for their risk of GDM or diabetes mellitus. The independent risk factors for the development of GDM during pregnancy can be seen in Table 1. If a higher risk is present, the woman should be tested for glucose metabolism disorders as early as possible. This can be done through fasting glucose measurement, random glucose measurement, HbA1c determination, and/or an oral glucose tolerance test (oGTT).

	OR	95%-KI
Pregnancies with a history of GDM		
History of GDM	50.4	42.1–60.3
Weight (> 69 kg)	1.02	1.01–1.03
Pregnancies without a history of GDM		
No GDM in previous pregnancy	0.45	0.4–0.5
Age (compared to ≤ 35 years)	1.08	1.07–1.09
Weight (> 69 kg)	1.03	1.01–1.04
Height (> 1.64 m)	9.94	0.93–0.95
First-degree relative with diabetes	2.5	2.2–2.8
Second-degree relative with diabetes	1.7	1.4–2.1
Ovulation induction	1.6	1.1–2.3
Origin from east asian region	2.9	2.2–3.8
Origin from south asian region	2.3	1.8–2.8
Z-score of birth weight of previous children	1.25	1.1–1.3

Table 1 - Independent risk factors for the development of GDM during pregnancy (2)

2.2.1. Screening according to maternity guidelines: 50-g screening test

Based on current evidence and international recommendations, all pregnant women should undergo a 75-g oral glucose tolerance test (oGTT) between 24+0 and 27+6 weeks of gestation as a one-step screening procedure for gestational diabetes mellitus (GDM). In Germany, however, the screening is typically performed using a two-step approach, which has been part of the official maternity care guidelines since March 2012. According to these guidelines, all pregnant women within this gestational age range are first offered a 50-g glucose challenge test (GCT). If the result is abnormal, it is followed by a diagnostic 75-g oGTT. (2).

The GCT is performed regardless of food intake or time of day, in a non-fasting state, by having the patient drink 50 g of anhydrous glucose dissolved in 200 ml of water. Blood glucose is then measured from venous plasma one hour after consuming the test solution. A blood glucose level of ≥135 mg/dl (7.5 mmol/l) is considered a positive screening result, necessitating a subsequent diagnostic 75-g oGTT. This process is known as a two-step screening, as a second test is required for a definitive diagnosis. However, if the blood glucose level after the 50-g GCT is >200 mg/dl (11.1 mmol/l), GDM is diagnosed directly, and the oGTT is deemed unnecessary (2).

The HAPO-study highlighted that 33% of women with GDM had an elevated fasting glucose level alone, which is not detected by the 50-g GCT. Given that fasting glucose levels have the closest correlation with adverse pregnancy outcomes, it is recommended to measure fasting blood glucose between 24+0 and 27+6 weeks of gestation if the 50-g GCT result is negative (2).

2.2.2. Fasting blood glucose as a screening test

The measurement of fasting blood glucose is an alternative screening method that has higher reproducibility compared to the Glucose Challenge Test (GCT), is easier to perform, and is less time-consuming. The two-step approach using fasting glucose determination as a screening method is commonly applied in Switzerland but not in Germany. The sensitivity of this method ranges from 78.5% to 96.9%. If the fasting blood glucose level is ≥ 91.8 mg/dl (5.1 mmol/l) (and the woman is indeed fasting), the diagnosis of GDM is confirmed. If the level is < 79.2 mg/dl (4.4 mmol/l), the diagnosis of GDM is unlikely. This approach allows 40% to 63% of women to avoid the oral glucose tolerance test (oGTT). A requirement for this strategy is that the labouratory results are available very quickly, or if necessary, the oGTT with 75 g of glucose must be repeated on another day if the fasting glucose level is between 79.2 and 91.8 mg/dl (4.4 and 5.0 mmol/l) (2).

2.2.3. HbA1c as a screening method

Screening using HbA1c has a significantly lower sensitivity for detecting a positive 75-g oral glucose tolerance test (oGTT) compared to GCT and fasting blood glucose. However, it may have high utility in identifying patients with previously undiagnosed pre-existing diabetes mellitus (2).

2.2.4. Diagnosis through oral glucose tolerance test

The 75-g oGTT must be performed under standard conditions in the morning after fasting. If the intended time window of 24+0–27+6 weeks of gestation is exceeded, the test can still be done later. Even in advanced pregnancy, initial or repeated hyperglycemia diagnosis may be advisable in the presence of specific risks.

Immediately before the test begins, fasting blood glucose is measured. Then, the pregnant woman drinks 75 g of anhydrous glucose dissolved in 300 ml of water or a comparable oligosaccharide mixture gradually over 3–5 minutes. Glucose measurements are taken one and two hours after the end of drinking the glucose solution. If severe pregnancy-related nausea or vomiting occurs, the test may need to be suspended (2).

Timing	Cut-offs venous plasma (mg/dl)	Cut-offs venous plasma (mmol/L)
Fasting	92	5.1
After 1 h	180	10
After 2 h	153	8.5

Table 2 - Blood glucose cut-off values for diagnosing gestational diabetes mellitus by using 75 g oral glucose tolerance test (adapted from (2))

2.3. Differential diagnosis

At the initial prenatal appointment before 24 weeks of gestation, pregnant women with an increased risk of glucose intolerance or pre-existing (previously undiagnosed) diabetes mellitus (type 1 or type 2) should be screened. Additionally, if diabetes-specific symptoms such as polyuria, polydipsia, or significant glucosuria in spontaneous urine are present, an investigation for previously undiagnosed diabetes mellitus should also be conducted (29).

Type 2 diabetes is usually present when blood glucose levels are measured in the manifest diabetic range in an obese, asymptomatic pregnant woman and/or the HbA1c level is ≥6.5%. In cases of suspected type 1 diabetes (normal weight, diabetes-associated symptoms), the diagnosis must be confirmed immediately according to guidelines and intensive insulin substitution should be initiated immediately (29).

Maturity Onset Diabetes of the Young (MODY) forms are hereditary in an autosomal dominant way. The common GCK-MODY (MODY2) is managed without medication outside of pregnancy, has a good prognosis, and almost never leads to complications. For these pregnant women, who are of normal weight and usually only have persistently elevated fasting glucose levels, insulin therapy is only initiated when fetal abdominal circumference is >75th percentile and disproportionate growth is observed. In the rarer HNF1α-MODY (MODY3), the hyperglycemic-symptomatic penetrance increases with age, and the usual complications occur if poor metabolic control. Children carrying the mutation manifest the disease approximately 12 years earlier if they were exposed to hyperglycemia in utero. While outside of pregnancy a very low-dose sulfonylurea therapy allows the control of the disease, even more than insulin therapy, pregnant women can only be treated with insulin (29).

2.4. Management and treatment

2.4.1. Nutritional management, diet therapy and lifestyle modifications

Effective management of gestational diabetes involves a multifaceted approach, integrating personalized nutritional plans, regular physical activity, and lifestyle modifications. These strategies not only help in controlling blood glucose levels but also contribute to overall health and well-being. Collaboration with healthcare professionals, including dietitians and diabetes educators, is essential to tailor these recommendations to the individual needs of each pregnant woman, ensuring optimal outcomes for both mother and child.

Nutritional management and diet therapy:

Nutritional management is essential in controlling blood glucose levels in women with GDM. The primary objectives are to achieve and maintain normoglycemia, ensure adequate maternal and fetal nutrition, and prevent excessive weight gain. This is achieved through a balanced diet, careful monitoring of carbohydrate intake, and strategic meal planning (26, 29).

To simplify dietary adjustments, it is recommended to limit carbohydrates to 35-45% of total daily caloric intake. This reduction helps to lower postprandial blood glucose levels (30). Effective meal planning involves distributing carbohydrate intake evenly throughout the day, with three moderate main meals and 2-3 smaller snacks, including a late-night snack to prevent excessive ketone production overnight (30).

Ensuring adequate intake of vitamins and minerals is also crucial. Key nutrients include folic acid, the vitamin B complex, calcium, vitamin D, magnesium, iron, and iodine (31).

The Institute of Medicine (IOM) provides guidelines for the recommended range of weight gain during pregnancy, based on the pre-pregnancy BMI of the woman. These recommendations aim to optimize maternal and fetal health outcomes by promoting appropriate weight gain throughout pregnancy (32).

- Underweight (BMI < 18.5): Recommended weight gain is 12.5 to 18 kg.
- Normal weight (BMI 18.5-24.9): Recommended weight gain is 11.5 to 16 kg.
- Overweight (BMI 25-29.9): Recommended weight gain is 7 to 11.5 kg.
- Obese (BMI ≥ 30): Recommended weight gain is 5 to 9 kg.

These ranges are designed to ensure that both the mother and infant receive the necessary nutrients for healthy growth and development while minimizing the risk of complications related to excessive or insufficient weight gain. Regular monitoring and individualized care are essential to achieving these weight gain targets.

Women are encouraged to monitor their weight weekly at home, in the morning without clothing, and to document their results (2). Self-monitoring of blood glucose levels is essential in managing GDM. Initially, women should measure their blood glucose levels in the morning while fasting and after each main meal (four measurements per day). If all values are within the target range and ultrasound findings are normal after two weeks of dietary therapy, subsequent monitoring can be reduced to a single daily measurement in a rotating schedule or a four-point profile twice a week (29, 2).

Physical activity and lifestyle modifications:

Regular physical activity is essential in managing GDM. Exercise enhances insulin sensitivity, controls blood glucose levels, and prevents excessive weight gain. Aerobic activities like walking, swimming, and cycling are recommended, with a target of 150 minutes of moderate-intensity exercise per week, ideally spread over most days. Sessions should last around 30 minutes, though shorter, frequent sessions are also beneficial (32, 33).

2.4.2. Pharmacological treatment

When lifestyle modifications such as diet and exercise are insufficient to control blood glucose levels in women with GDM, pharmacological treatment may be necessary. Approximately 10-20% of pregnant women with GDM require insulin therapy to achieve metabolic goals. The necessity for insulin therapy is typically evaluated within the first two weeks of initiating basic therapy, based on blood glucose self-monitoring results (29).

The effectiveness of insulin therapy is monitored by regular ultrasound to assess fetal abdominal circumference and growth patterns, as maternal hyperglycemia affects the fetus differently depending on these factors (29).

Oral hypoglycemic agents are generally not recommended during pregnancy due to a lack of approval, experience, and studies for most drug classes, except for metformin. Metformin is sometimes used, but it is not considered a primary alternative to insulin. Studies have shown that nearly half of the women initially treated with metformin required insulin after about three weeks due to insufficient glycemic control (34).

2.5. Complications in pregnancy with gestational diabetes

GDM presents significant risks to both the mother and fetus, resulting in various complications during pregnancy. Recognizing these complications is essential for effective management and intervention.

2.5.1. Maternal complications

Women with GDM face a higher likelihood of obesity, hyperlipoproteinemia, atherosclerosis, and hypertension. One prevalent issue is polyhydramnios, often resulting from glucosuria-induced polyuria, contributing to an elevated rate of preterm births. Additionally, these women experience a higher incidence of obstetric complications, including increased caesarean deliveries, more frequent operative vaginal deliveries, pregnancy-induced hypertension (PIH), preeclampsia, postpartum haemorrhage, and genital tract injuries (16, 35, 36).

Research indicates that pregnant women with impaired glucose tolerance are more susceptible to urinary tract infections, vaginal infections, and chorioamnionitis (36).

2.5.2. Fetal and neonatal complications

Pregnancies complicated by GDM often lead to significant fetal and neonatal complications. One of the most common issues is macrosomia, where the fetus grows excessively large, typically weighing over 4,000 grams at birth. This condition affects 15-45% of newborns from mothers with GDM and can result in delivery-related injuries such as shoulder dystocia, fractures, and nerve damage (35). Additionally, macrosomia increases the likelihood of caesarean delivery, especially if the estimated birth weight is 4,500 grams or more (16).

In pregnancies with pre-existing type 1 diabetes, poor metabolic control can lead to fetal malformations (heart defects and neural tube defects like spina bifida) up to ten times more frequently. This elevated risk does not seem to be the case for GDM because hyperglycemic phases in GDM typically start after the 20^{th} week of pregnancy, after the completion of embryogenesis (35).

Neonatal hypoglycemia is another serious concern, occurring when a newborn's blood sugar levels drop significantly after birth due to the continued high insulin

production in response to the mother's elevated blood glucose levels during pregnancy. Timely monitoring and management are crucial to prevent potential neurological damage (34).

Women with GDM are as well at a significantly increased risk of spontaneous preterm delivery (37). Preterm infants often face numerous health challenges, including underdeveloped organs, respiratory issues like respiratory distress syndrome, and difficulties in maintaining body temperature and blood sugar levels.

Jaundice, another potential complication, is more likely to occur in infants of mothers with GDM. While jaundice is typically benign, severe cases can lead to kernicterus, a form of brain damage, making it essential to monitor and manage bilirubin levels in newborns carefully (35).

Moreover, infants born to mothers with GDM face long-term metabolic risks. These children are at an increased risk of developing obesity, glucose intolerance, and metabolic syndrome later in life. This underscores the importance of effective management of GDM during pregnancy to minimize adverse outcomes and promote long-term health for the child (30).

2.6. Maternal complications after pregnancy with gestational diabetes

Women diagnosed with GDM are at a significantly increased risk of developing type 2 diabetes mellitus later in life. Around 10% of these women develop diabetes shortly after delivery, and within 5-10 years, 20-60% may develop diabetes if no interventions are taken to reduce this risk (38, 39).

Most women who develop diabetes after GDM exhibit characteristics of pre-type 2 diabetes mellitus, with a progressive decline in β-cell function and increased insulin resistance over time. Key risk factors for early development of diabetes include high glucose levels, severe insulin resistance, and poor β-cell function. Other factors, such as weight gain, elevated C-reactive protein levels, and lower adiponectin levels, contribute to worsening β-cell deterioration (38).

Moreover, GDM is often associated with components of metabolic syndrome, including obesity, insulin resistance, and cardiovascular risk factors. Women with a history of GDM are more likely to experience these metabolic and cardiovascular issues compared to women without GDM, further linking GDM to long-term health complications (38).

2.7. Induction of labour in the context of GDM and obesity

Induction of labour in the context of GDM and obesity presents unique challenges that require a tailored approach to care.

Current clinical guidelines emphasize the importance of individualized care for pregnant women with GDM and obesity. The management of these pregnancies includes close monitoring of maternal glucose levels, fetal growth assessments, and careful timing of labour induction to optimize outcomes.

An induction of labour before 39+0 weeks of gestation increases neonatal morbidity and should be avoided. An induction of labour between 39+0 and 39+6 weeks on women with GDM can be considered, but it is associated with a 50% increase in induction of labour rate and does not reduce neonatal morbidity. There is evidence that fetal morbidity in insulin-dependent GDM can be reduced by induction at 40 weeks of gestation and should therefore be offered. A well-controlled gestational diabetes managed through diet alone does not constitute an indication for labour induction. In cases of GDM with an estimated fetal weight greater than the 95th percentile by ultrasound, the potential benefits of induction from 37+0 weeks should be weighed against the impacts of an earlier gestational age at birth (2).

Obesity alone does not constitute an indication for labour induction. However, when additional risk factors are present, offering and carefully considering induction of labour at 39+0 weeks of gestation for obese pregnant women is recommended (40).

A Randomized Controlled Trial published in the New England Journal of Medicine in 2018, focused on low-risk nulliparous women, found that induction of labour at 39 weeks did not significantly reduce the incidence of composite adverse perinatal outcomes. However, it did lead to a significantly lower rate of caesarean delivery, suggesting a potential benefit of labour induction at this stage in certain populations (41).

3. The study

3.1. Purpose of the study

3.1.1. Objective and hypothesis

GDM is associated with considerable maternal and fetal morbidity and mortality, encompassing stillbirth, perinatal death, neonatal death and infant mortality. Furthermore, GDM is linked to adverse perinatal outcomes. Over the years, research on the delivery processes in women with GDM has offered indirect insights into various factors affecting labour outcomes.

The primary hypothesis of this study is that GDM significantly increases the risk of adverse maternal and labour outcomes, specifically prolonged labour induction, as defined by the duration from the initiation of induction to the onset of contractions, extended first stage of labour and a higher incidence of non-elective caesarean sections, including emergency or unplanned caesarean deliveries.

Other variables examined embraced both maternal and neonatal health. These include the frequency of postpartum haemorrhage (PPH), defined as the loss of 500 ml or more of blood following vaginal delivery or 1000 ml or more following caesarean section, the incidence of macrosomia, defined as newborns with a birth weight of 4000g or more, and evaluating the occurrence and severity of perineal tears during delivery. The study will also examine the frequency of suspect or pathological CTG readings (based on the FIGO-Score), which may indicate potential fetal distress. Regarding neonatal outcomes, the study will investigate the occurrence of live births or stillbirths, measure birth weights, and document admissions to the Neonatal Intensive Care Unit (NICU). Furthermore, it will measure arterial cord blood pH to evaluate neonatal acid-base status, and review APGAR scores at 1 and 5 minutes post-delivery to assess neonatal health and vitality.

3.2. Materials and Methods

3.2.1. Study population and oversight

We conducted a single-center prospective case-control study to compare healthy pregnant women with those diagnosed with GDM. This study population included women over the age of eighteen who delivered at LMU University Hospital between 39+0 and 42+0 weeks of gestation. The study group comprised pregnant women with GDM who had labour between 39+0 and 42+0 weeks of pregnancy, while the control group included healthy pregnant women delivering within the same gestational period, both groups having a singleton live fetus.

The recruitment for this study took place at the Obstetric Department of the University Hospital, LMU Munich (Campus Innenstadt) from January 2022 to November 2023. Information about the study was prominently posted, targeting all women who visited our hospital. The patients were thoroughly informed by the medical team at the time of registration for delivery. Upon admission for delivery, they were asked again if they consented, and if they had not yet been informed, they were provided with the necessary information.

Exclusion criteria included pregnancies complicated by blood clotting disorders or multiple pregnancies.

Participants self-reported their pre-pregnancy weight and provided detailed information about their clinical and pregnancy history. This included data on medications, chronic diseases, and any complications related to the current or previous pregnancies.

In the postpartum phase of the study, data on pregnancy outcomes, including maternal complications and neonatal outcomes, were extracted from medical records. Additional relevant data from the pregnant woman's medical records were also collected and analysed.

A total of 19 women were excluded from the study. Of these, 13 participants met the exclusion criteria. An additional six participants were lost to follow-up due to various reasons, such as relocating, withdrawing consent, or being unable to be contacted despite multiple attempts.

A total of 128 pregnant women participated in the study: 93 healthy women with a singleton live fetus (control group) and 35 women diagnosed with GDM through 50-

g-oGTT or 75-g-oGTT test (experimental group). The experimental group included both insulin-controlled GDM and diet-controlled GDM patients.

Patients who underwent planned caesarean sections, even without labour induction or uterine contractions, were included in this study due to the significance of their data for future analyses. Our research group plans to conduct immunohistochemical analyses on placental tissue samples to assess microvessel density, as well as quantitative PCR on myometrial tissue samples. These materials were collected from all patients included in this study.

All patients were pseudonymized using randomly generated numerical codes to ensure confidentiality. Clinical data were meticulously collected by the study physicians and stored in a pseudonymized format to protect patient identity. Each patient sample was labeled with the patient's unique pseudonym, followed by a sample identification abbreviation, before being subjected to further testing or storage.

Statistical analyses were conducted using IBM SPSS Statistics (Version 29.0.1.0). Maternal characteristics were compared between both groups and were described by the percentage (%) or using median. The normality of the variables was assessed using the Shapiro-Wilk test. For normally distributed data, a t-test was used for comparison ($p < 0.05$ was considered statistically significant). For non-normally distributed variables, the Mann-Whitney U test was applied ($p < 0.05$ was considered statistically significant). The Pearson chi-square test was used for comparisons of categorical variables. A p-value < 0.05 was considered statistically significant.

The author ensures the accuracy and completeness of the collected data and affirm the integrity of this report. Ethical approval for this study was initially granted by the LMU Munich ethics committee (project number 18-700). Due to subsequent changes in the study objectives, an additional approval was obtained under project number 22-0435. The participation in this study was voluntary and all participants provided written informed consent prior to enrolment in the study.

3.3. Results

3.3.1. Demographic characteristics and clinical presentation

The final analysed cohort included 128 women: 93 in the control group and 35 in the experimental group. Baseline demographic characteristics are presented in Table 3. The mean age of the participants was similar between the two groups, with no significant difference observed (35.19 ± 5.25 years vs. 34.80 ± 5.68 years, p = 0.723). Parity distribution was also comparable between the groups, with nulliparous women comprising 60.2% in the control and 60.0% in the GDM group (p = 0.982).

The mean BMI before pregnancy was significantly higher in the GDM group compared to the control group (29.69 ± 8.22 kg/m² vs. 23.56 ± 3.97 kg/m², p < 0.001). A similar trend was observed for the mean BMI at delivery, which was also significantly higher in the GDM group (33.62 ± 7.54 kg/m² vs. 27.79 ± 3.78 kg/m², p < 0.001).

Maternal weight before pregnancy was significantly different between the groups, with the GDM group having a higher mean weight (80.84 ± 24.45 kg vs. 66.45 ± 11.76 kg, p = 0.003). Likewise, the mean maternal weight at delivery was higher in the GDM group compared to the control group (91.82 ± 22.93 kg vs. 78.75 ± 11.80 kg, p = 0.011).

The mean weight gained during pregnancy was significantly lower in the GDM group (10.58 ± 6.32 kg) compared to the control group (12.36 ± 6.46 kg, p = 0.012).

A significantly higher proportion of women in the GDM group had a pre-pregnancy BMI ≥ 30 kg/m² (66.7% vs. 33.3%, p < 0.001). On the other side, the proportion of women with a BMI ≥ 30 kg/m² at delivery was lower in the GDM group compared to the control group (45.8% vs. 54.2%, p < 0.001).

Characteristics	Non-Diabetic Group (n = 93)	GDM Group (n = 35)	p-value
Age – Mean	35.19 years (± 5.25 years)	34,80 years (± 5.68 years)	0.723
Nulliparous	60.2 %	60.0 %	0.982
Multiparous	39.8 %	40.0 %	0.894
Mean gestational age at delivery (weeks)	39.84	39.48	0.062
Mean BMI before pregnancy	23.56 kg/m^2 (± 3.97 kg/m^2)	29.69 kg/m^2 (± 8.22 kg/m^2)	<0.001
Mean BMI at delivery	27.79 kg/m^2 (± 3.78 kg/m^2)	33.62 (± 7.54 kg/m^2)	<0.001
Mean maternal weight before pregnancy	66.45 kg (± 11.76 kg)	80.84 kg (± 24.45)	0.003
Mean maternal weight at delivery	78.75 kg (± 11.80 kg)	91.82 kg (± 22.93kg)	0.011
Mean weight gained during pregnancy	12.36 kg (± 6.46 kg)	10.58 kg (± 6.32 kg)	0.012
BMI ≥ 30 before pregnancy	33.3 %	66.7%	<0.001
BMI ≥ 30 at delivery	54.2 %	45.8 %	<0.001
Medical history			
No medical conditions	53.76 %	28.57 %	0.01
Thyroid diseases	25.80 %	14.29 %	0.165
Neurological diseases	5.38 %	0 %	0.162
Insulin controlled gestational diabetes	0 %	22.86 %	<0.001
Dietary controlled gestational diabetes	0 %	77.14 %	<0.001
Other condition	15.05 %	11.43 %	0.599
Induction of labour	45.2 %	60.0 %	0.134
Epidural	70.9 %	68.57 %	0.791

Table 3 - Basic characteristics of the participants

Nearly half (49.2%) of the study population underwent labour induction with different methods. In Table 4, the different methods employed for labour induction are detailed.

The induction rate was slightly higher in the GDM group (60.0%) compared to the control group (45.2%) (p = 0.134), with postterm pregnancy being the primary reason for induction in the control group (10 %) and GDM the primary reason in the GDM group (31.4%).

	Non-Diabetic Group	GDM Group
Vaginal insert	19,04%	25,00%
Misoprostol p.o.	22,27%	20,00%
Double balloon catheter	2,27%	0%
Amniotomy	0%	0%
More than one method	52,27%	55,00%

Table 4 – Methods for induction of the labour

3.3.2. Primary outcomes

Table 5 illustrates the comparison of the duration of various labour stages between the control group and the GDM group for patients undergoing induction of labour (planned caesarean sections were excluded). The duration of labour induction was defined as the time from the initiation of induction (whether pharmacological or mechanical) to the onset of frequent uterine contractions. The first stage of labour was measured from the onset of frequent uterine contractions to full cervical dilation (10 cm), and the second stage was defined as the time from complete cervical dilation to the delivery of the infant. Women with GDM experienced a marginally shorter labour induction period compared to non-diabetic women (17.09 hours vs. 22.86 hours, p = 0.353). For the first stage of labour, the GDM group had a longer duration (17.05 h ± 6.45 hours) compared to the control group (09.00 ± 1.07 hours), although the difference was not statistically significant (p = 0.749). The second stage of labour duration was similar between the groups, with the control group having a mean of 1.75 ± 0.23 hours, and the GDM group 1.47 ± 0.33 hours (p = 0.499). Lastly, the overall duration of labour did not show a statistically significant difference between the groups. The GDM group had a mean labour duration of 18.53 ± 6.6 hours, compared to 10.77 ± 1.08 hours in the control group (p = 0.833). This difference is mainly due to a longer first stage of labour in the GDM group compared to the control group.

Duration of labour stages after induction	Non-Diabetic Group (n = 42)	GDM Group (n = 21)	p-value
Duration of labour induction	22.87 h (± 3.8 h)	17.9 h (± 3.77 h)	0.353
Duration of the first stage of labour	09.00 h (± 1.07 h)	17.05 h (± 6.45 h)	0.749
Duration of the second stage of labour	1.75 h (± 0.23 h)	1.47 h (± 0.33 h)	0.499
Duration of the labour	10.77 h (± 1.08 h)	18.53 h (± 6.6 h)	0.833

Table 5 - Duration of labour stages for patients undergoing labour induction

Table 6 presents the comparison of labour duration between patients in the control and GDM groups, specifically for those who did not undergo labour induction. In the first stage of labour, the mean duration was 8.3 hours (± 1.15 h) in the control group and 6.77 hours (± 1.42 h) in the GDM group. Despite the observed difference, the p-value of 0.828 suggests no statistically significant difference between the two groups. For the second stage of labour, the mean duration was 1.45 hours (± 0.22 h) for the control group and 1.42 hours (± 0.62 h) for the GDM group. Similar to the first stage, the p-value of 0.841 indicates no significant difference between the groups. Finally,

the overall duration of labour was 9.77 hours (± 1.27 h) for the control group and 8.18 hours (± 1.82 h) for the GDM group. The p-value of 0.920 shows that the total labour duration did not differ significantly between the groups.

Duration of labour stages without induction	Non-Diabetic Group (n = 41)	GDM Group (n = 6)	p-value
Duration of the first stage of labour	08.3 h (± 1.15 h)	6.77 h (± 1.42 h)	0.828
Duration of the second stage of labour	1.45 h (± 0.22 h)	1.42 h (± 0.62 h)	0.841
Duration of the labour	9.77 h (± 1.27 h)	8.18 h (± 1.82 h)	0.920

Table 6- Duration of labour stages for patients without labour induction

Table 7 compares the mode of delivery between the control group and the GDM group. While vaginal delivery was more common in the control group (62.4%) compared to the GDM group (45.7%), the difference was not statistically significant (p = 0.089).

The rate of caesarean section was significantly higher in the GDM group (40.0%) compared to the control group (21.5%), with p = 0.035. Further analysis showed that planned caesarean section occurred in 22.9% of the GDM group compared to 10.8% of the control group (p = 0.079), though this difference was marginally non-significant. Unplanned caesarean section occurred in 17.1% of the GDM group compared to 10.8% of the control group (p = 0.330).

When analysing the absolute numbers, a total of 63 patients underwent labour induction. Among these, two experienced unplanned caesarean sections due to induction failure (one in the control group and one in the GDM group). Of the 61 patients who developed uterine contractions following induction, 44 achieved vaginal delivery, while 12 required an unplanned caesarean section. The reasons for the unplanned caesarean sections included labour arrest during the first stage (nine cases - six in the control group and three in the GDM group), labour arrest during the second stage (one case in the GDM group), and pathological CTG (two cases - one in the control group and one in the GDM group).

In contrast, among the 47 patients who developed uterine contractions spontaneously, 45 successfully delivered vaginally, and two underwent unplanned caesarean sections due to labour arrest during the first stage of labour (both in the control group).

The median time from labour induction to the decision for unplanned caesarean section showed no significant difference between the two groups (p=0.466). In the control group, the time was 30.43 hours (± 5.73 h), while in the GDM group it was 38.23 hours (± 8.35 h).

In an intention-to-treat analysis, all women intended to deliver vaginally following labour induction were included, regardless of the actual mode of delivery. The vaginal birth rate was 81% in the control group and 71.4% in the GDM group, without a significant difference observed (p = 0.391).

Mode of delivery	Non-Diabetic Group (n = 93)	GDM Group (n = 35)	p-value
Vaginal delivery	62.4%	45.7%	0.089
Caesarea section (%)	21.5%	40.0%	0.035
Planned	10.8%	22.9%	0.079
Unplanned	10.8%	17.1%	0.330
Vacuum extraction	16.1%	14.3%	0.798

Table 7 - Mode of delivery

Table 8 shows the reasons for caesarean sections in both the GDM and control groups. The most common reason for planned caesarean section in the control group was a previous caesarean section (60%), while the most frequent reason for unplanned caesarean section was labour arrest (80%).

In the GDM group, the most common reason for planned caesarean section was also a previous caesarean section (75%). Reasons for unplanned caesarean section included suspect or pathological CTG (16.7%), labour arrest (66.7%), and failed induction (16.7%).

Finally, vacuum extraction was similar between groups, occurring in 16.1% of the control group and 14.3% of the GDM group, without a statistically significant difference (p = 0.798).

There were no cases of forceps extraction observed in either the control group or the GDM group in this study population.

		Non-Diabetic Group (n = 20)	GDM Group (n = 14)	p-value
Planned caesarean section	Previous caesarean section	60%	75%	0.502
	Breech position	20%	0%	0.180
	Macrosomia	0%	12.5%	0.250
	Wish	20%	12.5%	0.671
Unplanned caesarean section	Suspect or pathological CTG	10%	16.7%	0.696
	Labour arrest	80%	66.7%	0.551
	Failed induction	10%	16.7%	0.696

Table 8 - Reasons for caesarean section

3.3.3. Secondary outcomes

The rate of suspicious or pathological CTG readings (based on the FIGO-Score) was similar between the two groups. In the control group, 25.8% of CTG readings were suspicious or pathological, compared to 20% in the GDM group (p = 0.494).

Postpartum blood loss did not differ significantly between the control and experimental groups (control: mean blood loss 505.38 ml, ± 316.95; experimental: mean blood loss 520.0 ml, ± 266.84; p = 0.746).

Perineal tears were categorized into low-grade (first and second degree) and high-grade (third degree) tears. In the control group, 62.4% of women experienced low-grade perineal tears, while 2.2% had high-grade tears. In the GDM group, 45.7% had low-grade perineal tears, and no cases of high-grade tears were observed. The p-value for the comparison of high-grade perineal tears between the two groups was 0.382, while the p-value for low-grade tears was 0.242, indicating no statistically significant differences.

Table 9 shows the neonatal outcome with no significant differences between the control and experimental groups in terms of median percentile for birth weight, however it was slightly higher in the GDM group (48.86 P. vs. 44.0 P., p = 0.391). Birth weight was similar between the groups (control: 3443.28g ± 411.88g, GDM: 3487.29g ± 441.83g, p = 0.523). The incidence of macrosomia, defined as a birth weight exceeding 4,000 grams, did not differ significantly between the groups. In the GDM

group, 8.6% of newborns were classified as macrosomic, while the control group exhibited a slightly higher rate of 10.8% (p = 0.716).

There were as well no significant differences between the Apgar scores (all neonates had scores ≥7 at 5 minutes).

There was a significantly higher proportion of neonates in the GDM group with an arterial pH < 7.1 (11.43% in GDM vs. 2.15% in non-diabetic), with a p-value of 0.027, indicating a higher likelihood of neonatal acidosis in the GDM group. There were five cases of arterial cord pH < 7.1, three of which occurred in patients with GDM. Among the GDM patients, two underwent labour induction, with one requiring vacuum extraction and the other an unplanned caesarean section. The third GDM patient, who developed spontaneous uterine contractions without induction, achieved a spontaneous vaginal delivery. In the control group, two cases of pH < 7.1 were observed. One patient underwent labour induction and delivered via vacuum extraction, while the other, who had spontaneous uterine contractions, delivered vaginally without intervention.

Similarly, a higher proportion of neonates in the experimental group required admission to the neonatal intensive care unit (NICU) (8.57%) compared to the control group (3.23%) (p = 0.202).

Neonatal outcome	**Non-Diabetic Group (n = 93)**	**GDM Group (n = 35)**	**p-value**
Neonatal weight	3443.28 g (± 411.88 g)	3487.29 g (± 441.83 g)	0.523
Weight ≥ 4000g	10.8%	8.6%	0.716
APGAR score < 7 at 5min. (%)	0%	0%	1
Percentile child	44.40 P.	48.86 P.	0.391
Arterial pH	7.24 (± 0.30)	7.27 (± 0,09)	0.401
Arterial pH < 7,1	2.15%	11.43%	0.027
Base excess child	-5.07mmol/l (± 2,99 mmol/l)	-4.58mmol/l (± 3.67 mmol/l)	0.389
NICU admission	3.23%	8.57%	0.202
Neonatal sepsis	2.15%	2.86%	0.814

Table 9 - Neonatal outcome

3.4. Discussion

This study aimed to explore the effects of GDM on maternal and labour outcomes, concentrating on the duration of labour induction, overall labour duration (emphasising the first stage of labour), and the prevalence of non-elective caesarean sections. Our findings contribute to the growing body of knowledge regarding GDM's impact on the labour and delivery process, offering valuable insights into potential areas for improved management strategies.

The results reveal a noteworthy association between GDM and specific adverse labour outcomes, although some findings diverge from existing literature. Notably, women with GDM who underwent labour induction had a marginally shorter induction period compared to the control group (17.9 hours (± 3.77 h) vs. 22.87 hours (± 3.8 h), p = 0.353). This finding contrasts with the results of Sak et al. (6), who reported that hyperglycemia was associated with a longer induction-to-abortion interval in second-trimester terminations using misoprostol. Although these studies involve different populations of pregnant women, the comparison can still provide valuable insights. The relatively shorter induction duration in this study might be attributed to the more proactive and intensive management of GDM patients, where labour is induced earlier to prevent complications such as fetal macrosomia. However, despite the shorter induction duration, women in the GDM group experienced a longer first stage of labour, possibly due to the metabolic and physiological effects of GDM on uterine function and contractility.

Indeed, the prolonged first stage of labour in the GDM group, although not statistically significant, aligns with previous studies by Hawkins et al. (5) and Timofeev et al. (7), both of whom suggested that GDM can impair uterine contractility and lead to a longer latent phase. Hawkins et al. hypothesized that diabetes mellitus would be an independent predictor of prolonged labour induction when prostaglandins are used, due to a longer latent phase compared to non-diabetic pregnancies. They aimed to investigate whether diabetes increases the duration of labour induction in this population, focusing on cervical ripening and labour progression following prostaglandin use. Their study found that women with diabetes experienced longer induction times and were less likely to deliver within 36 or 48 hours compared to non-diabetic women (5). Timofeev et al. tested the hypothesis that the first stage of labour would be longer in women with diabetes, compared to non-diabetic women. They aimed to assess the influence of diabetes on labour curves, particularly focusing on labour duration and progression, stratified by parity and matched for BMI and birth weight. Their findings showed that while diabetes was associated with slower cervical

dilation in some stages of labour, the overall progression of active labour was similar between diabetic and non-diabetic women, although women with diabetes showed slightly longer labour phases due to factors like fetal size and obesity (7). Our findings support these observations, showing that the GDM group undergoing induction of labour had a mean first stage labour duration of 17.05 hours (± 6.45 h) compared to 09.00 hours (± 1.07 h) in the control group. Although this difference did not reach statistical significance (p = 0.749), the trend suggests that GDM may influence labour progression, particularly during the early stages.

In contrast, the duration of the second stage of labour was similar between the groups, with the control group having a mean duration of 1.75 hours (± 0.23 h) and the GDM group 1.47 hours (± 0.33 h) (p = 0.499). Additionally, the overall duration of labour did not show a statistically significant difference between the groups after induction, with the GDM group having a mean labour duration of 18.53 hours (± 6.6 h) compared to 10.77 hours (± 1.08 h) in the control group (p = 0.833). The longer overall duration of labour in the GDM group is largely attributed to the extended first stage.

The higher rate of non-elective caesarean sections observed in the GDM group is another important finding. Caesarean deliveries, both planned and unplanned, were significantly more common in women with GDM. Unplanned caesarean sections occurred more frequently in the GDM group, likely as a response to complications such as labour arrest, fetal distress or failed induction. This finding is consistent with existing literature, which has repeatedly linked GDM to an increased risk of operative delivery (8). Ehrenberg et al. (8) hypothesized that pregravid obesity and diabetes (both gestational and pregestational) would independently increase the likelihood of caesarean delivery. The study aimed to evaluate whether these conditions are independent risk factors for caesarean delivery, even when other contributing factors such as fetal macrosomia, induction of labour, and parity are taken into account. Their findings confirmed that both obesity and diabetes significantly heightened the risk of caesarean delivery.

It is also worth noting that planned caesarean sections were more frequent in the GDM group, likely due to pre-existing conditions like previous caesarean deliveries. The higher caesarean rate in the GDM group reinforces the need for individualized management strategies to monitor labour progression closely and intervene appropriately when labour does not progress as expected.

While GDM is often associated with an increased risk of macrosomia, this study did not observe a significant difference in birth weight or the incidence of macrosomia

between the GDM group and the control group. This is likely a reflection of effective glycemic control and careful fetal monitoring in the GDM group, as well as the timely induction of labour. These management strategies appear to mitigate some of the risks traditionally associated with GDM, particularly those related to excessive fetal growth. This finding contrasts with earlier studies, which have shown significantly higher rates of macrosomia in GDM pregnancies (35). It suggests that with proper monitoring and management, the risk of macrosomia in GDM pregnancies can be effectively controlled. On the other side, this may also reflect a selection bias, as patients participating in a study are likely to have better blood glucose management.

Considering again Timofeev et al.'s hypothesis that increased fetal size can contribute to prolonged labour by affecting uterine contractility, the similar birth weights observed between the GDM group and the control group suggest that other factors may be influencing the duration of labour in the GDM group. This finding implies that GDM could affect labour dynamics through mechanisms beyond fetal macrosomia, such as altered myometrial responsiveness or changes in uterine contractility that are independent of fetal weight.

Another key aspect of this study was examining postpartum haemorrhage. Although no significant difference was observed in mean blood loss between the two groups, underlying physiological factors related to GDM warrant attention. Previous studies, such as those by Al-Qahtani et al. (11), compared uterine contractions in diabetic and non-diabetic patients undergoing elective caesarean sections. They found that diabetic patients had significantly reduced uterine contractility, both spontaneous and oxytocin-induced, due to lower calcium channel expression and signaling, despite insulin treatment. Additionally, diabetic patients exhibited a slight reduction in myometrial mass, contributing to this reduced contractility. However, oxytocin was shown to increase myometrial force and calcium transients similarly in both diabetic and non-diabetic patients, indicating preserved oxytocin responsiveness. While this study did not find evidence of increased postpartum haemorrhage risk, this theoretical predisposition remains an important consideration. Further research into the effects of oxytocin and other uterotonic agents on the diabetic myometrium could provide valuable insights into how to better manage this potential risk.

The reduced weight gain observed in the GDM group was another significant finding. Despite having a higher pre-pregnancy BMI, women in the GDM group gained less weight during pregnancy, likely due to dietary modifications and more rigorous monitoring of their glucose levels. This reduction in gestational weight gain is an important factor in managing GDM, as excessive weight gain has been associated

with increased risks of complications, including macrosomia and caesarean delivery. The findings underscore the importance of closely managing gestational weight gain in women with GDM to optimize maternal and neonatal outcomes.

Finally, neonatal outcomes in this study also require attention. While there were no significant differences in birth weights or Apgar scores between the GDM and control groups, neonates in the GDM group were more likely to experience acidosis, with a significantly higher proportion of arterial pH < 7.1. This finding is concerning, as neonatal acidosis can have serious short- and long-term consequences for the newborn. Moreover, although not statistically significant, the higher rate of NICU admissions in the GDM group highlights the potential impact of GDM on neonatal outcomes. Neonates may experience dangerously low blood glucose levels after birth, which reinforces the necessity for vigilant glucose monitoring and timely interventions to prevent adverse outcomes.

3.5. Streng and limitations

A key strength of this study is the comparison of well-matched groups of women with and without GDM, allowing for meaningful insights into how GDM influences pregnancy and labour. However, the relatively small sample size, particularly in the GDM group, may limit the generalizability of the findings. Another limitation is the potential selection bias, as women with GDM who participate in such studies maybe have better-controlled diabetes. This could mean that the GDM population in our study may not fully represent the broader GDM population, particularly those with suboptimal management, potentially skewing the results toward more favourable outcomes in terms of blood glucose control and related complications. Another limitation of this study is the lack of matching between the GDM and control groups regarding to body mass index. Since elevated BMI is independently associated with adverse pregnancy and labour outcomes, this imbalance represents a major confounding factor that may significantly affect the interpretation of group differences. Additionally, variations in induction methods, though not statistically significant, could introduce bias in the duration of labour and mode of delivery.

3.6. Conclusion

In conclusion, this study offers important insights into how gestational diabetes mellitus influences maternal and labour outcomes, particularly in terms of labour induction, the duration of the first stage of labour, and the likelihood of non-elective caesarean sections. While the total labour duration did not differ significantly between women with GDM and those in the control group, the extended first stage and higher caesarean section rate observed in the GDM group underscore the complexities of managing labour in this population. Proper management of gestational weight gain and timely intervention during labour induction are essential for improving outcomes. These findings enhance our understanding of GDM's impact on pregnancy and point to the need for further research to develop more tailored obstetric care for women with GDM.

4. Future directions and final thoughts

As part of our ongoing investigation, we have also collected placental and myometrial samples from all participating women. The next steps involve performing immunohistochemistry on placental tissue samples to assess microvessel density, comparing healthy pregnant women with those diagnosed with GDM. This analysis aims to provide valuable insights into the vascular changes associated with gestational diabetes, potentially uncovering mechanisms that contribute to fetal and maternal complications.

Additionally, we plan to conduct quantitative polymerase chain reaction on myometrial tissue samples from both healthy pregnant women and those with GDM. This will enable us to assess the expression levels of oxytocin receptors, potentially explaining differences in uterine contractility and labour progression between these groups.

Our research underscores the importance of continued investigation into the complexities of GDM and its impact on pregnancy. The insights gained from this study will advance scientific knowledge and pave the way for improved clinical practices and interventions. We are committed to furthering our understanding of GDM and enhancing health outcomes for all affected.

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