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Gestational Diabetes Mellitus: Short- and Long-Term Maternal and Offspring Outcomes and Management Strategies

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Abstract

Gestational diabetes mellitus (GDM) is one of the most common complications of pregnancy and has significant short- and long-term impacts on both maternal and offspring health. GDM is associated with adverse pregnancy outcomes and contributes to an increased risk of long-term metabolic and cardiovascular disorders in mothers and their offspring. Current management strategies for GDM are primarily based on lifestyle interventions, particularly medical nutrition therapy and combined diet-exercise approaches, with pharmacological treatment as an adjunct when glycemic control is insufficient. Individualized management is essential to optimize outcomes. In addition, growing evidence emphasizes the importance of continuous management across the life course, including preconception screening, antenatal care, and postpartum follow-up. This review summarizes the short- and long-term effects of GDM and outlines recent advances in comprehensive management strategies, providing a reference for clinical nursing practice and maternal health management.

Keywords

Gestational Diabetes Mellitus, Maternal and Offspring Outcomes, Cardiovascular Disease, Metabolic Abnormalities, Comprehensive Intervention

1. Introduction

Gestational diabetes mellitus (GDM) is defined as glucose intolerance first recog-

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nized during pregnancy in women with previously normal glucose metabolism, and represents one of the most common complications of pregnancy [1]. Its pathogenesis is closely related to pregnancy-induced insulin resistance and relatively insufficient insulin secretion [2]. The prevalence of GDM varies depending on screening strategies, diagnostic criteria, and population characteristics. It should be noted that the reported prevalence of GDM varies substantially depending on the screening strategy and diagnostic criteria applied, including one-step versus two-step screening approaches and diagnostic thresholds established by the IADPSG, WHO, and ADA. According to the International Diabetes Federation (IDF), the global prevalence of GDM was approximately 15.7% in 2024, affecting nearly 23 million live births worldwide [3]. The prevalence rate of GDM in our country is approximately 14.8% to 17.8%, and it has shown a significant upward trend in recent years [4].

GDM not only affects perinatal outcomes, but is also closely associated with long-term metabolic disorders in both mothers and their offspring, making it a significant global public health concern. Therefore, early identification and appropriate management are essential for improving both short- and long-term health outcomes. This review aims to summarize the short- and long-term effects of GDM on maternal and offspring health, and to discuss advances in comprehensive management strategies, in order to provide a reference for clinical nursing practice and maternal health management.

2. Short- and Long-Term Effects of Gestational Diabetes Mellitus on Maternal and Offspring Health

The clinical significance of GDM lies in its substantial short- and long-term impacts on both maternal and offspring health. GDM not only increases the risk of adverse pregnancy-related complications in mothers and neonates, but also contributes to a markedly elevated risk of long-term metabolic disorders in both. For mothers, GDM is associated with an increased risk of developing type 2 diabetes mellitus, cardiovascular disease, and metabolic syndrome. For offspring, intrauterine exposure to hyperglycemia significantly increases the likelihood of obesity, impaired glucose tolerance, and metabolic dysregulation later in life [5].

2.1. Effects of GDM on Short-Term Maternal Pregnancy Outcomes

A large body of evidence indicates that GDM is associated with an increased risk of adverse pregnancy and delivery outcomes, including cesarean delivery, placental abruption, postpartum hemorrhage, and multi-organ dysfunction [6].

A systematic review and meta-analysis including over 200,000 women with GDM demonstrated that fasting glucose levels and post-load glucose concentrations measured by oral glucose challenge) test (OGCT) and oral glucose tolerance test (OGTT) were linearly associated with adverse perinatal outcomes such as cesarean delivery, labor induction, large-for-gestational-age infants, macrosomia, and shoulder dystocia, without a clear threshold effect [7]. The Hyperglycemia and Adverse Pregnancy Outcome (HAPO) study further confirmed that even mild hyperglycemia below the diagnostic threshold for diabetes is associated with a continuous increase in adverse outcomes [8].

Mechanistically, maternal hyperglycemia stimulates fetal pancreatic β-cell hyperplasia and hyperinsulinemia, leading to excessive fetal growth and macrosomia, which in turn increases the risk of preterm birth and cesarean delivery. In addition, hyperglycemia creates a favorable environment for pathogen proliferation, thereby increasing the risk of puerperal infection [9].

Collectively, GDM adversely affects pregnancy outcomes through multiple pathways, highlighting the importance of strict glycemic control and enhanced perinatal monitoring.

2.2. Effects of GDM on Long-Term Maternal Cardiovascular and Metabolic Risks

2.2.1. Cardiovascular Risk

In addition to long-term cardiovascular sequelae, GDM is also associated with pregnancy-specific vascular complications such as hypertensive disorders and preeclampsia during gestation.

Accumulating evidence suggests that GDM is strongly associated with an increased long-term risk of cardiovascular disease. Persistent hyperglycemia during pregnancy can induce inflammatory responses, endothelial dysfunction, and arterial stiffness, thereby promoting the development of hypertension and vascular injury [10] [11]. A large retrospective cohort study including over 1.07 million pregnant women with a mean follow-up of 25 years reported that, compared with women with normal glucose tolerance during pregnancy, those with GDM had a higher cumulative incidence of hospitalization for cardiovascular disease (190.8‰ vs. 117.8‰). GDM was significantly associated with increased risks of ischemic heart disease (adjusted OR = 1.23, 95% CI: 1.12 - 1.36), myocardial infarction (adjusted OR = 2.14, 95% CI: 1.15 - 2.47), coronary angioplasty (adjusted OR = 2.23, 95% CI: 1.87 - 2.65), and coronary artery bypass grafting (adjusted OR = 3.16, 95% CI: 2.24 - 4.47) [12]. This risk is further amplified in women with additional risk factors such as obesity and chronic hypertension [13].

Beyond pregnancy, women with prior GDM remain at increased long-term cardiovascular risk. A large meta-analysis involving approximately 5.39 million women demonstrated that GDM nearly doubles the risk of future cardiovascular events (RR ≈ 1.98), and even in women who do not develop type 2 diabetes, the risk remains significantly elevated (RR ≈ 1.56) [14]. Furthermore, GDM has been associated with a 2.3-fold increase in cardiovascular events within 10 years postpartum. A study of the Chinese population has shown that the incidence of hypertension in women with GDM 15 years after pregnancy is significantly higher than that in women with normal glucose tolerance. The 10-year cardiovascular risk odds ratio (OR) is 1.26. During the 10-year follow-up, the risk of cardiovascular disease in women with a history of GDM increased, and the average onset time was 7 years earlier [13].

2.2.2. Metabolic Risk

GDM significantly increases the long-term risk of type 2 diabetes mellitus in mothers. In China, women with a history of GDM have an annual conversion rate of approximately 1.6% to type 2 diabetes, representing a sevenfold increased risk compared with women with normoglycemic pregnancies [10].

More than 30% of cases of type 2 diabetes diagnosed after pregnancy occur in women with a history of GDM [15], underscoring GDM as an important risk factor for later type 2 diabetes in adult women. In a secondary analysis of the National Institutes of Health Maternal-Fetal Medicine Units (MFMU) Network, Battarbee *et al*. [11] included 642 women 5 - 10 years postpartum and found that both mild GDM and maternal obesity during pregnancy were associated with a significantly increased risk of insulin resistance. Notably, their long-term metabolic effects appeared to be driven primarily by persistent insulin resistance, without significant impairment of pancreatic β-cell secretory function or clear associations with other cardiovascular biomarkers, thereby providing evidence to support more targeted postpartum metabolic surveillance. In addition, an international multiethnic cohort study with a mean follow-up of 11.4 years in 4,697 women showed that 52.2% of mothers with prior GDM developed glucose metabolism disorders, confirming that untreated GDM substantially increases the risk of postpartum dysglycemia 10 - 14 years after delivery. Women diagnosed with GDM according to the IADPSG criteria likewise remain at elevated risk of progressing to prediabetes and type 2 diabetes [16]. More broadly, many pregnancy complications that affect fetal growth and outcomes are also associated with an increased long-term risk of maternal metabolic complications, particularly cardiovascular disease. Taken together, these findings indicate that GDM is an important predictor of long-term metabolic disease in both mothers and their offspring. Pregnancy outcomes may serve as a useful window for identifying high-risk women and initiating early intervention to reduce future metabolic and cardiovascular morbidity and mortality.

3. Effects of GDM on Offspring Outcomes

3.1. Perinatal Outcomes (Short-Term)

GDM is associated with a range of adverse short-term outcomes in offspring, including preterm birth, premature rupture of membranes, macrosomia, fetal growth restriction, neonatal asphyxia, intrauterine fetal death, and neonatal mortality. Among these, macrosomia is the most common and clinically significant outcome, closely linked to poor glycemic control during pregnancy.

Data from the HAPO study, involving over 23,000 women, showed that the prevalence of macrosomia increased from 6.7% in non-obese women without GDM to 10.2% in non-obese women with GDM, and further to 20.2% in obese women with GDM, representing an approximately 50% higher risk overall in GDM pregnancies. Macrosomia substantially elevates the risk of birth trauma; neonates weighing ≥ 4500 g have a sixfold increased risk of birth injury and an approximately 20-fold increased risk of brachial plexus injury, as well as higher rates of admission to neonatal intensive care units [17]. These findings indicate that GDM poses significant threats to early neonatal health.

3.2. Long-Term Metabolic Outcomes (Obesity and Diabetes)

GDM significantly increases the risk of long-term metabolic disorders in offspring. However, these associations should be interpreted cautiously, as offspring outcomes may also be influenced by confounding factors including maternal pre-pregnancy BMI, obesity, family history, adequacy of glycemic control, and shared postnatal environmental exposures. Up to 20% of individuals exposed to GDM in utero develop type 2 diabetes or prediabetes before the age of 22 years [18], and the risk is further elevated when both parents have abnormal glucose metabolism [19]. Although some early studies were limited by inadequate control of confounding factors, a meta-analysis by Guan *et al.* [20] confirmed a significantly increased risk of diabetes in offspring of mothers with GDM (OR ≈ 4.50). Mechanistically, maternal glucose readily crosses the placenta, whereas insulin does not. Maternal hyperglycemia induces fetal hyperinsulinemia and activates the placental mTOR pathway, promoting nutrient transfer and excessive fat accumulation. Persistent exposure to high glucose levels may contribute to long-term metabolic dysregulation, potentially through epigenetic modifications that predispose offspring to obesity and diabetes [18]. In addition, approximately 15% - 45% of women with GDM deliver macrosomic infants, who are themselves at increased risk of developing type 2 diabetes later in life.

3.3. Neurodevelopmental and Behavioral Disorders

GDM-associated intrauterine metabolic disturbances may adversely affect fetal brain development, and these effects may persist over time, thereby increasing the risk of neurodevelopmental disorders in offspring. The underlying mechanisms likely involve maternal hyperglycemia- and obesity-induced neuroinflammation and abnormal microglial activation. These alterations may extend into adolescence and adulthood; moreover, postnatal exposure to a high-fat diet may further exacerbate neural injury, leading to structural and functional abnormalities in hippocampal CA1 pyramidal neurons and ultimately resulting in cognitive impairment [21].

In addition, metabolic abnormalities during pregnancy can adversely affect neurobehavioral development and motor function in childhood, while intrauterine hyperglycemia may directly disrupt normal brain development [22]. A large systematic review and meta-analysis including 202 studies demonstrated that maternal diabetes is significantly associated with an increased risk of neurodevelopmental disorders and impaired neurodevelopmental function in offspring. Specifically, children born to mothers with GDM had a 28% higher overall risk of neurodevelopmental disorders, including autism spectrum disorder (25%), attention-deficit/hyperactivity disorder (30%), and intellectual disability (32%) [23].

Furthermore, macrosomia associated with GDM increases the risk of shoulder dystocia, clavicle fracture, and brachial plexus injury [17], thereby contributing to additional perinatal neurological damage.

3.4. Cardiovascular and Other Long-Term Risks

Offspring of mothers with GDM have been reported to have an approximately 29% higher risk of early-onset cardiovascular disease compared with those born to normoglycemic mothers [18] and exhibit adverse cardiometabolic profiles. Studies have shown that these individuals tend to have higher triglyceride and low-density lipoprotein cholesterol levels, along with lower high-density lipoprotein cholesterol levels [20].

The increased cardiovascular risk is multifactorial. Maternal hyperglycemia and excessive gestational weight gain contribute to a higher prevalence of childhood overweight and obesity, which are key risk factors for cardiovascular disease. In addition, intrauterine hyperglycemia may impair renal development, increasing the risk of chronic kidney disease in adulthood, which further exacerbates cardiovascular risk [24].

4. Comprehensive Management Strategies for Gestational Diabetes Mellitus

GDM is associated with an increased risk of adverse pregnancy outcomes, including hypertensive disorders of pregnancy, preterm birth, polyhydramnios, urinary tract infections, and macrosomia, and thus represents a major challenge to maternal and neonatal health. In China alone, the annual economic burden related to GDM is estimated to reach approximately USD 5.5 billion [25].

Current management of GDM aims to reduce both adverse perinatal outcomes and long-term metabolic risks. The major strategies include lifestyle interventions, pharmacological therapy, and continuous life-course management. Prevention of progression to type 2 diabetes mellitus and reduction of GDM recurrence are key priorities in maternal metabolic health management [26] [27]. In clinical practice, a goal-oriented management model involving healthcare providers, patients, and family members is often adopted to develop individualized intervention plans and improve adherence.

4.1. Lifestyle Interventions

Lifestyle intervention before or in early pregnancy has been shown to reduce the incidence of GDM in high-risk women. Once GDM is diagnosed, lifestyle modification remains first-line therapy for glycemic control [28]. Diets rich in vegetables and fruits, together with increased physical activity during pregnancy, are also associated with a lower risk of GDM [29]. In addition, appropriate dietary and exercise programs can reduce the rates of cesarean delivery and macrosomia and promote vaginal delivery.

4.1.1. Medical Nutrition Therapy

Medical nutrition therapy (MNT) is the core component of lifestyle intervention and the first-line treatment for GDM. It is based on individualized energy intake and weight management, with a focus on appropriate regulation of carbohydrate intake, combined with adequate high-quality protein and healthy fats. Essential micronutrients, including folic acid, vitamin D, calcium, and iron, should be supplemented as needed, while excessive caloric intake, added sugars, and inappropriate supplementation should be avoided. When combined with physical activity, MNT contributes to glycemic control and improved maternal and neonatal outcomes [30].

Dietary patterns emphasizing plant-based protein sources, such as legumes and nuts, have been associated with a reduced risk of GDM [5]. In addition, low glycemic index (GI), low glycemic load (GL), and DASH dietary patterns have been shown to significantly improve glycemic control, limit gestational weight gain, reduce insulin use, and decrease the incidence of adverse pregnancy outcomes, including cesarean delivery and macrosomia [31].

A randomized controlled trial by Zhang *et al.* [32] demonstrated that a 12-week comprehensive nutritional management program significantly reduced glycated hemoglobin, fasting glucose, and 2-hour postprandial glucose levels, while decreasing the rate of adverse pregnancy outcomes from 38.0% to 7.8% and improving patient self-management. Although the central role of MNT in GDM management has been well established, further large-scale, high-quality studies are needed to evaluate the long-term effects of different dietary patterns and optimize individualized nutritional strategies.

4.1.2. Combined Diet and Exercise Interventions

Exercise interventions are rarely applied alone in GDM management and are typically combined with dietary modification as part of an integrated lifestyle approach. However, recommendations for physical activity during pregnancy vary across clinical guidelines.

A Cochrane systematic review by Martis *et al.* [33] showed that combined diet and physical activity interventions improved maternal and neonatal outcomes and significantly reduced the incidence of macrosomia, though they were associated with an increased rate of labor induction. A randomized controlled trial involving 360 women with GDM demonstrated that individualized exercise prescriptions based on maternal age and body mass index were more effective than standard exercise programs in controlling postprandial glucose levels and reducing the incidence of macrosomia, polyhydramnios, and hypertensive disorders of pregnancy, without increasing the risk of preterm birth [34]. Furthermore, a meta-analysis by Zhang *et al.* [35] confirmed that combined diet and exercise interventions are effective strategies for GDM management. Approaches such as aerobic exercise combined with resistance training, or low-GI diets combined with yoga, have been shown to significantly reduce 2-hour postprandial glucose levels. Combined interventions appear to be more effective than single-modality approaches and may be particularly beneficial for patients with poor glycemic control or insulin dependence. Therefore, individualized diet-exercise programs should be developed collaboratively by healthcare providers, patients, and their families, with clearly defined intensity and frequency of physical activity, in order to reduce long-term maternal and offspring complications.

4.1.3. Weight Management

Weight management is an essential component of lifestyle intervention and should be maintained throughout pregnancy and extended into the postpartum period. Gestational weight gain in women with GDM is closely associated with multiple clinically important outcomes. He *et al*. [36] demonstrated that timely weight management after the diagnosis of GDM can improve pregnancy outcomes and glycemic control. Remote health management combined with locally adapted weight gain targets may better meet clinical needs and support the development of population-specific intervention strategies. Similarly, Ferrara *et al*. [37], in the GLOW randomized controlled trial, applied a remote lifestyle intervention based on the Diabetes Prevention Program, consisting of two in-person sessions and eleven telephone-based sessions in addition to routine prenatal care. This approach effectively reduced excessive gestational weight gain in overweight and obese women and was found to be feasible and cost-effective for clinical implementation.

For long-term weight management in women with a history of GDM, Yang *et al*. [38] reported that both improved diet quality and increased physical activity significantly reduced weight gain, with combined interventions showing greater effectiveness. Notably, the weight reduction effect was more pronounced in women with prior GDM compared to those without. However, current studies are limited by a lack of standardized intervention protocols and insufficient long-term follow-up data. Some evidence suggests that while weight management can limit gestational weight gain, it may not significantly reduce the incidence of GDM [39]. Therefore, further research is needed to clarify the effectiveness of weight management strategies in this population.

4.2. Pharmacological Interventions

Lifestyle intervention remains the first-line treatment for GDM. However, pharmacological therapy is generally initiated when target glucose levels cannot be achieved after 1 - 2 weeks of lifestyle intervention, typically defined as fasting glucose ≥ 95 mg/dL, 1-hour postprandial ≥ 140 mg/dL, or 2-hour postprandial ≥ 120 mg/dL. In clinical practice, insulin, metformin, and glyburide are the most commonly used agents. Insulin remains the preferred option when rapid or reliable glycemic control is required. Metformin may be considered in women unwilling to use insulin or with relatively mild hyperglycemia, whereas glyburide is now less favored because of less reassuring neonatal outcomes.

Among these agents, insulin has the most established efficacy and safety profile and is therefore regarded as the standard pharmacological treatment for GDM. Metformin, although it crosses the placenta, has been associated with reduced maternal weight gain and a lower risk of hypoglycemia compared with insulin, and may also reduce the risks of hypertensive disorders of pregnancy, macrosomia, and neonatal hypoglycemia [40]. By contrast, glyburide has been linked to a higher risk of neonatal hypoglycemia and macrosomia, which has limited its use in many settings. A study by Wu *et al.* [41] showed that insulin combined with exercise therapy was effective in improving treatment response and reducing fasting and postprandial glucose levels, with potential benefits for pregnancy outcomes.

In recent years, the combination of traditional Chinese medicine (TCM) with conventional pharmacological therapy has also gained attention. For example, formulations such as Huangqi Sijunzi Decoction, when combined with insulin analogs or metformin, may enhance glycemic control and reduce adverse outcomes, including preterm birth, macrosomia, and cesarean delivery rates [42] [43]. However, evidence supporting TCM adjunctive therapy remains limited and less robust than that for standard pharmacological agents. Overall, pharmacological treatment should be individualized based on patient characteristics, with careful consideration of both glycemic control and maternal-fetal safety to optimize clinical outcomes.

4.3. Life-Course Management and Follow-Up Strategies

The management of GDM should extend beyond glycemic control during pregnancy and instead adopt a continuous life-course approach encompassing the preconception, antenatal, and postpartum periods [44]. During the preconception stage, screening and health education should be strengthened in high-risk populations, particularly among women with obesity, a family history of diabetes, or a prior history of GDM. Early glucose assessment and lifestyle optimization may help reduce the risk of GDM development [45].

Pregnancy management represents the core of intervention. On the basis of standardized screening and diagnosis, individualized glucose monitoring should be implemented, and comprehensive management strategies—including medical nutrition therapy and appropriate physical activity—should be applied. Pharmacological therapy should be initiated when necessary to achieve adequate glycemic control and reduce adverse pregnancy outcomes. In addition, frequent glucose monitoring and dynamic assessment are essential to guide timely adjustment of treatment plans. A multidisciplinary care model should also be adopted to enhance the continuity and effectiveness of interventions.

The postpartum period is equally critical. Women with a history of GDM are at significantly increased risk of developing type 2 diabetes and cardiovascular disease. Therefore, a 75-g OGTT is recommended at 6 - 12 weeks postpartum, followed by long-term follow-up to monitor metabolic status. Furthermore, health education and lifestyle interventions should be continued to reduce recurrence risk. Attention should also be given to the long-term metabolic and developmental health of offspring, thereby promoting sustained improvements in maternal and child health outcomes.

5. Conclusions

GDM is a major public health concern with significant short- and long-term impacts on both maternal and offspring health. Its effects extend throughout pregnancy and persist into the postpartum period, encompassing maternal metabolic dysregulation, increased cardiovascular risk, as well as neurodevelopmental and metabolic abnormalities in offspring. Current management strategies for GDM have established an individualized framework based on lifestyle intervention as the foundation, with pharmacological therapy as an adjunct. This approach includes the implementation of medical nutrition therapy and personalized exercise prescriptions, as well as the appropriate use of pharmacological agents such as insulin and metformin, providing substantial benefits in improving maternal and neonatal outcomes. However, existing interventions still face several challenges, including optimization of dietary strategies for specific populations and the need for further validation of the long-term safety of oral hypoglycemic agents.

Future research should focus on a deeper understanding of the underlying pathophysiological mechanisms and the identification of novel therapeutic targets. A comprehensive life-course prevention and management model—integrating preconception screening, antenatal care, and postpartum follow-up—should be further developed. In addition, the integration of precision medicine with public health strategies may offer more effective approaches to reducing the burden of GDM and interrupting the intergenerational transmission of metabolic diseases. Moreover, there is a need for large-scale, long-term, high-quality studies to strengthen the evidence base. Enhancing public awareness through health education and science communication is also essential to improve understanding and management of GDM, ultimately achieving sustained improvements in maternal and offspring metabolic health.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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