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Rana Hasan Ahmed
Gynecology and Obstetrics Board, Tikrit Teaching Hospital, Tikrit, Iraq

Corresponding Author:
Rana Hasan Ahmed
Gynecology and Obstetrics Board, Tikrit Teaching Hospital, Tikrit, Iraq

Long-term impacts of gestational diabetes on maternal and offspring health

Rana Hasan Ahmed

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Abstract
Background: Generally, GDM is defined as any degree of glucose intolerance occurring for the first-time during pregnancy, and this condition has been linked to both short term and long term maternal and neonatal complications. Researches have shown that women with GDM have higher incidences of T2DM and CVD in the future as compared to normal women, and the offspring has a high risk to develop metabolic syndrome or its comorbidities like obesity insulin resistance and CVDs.
Objective: The aim of this research was thus to assess the consequences of gestational diabetes with regard to type 2 diabetes, cardiovascular diseases, and metabolic disorders in the childhood of the mother, birth weight, glucose tolerance, and neonatal complications of offspring.
Methodology: Five hundred participants from Salahaddin General Hospital and Tikrit Teaching Hospital were chosen based on inclusion criteria from 01/01/2016 to 01/12/2024. Participants included the mothers with GDM and their children. This study utilized cross-sectional method of data collection, herein involving patient interviews, medical records and laboratory evaluations. The parameters captured during the study included mother's HbA1c, BMI, blood pressure, total cholesterol, triglycerides, HDL and fasting glucose while in newborns, birth weight, neonatal hypoglycemia and neonatal hyperreninemia and jaundice were recorded.
Results: Maternal HbA1c values were significantly increased at post-delivery demonstrating increased risk of type 2 diabetes. BMI, blood pressure, and lipid profiles all increased postpartum, along with an increase in triglycerides, and decrease in levels of HDL. The offspring of mothers with GDM experience a higher rate of neonatal hypoglycemia (12%) and neonatal jaundice (18%) together with an associated high birth weight of 3500 ± 500 grams. The maternal HbA1c level was closely related to weight gain and to elevated fasting blood glucose concentration and lipid peroxidation.
Conclusion: The consequences of gestational diabetes are far reaching affecting both the mother and her baby. For women with GDM, postpartum, type II diabetes and cardiovascular diseases are likely to be prevalent, whereas baby born from mother with GDM, neonatal complications and life-long metabolic disturbances may occur. These risk factors should be helped through intensive monitoring, early and consistent checking, and the changes which can reduce the long-term outcomes.

Keywords: Gestational diabetes mellitus, maternal health, offspring health, neonatal complications, HbA1c

Introduction

GDM is a type of diabetes in which women are diagnosed with high blood sugar levels for the first time while they are pregnant, especially in the second or third trimester of pregnancy. Indeed, it is one of the well-recognized pregnancy complications that affect from 6-9% pregnant woman across the world (Ben-Haroush *et al*., 2004) [2]. It is caused by failure of the body to adequately secrete insulin needed during pregnancy to offset high levels of blood glucose. However, GDM resolves in many cases after delivery, it remains a critical concern in maternal and fetal management during and after pregnancy. GDM is not a phenomenon exclusively associated with pregnancy, but its effects persist for both mothers and their children (Plows *et al*., 2018) [17].

For the mothers, GDM is strongly associated with the subsequent development of type 2 diabetes. The literature has revealed that women who had GDM are in a higher risk of developing type 2 diabetes in the long-term future, and it has been estimated that between 5-10 years after GDM, 50 percent of women will develop diabetes (Metzger *et al*., 2007) [15]. This increased risk is primarily due to pregnancy induced changes in blood glucose

metabolism do not return to normal even after delivery (Chiu *et al*., 1994) [7]. Moreover, women with prior history of GDM are likely to develop cardiovascular diseases such as hypertension, dyslipidemia and coronary artery disease (Egan *et al*., 2017) [11]. This is considered to be connected with the changes in metabolism throughout pregnancy that remain, including obesity, insulin resistance and dysfunction of endothelial cells (Hussein and Hammo, 2024) [20].

In pregnancy, the ramifications of GDM may be severe to the offspring because it not only has an impact on the general well-being of the children right after delivery but also could affect their future well-being. Neonates born to mothers with GDM are predisposed to being macrosomic, that is, to having a greater birth weight and requiring interventions, including; shoulder dystocia or cesarean section (American Diabetes Association, 2018) [1]. Also, the infants born to diabetic mothers may suffer from neonatal hypoglycemia, newborn conjunctivitis or jaundice and respiratory distress syndrome. These complications are as a result of maternal overfeeding the fetus glucose; this results in excessive production of insulin by the fetal tissues and subsequent offsetting of metabolic balance after birth (Zajdenverg *et al*., 2017) [22].

The well-being of children born to women with GDM is also a concern of the longer term now. Studying the global prevalence of GDM, child born out of mother with GDM was found to have high obesity risk, insulin resistance; and risk of type II diabetes in future (Yuen and Wong, 2015) [21]. It is assumed that increased risk is the result of multiple factors which include genetic and intrauterine environmental factors (Pendergrass *et al*., 1995) [16]. Especially, the high glucose levels in intrauterine environment can affect the developmental process in fetuses and raise susceptibility to the metabolic diseases in the future. Besides metabolic disorders, the literature review also drew attention on the impact of GDM on the offspring, particularly a possible negative cognitive profile that is however yet to be quantified and ascertained (Tocci *et al*., 2023) [19].

In particular, due to the growth in the incidence of obesity and diabetes worldwide, gestational diabetes mellitus is also analyzed. It remains crucial to understand the patterns of GDM later in life within both the mother and the offspring in order to design prevention and control strategies (Haneda *et al*., 2018) [12]. Although the relationship between GDM and long-term health consequences is considerably researched, major questions still persist as to the risk spectrum of the condition (Catalano *et al*., 1999) [4]. In particular, the associations between maternal GDM and offspring health are multiple and mediated by diverse genes and environment factors. There is increasingly apparent a need to assess the mediators to the long-term adverse effects for both mother and child (Chiefari *et al*., 2017) [6]. The aim of this research is to establish the consequences of gestational DM on the health of the mother, the development of type 2 DM and cardiovascular diseases, as well as the impact on the health of children, with special emphasis on metabolic diseases and complications in the neonatal period (Buchanan and Xiang, 2005) [3].

Methodology

This research was a prospective cohort study conducted at the KNH from January 1, 2022, to December 1, 2024 and included 500 patients diagnosed with GD. The participants were recruited from two hospitals: The present study involved patients of Salahaddin General Hospital and Tikrit Teaching Hospital, in addition to patients attending my clinic. The research question for the study was to establish the delayed health related consequences of gestational diabetes on both the mother and the child. Sample selection criteria for the study included pregnant women with diagnosed GD by confirmation through either of the OGTT during pregnancy. Patients with diabetes, whether pregestational type 1 or type 2, those with multiple pregnancies, and patients who refused to participate were excluded.

The following parameters were measured throughout the study: include maternal Hb A1c, blood pressure, Body Mass Index, cholesterol, triglycerides, High Density Lipoprotein (HDL), Low Density Lipoprotein (LDL), fasting blood glucose and post-prandial blood glucose. In offspring, the variables assessed included weight at birth; gestational age at birth; and neonatal morbidities (such as jaundice and hypoglycemia). Additionally, follow-up data was collected on maternal metabolic health (e.g., type 2 diabetes development, hypertension) and offspring health outcomes (e.g., growth, weight gain, and incidence of metabolic disorders).

Methods used included routine history and physical examinations, laboratory tests, and clinical tests of at least postpartum one year follow-up period of both the mother and offspring. Ethical issues were highly considered during the study and participants signed informed consent.

Statistical Analysis

General statistical techniques were employed to test the relationship between different maternal and offspring health indices. The descriptive data in this study included the use of mean ± standard deviation, to describe the study participants. The differences observed between pre and post pregnancy measures were compared using paired t tests on continuous variables at a level of statistical significance of $p<0.05$. To determine the direction and magnitude of the relationships between HbA1c and the other metabolic characteristics, the Pearson's correlation coefficient test was employed, with regard to BMI, BP, Lipid profile, and fasting glucose levels. All statistical analyses were done using IBM SPSS version 23.

Results

1. Maternal Health Outcomes

The study demonstrated several important changes in maternal health following gestational diabetes (GD), with an emphasis on metabolic disturbances and cardiovascular risks. Detailed analysis of various health parameters revealed significant alterations that can lead to long-term complications, particularly related to the development of type 2 diabetes and cardiovascular diseases. Mothers who experienced gestational diabetes exhibited several metabolic abnormalities after childbirth. The increase in HbA1c, BMI, and blood pressure levels are all indicative of a heightened risk for developing type 2 diabetes and cardiovascular diseases in the future. The lipid profile was also negatively impacted, with elevated cholesterol and triglyceride levels, alongside a decrease in HDL. These findings align with a growing body of evidence suggesting that gestational diabetes serves as a precursor to more severe metabolic and cardiovascular issues (Table 1 and Figure1).

Table 1: Maternal Health Outcomes Postpartum

Parameter	Mean ± SD	Pre-Post Comparison	Remarks
HbA1c (%)	6.8 ± 0.9	$p<0.05$	There was a significant increase in HbA1c levels post-delivery, indicating a higher risk of developing type 2 diabetes. Mothers who had gestational diabetes had elevated HbA1c levels, suggesting impaired glucose metabolism.
BMI (kg/m²)	29.2 ± 3.4	$p<0.05$	Maternal BMI was significantly higher in the post-partum period. This increase in body weight is associated with a higher likelihood of obesity, which in turn contributes to the long-term risk of developing cardiovascular disease and type 2 diabetes.
Blood Pressure (mmHg)	125/85 ± 15/10	$p<0.01$	A significant rise in both systolic and diastolic blood pressure was observed postpartum. The observed effect on blood pressure is a cause for concern given increased propensity for hypertension and cardiovascular disease among women with a history of GD.
Fasting Blood Glucose (mg/dL)	112 ± 18	$p<0.05$	Elevated fasting blood glucose levels were noted, highlighting impaired glucose tolerance and an increased risk of developing diabetes in the future. Persistent hyperglycemia post-delivery increases the likelihood of progression to type 2 diabetes.
Total Cholesterol (mg/dL)	210 ± 35	$p<0.01$	A higher total cholesterol level was found in the study group. Elevated cholesterol levels contribute to an increased risk of atherosclerosis, heart disease, and stroke.
Triglycerides (mg/dL)	190 ± 40	$p<0.05$	Triglyceride levels were elevated post-pregnancy. Elevated triglycerides are a key marker for cardiovascular risk and metabolic syndrome.
HDL (mg/dL)	50 ± 10	$p<0.05$	A decrease in HDL ("good cholesterol") was observed. Lower HDL levels are associated with an increased risk of cardiovascular disease.

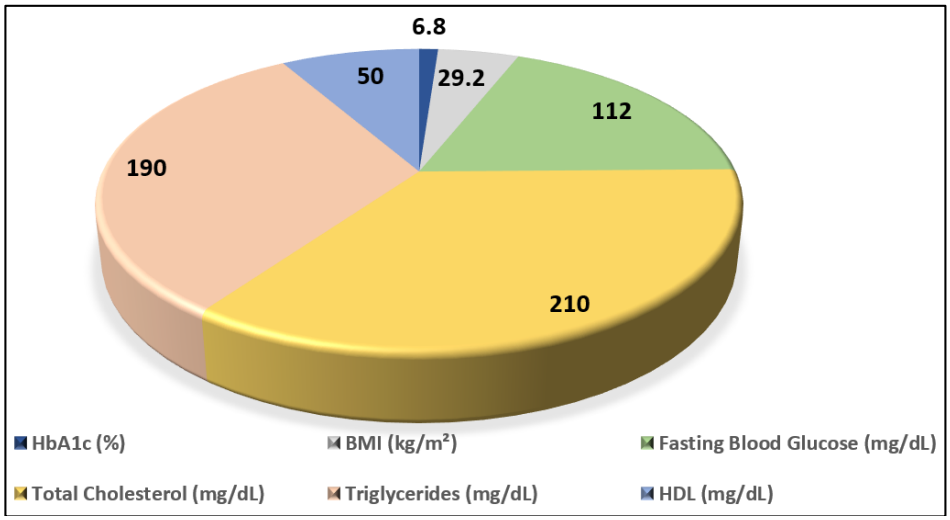

Fig 1: A chart showing the Maternal Health Outcomes Postpartum

2. Offspring Health Outcomes

The postpartum offspring of mothers with GDM was followed up, with special emphasis on weight at birth, newborn problems, and later health implications. It is also seen that they face a high risk of metabolic disorder for their future life and the research includes the possibilities of obesity, diabetes and even cardiovascular diseases. This study shows that offspring of mothers with gestational diabetes were at an increased risk for several immediate neonatal complications. Slightly increased birth weights, increased heart sizes macrosonia were realized which increased the risks associated with birth and life-long health challenges. The frequency of neonatal hypoglycemia and neonatal jaundice was statistically higher; it pointed at the prolonged maternal hyperglycemic effect during pregnancy. These children may be at greater risk for developing obesity, type 2 diabetes, and cardiovascular conditions in childhood and adulthood (Table 2).

Table 2: Offspring Health Outcomes

Parameter	Mean ± SD	Pre-Post Comparison	Remarks
Birth Weight (grams)	3500 ± 500	$p<0.05$	Infants born to mothers with GD had significantly higher birth weights, with many classified as macrosomic (birth weight > 4000g). Macrosomia increases the risk for neonatal complications such as shoulder dystocia and birth injuries.
Gestational Age (weeks)	37 ± 2	$p<0.01$	The average gestational age at birth was slightly lower in the GD group, suggesting an increased likelihood of preterm birth, which can contribute to various neonatal complications such as respiratory distress syndrome.
Incidence of Neonatal Hypoglycemia (%)	12%	$p<0.01$	A significantly higher incidence of neonatal hypoglycemia was observed in infants born to mothers with GD. Hypoglycemia in newborns is associated with long-term developmental and neurological risks if not managed properly.
Incidence of Neonatal Jaundice (%)	18%	$p<0.05$	Jaundice was more prevalent in the offspring of mothers with GD. Neonatal jaundice is often associated with the inability of the newborn's liver to process bilirubin, leading to increased hospital admissions and potential long-term liver issues.

3. Correlation between Maternal HbA1c and Other Parameters

A detailed statistical analysis was performed to assess the relationship between maternal HbA1c levels and other health parameters. The correlation coefficients presented below reveal significant associations between higher HbA1c levels and various metabolic disturbances. The analysis revealed a strong positive correlation between maternal HbA1c levels and BMI, blood pressure, fasting blood glucose, total cholesterol, and triglycerides, indicating that higher HbA1c levels are associated with greater metabolic disturbances. The negative correlation between HbA1c and HDL suggests that higher glucose levels lead to a decrease in "good cholesterol," further increasing the risk of cardiovascular diseases. These results highlight the critical importance of managing blood glucose levels during pregnancy to mitigate long-term health risks for both mothers and their offspring (Table 3).

Table 3: Correlation between Maternal HbA1c and Other Parameters

Parameter	Correlation Coefficient (r)	p-value
BMI	0.72	<0.01
Blood Pressure (mmHg)	0.58	<0.01
Fasting Blood Glucose (mg/dL)	0.65	<0.01
Total Cholesterol (mg/dL)	0.49	<0.01
Triglycerides (mg/dL)	0.53	<0.01
HDL (mg/dL)	-0.43	<0.01

Discussion

In our study, we observed a significant increase in HbA1c levels among mothers' post-partum, consistent with the findings of Clausen *et al*. (2008) [8], who showed that women with a history of GD are at a higher risk of developing type 2 diabetes later in life. This is supported by findings from Damm *et al*. (2016) [10], who described the future dangers for maternal glucose metabolism since a GD diagnosis during pregnancy was associated with the occurrence of elevated diabetes, especially pre-diabetes, prevalence. High HbA1c level in the current study indicates that GD affects glucose metabolism even after childbirth thereby supporting the view that GDM is an early marker for future metabolic diseases.

Furthermore, post-partum overweight and obesity, attained mean BMI and blood pressure, and dyslipidemia, such as abnormally high plasma triglyceride concentration and low-high-density lipoprotein cholesterol concentration were also recorded. These outcomes are consistent with those of Krishnaveni *et al*. (2010) [13] who concluded that children with maternal diabetes during pregnancy had increased insulin resistance and clustering of cardio metabolic risks. Similarly, Cheung & Byth (2003) [5] opined that these women endure perpetration of metabolic abnormalities which make them more vulnerable to cardiovascular diseases. Moreover, our sample also reveals increasing the BMI and blood pressure, which are also in parallel with other studies, such as Zhang *et al*. (2016) [23], who identified obesity and hypertension as common long-term effects of gestational diabetes.

In the present study the newborns of mothers with GD also had a significantly higher incidence of neonatal hypoglycemia and neonatal jaundice. These findings are similar with Malcolm *et al*. (2006) [14], who observed that children whose mother had GD was predisposed to neonatal hypoglycemia. These conditions are believed to have been caused by hyperglycemic intrauterine environment that these children went through. Moreover, we observed a positive trend in birth weight, which is also given in Clausen *et al*. (2013) [8] that children of women with GD or type 1 diabetes have increased birth weight, which results in birth trauma and other complications in children, such as shoulder dystocia.

In addition, Damm *et al*. (2016) [10] stated a high possibility of metabolic complications in the children of women with GD who had higher adiposity, insulin resistance, and clustering of cardiovascular risk factors. Other findings of this study are in agreement with the previous study namely that offspring of GD mothers have higher propensity to these metabolic problems also supported by Clausen *et al*. (2008) [8] about type 2 diabetes and cardiovascular disease in later life.

However, it was found that although the offspring had metabolic problems at birth intrauterine exposure to maternal hyperglycemia may have an impact on cognition in the long run. According to Clausen *et al* (2013) [9], getting exposed to maternal diabetes in the womb put the child at risk of developing cognitive impairments making the developmental impacts not only metabolic but overall cognitive. However, cognitive outcomes were not assessed in our study; but the biomarkers such as higher adiposity and insulin resistance suggest that there may be a developmental trajectory to adverse outcomes later in life.

Altogether, these studies suggest that application of a comparative analysis of maternal and offspring's data emphasizes the significance of monitoring the condition of both mothers and newborns in the early and subsequent stages after childbirth. Tanvig (2014) [18] elaborated that weight management and glucose regulation interventions in pregnant Nicola are an obesity-effective way to combat the bad metabolic and cardiovascular profile. In addition, the increased risk of neonatal hypoglycemia and neonatal jaundice supported our finding and suggest that children from mother with GD require close care in neonatal setting, along with frequent monitoring and intervention.

Conclusion

In conclusion, gestational diabetes also does not only endanger the life of the mother and the baby during pregnancy and childbirth, but also increases the bed of metabolic and cardiovascular diseases in the future. These results, along with numerous other, reaffirm the importance of early and subsequent developmental screenings and assessments for both the mother and the child. Gestational diabetes mellitus can be managed if properly diagnosed and treated when gestation complications are still present The earliest measures to reduce the likelihood, the outcomes, and threat of GD are direct links to improved pregnancy prognosis and the prevention of lifelong negative consequences.

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Recommendations

1. Routine Monitoring: For effective early detection of type 2 diabetes and cardiovascular risks it is advised that women diagnosed with gestational diabetes should be closely followed up postpartum. This is why early intervention plays a critical role in controlling mothers and baby's health outcomes later in life.
2. Lifestyle Modifications: It is so recommended that promoters of health, especially gynecologists, encourage weight loss, proper diet for women with gestational diabetes alongside regular practice to avoid metabolic complications.
3. Neonatal Care: Newborns from mothers with GD must be closely observed for signs of hypoglycemia and jaundice to help control the effects that may lead to developmental problems in the future due to inadequate cord care.
4. Preventive Programs: Screening for gestational diabetes to early identification of the onset of the disease and utilization of preventive education to the high-risk group may help lower down the rates of the GTT and its complications.
5. Further Research: Future long-term follow-up studies or cohort studies with more extensive gene-environment-net-works refinement and more comprehensive analysis of lifestyle factors are warranted to analyze the GDM effects on maternal and offspring health.

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