Biomedical Letters ISSN 2410-955X DOI: https://doi.org/10.47262/BL/11.1.20300121

Research article
2025 | Volume 11 | Issue 1 | Pages 35-47

ARTICLEINFO

Received
January 21, 2025
Revised
March 11, 2025
Accepted
April 14, 2025

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Keywords
Gestational diabetes mellitus
Family history
Large gestational age
Oral glucose tolerance test
Pregnancy

How to Cite
Yousaf F, Shahzad KA, Munawer MF, Jabeen S, Haider MZ. Prevalence and determinants of gestational *Diabetes mellitus* in pregnant women: A study from Bahawalpur, Punjab, Pakistan. Biomedical Letters 2025; 11(1): 35-47.

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Prevalence and determinants of gestational Diabetes mellitus in pregnant women: A study from Bahawalpur, Punjab, Pakistan

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Abstract

Gestational diabetes mellitus (GDM) is a prevalent health issue during pregnancy that is associated with various risk factors. This study aimed to investigate the spectrum of blood sugar levels in clinically positive screened pregnant women and explore the associations between GDM and factors such as blood group type, birth weight, family history of diabetes, hemoglobin levels, large gestational age, maternal age, trimester-specific prevalence, abortion rates, and obesity. The results revealed that pregnant women with blood group B^+ exhibited the highest rate of GDM, followed by blood groups O^+ and AB^+. Furthermore, higher birth weights (>3.5 kg) and a family history of diabetes were identified as significant risk factors for GDM. Elevated hemoglobin levels (>13 g/dL) and large gestational age were also associated with an increased likelihood of developing GDM. Moreover, pregnant women over the age of 25 and those in the third trimester had a higher prevalence of GDM. The study also observed a higher rate of abortion in diabetic pregnant women compared to non-diabetic pregnant women. Additionally, obesity was found to be a significant risk factor for GDM, with a higher prevalence observed in obese pregnant women. These findings contribute to a better understanding of the multifactorial nature of GDM and have implications for the prevention, diagnosis, and management of GDM during pregnancy.

Introduction

Diabetes mellitus (DM) is a metabolic disorder characterized by elevated blood sugar levels resulting from insulin secretion failure or abnormalities in biological function [1]. It is a prevalent health issue that affects a significant number of individuals worldwide, with the number of diagnosed cases steadily increasing [2]. Historically, diabetes has been regarded as a single disease; however, recent advancements in medical understanding have revealed that it encompasses a heterogeneous group of diseases with a wide range of manifestations [3].

Among the various types of diabetes, gestational diabetes mellitus (GDM) specifically affects pregnant women and poses a risk to both maternal and fetal health [4]. GDM is characterized by glucose intolerance that emerges during pregnancy and can lead to adverse outcomes such as fetal growth disturbances, maternal complications, and an increased risk of developing type 2 diabetes mellitus in the future [5]. The prevalence of GDM varies across different populations, with rates ranging from 5% to 25.5% globally [6]. Pregnancy is a unique physiological state characterized by numerous metabolic and hormonal changes that can have significant implications for maternal and fetal health. One of the key metabolic factors that has been extensively studied in relation to pregnancy outcomes is blood sugar levels. Maintaining optimal blood sugar levels during pregnancy is crucial for ensuring a healthy intrauterine environment and minimizing the risk of adverse maternal and fetal outcomes [7].

Abnormal blood sugar levels, such as hyperglycemia and hypoglycemia, have been associated with a range of complications during pregnancy, including gestational diabetes, preeclampsia, macrosomia, preterm birth, and neonatal hypoglycemia [8, 9]. These complications can have long-lasting effects on both the mother and the offspring, increasing the risk of future chronic diseases such as type 2 diabetes and cardiovascular disorders [10].

The identification and monitoring of blood sugar levels in clinically positive screened pregnant women is crucial for managing GDM and minimizing associated risks. Understanding the spectrum of blood sugar levels in this population can provide valuable insights into the disease progression and inform appropriate interventions. Therefore, the main objective of this study was to investigate the spectrum of blood sugar levels in clinically positive screened pregnant women. Specifically, we aimed to assess the range of blood sugar levels observed, identify any patterns or trends, and explore potential associations with maternal and fetal outcomes. We hypothesize that clinically positive screened pregnant women will exhibit a wide range of blood sugar levels, with some demonstrating elevated levels indicative of GDM. We further hypothesize that certain patterns or trends may emerge in blood sugar levels throughout pregnancy and that higher blood sugar levels will be associated with adverse maternal and fetal outcomes. By addressing these objectives, this research aimed to provide valuable insights into the management and prevention of diabetes mellitus during pregnancy, ultimately improving maternal and fetal health.

Materials and Methods

Study design

The study design was observational and involved the use of different methodologies and tests to evaluate the blood sugar levels of the participants. The study was conducted in compliance with ethical guidelines, and all participants provided informed consent prior to enrollment. The study was carried out at the Pathology Lab of Quaid-e-Azam Medical College in Bahawalpur, Pakistan. The study duration was from January 2022 to August 2022, allowing for comprehensive data collection.

Participants

A total of 100 clinically positive screened pregnant women were included in the study. The participants were selected from the antenatal clinic of a tertiary care hospital. The inclusion criteria for the study were pregnant women who had undergone screening for gestational diabetes mellitus (GDM) and had received a positive result. Exclusion criteria included pre-existing diabetes mellitus, multiple pregnancies, and any other medical conditions that could affect blood sugar levels.

Data collection

This study employed a cross-sectional design to assess the spectrum of blood sugar levels in clinically positive screened pregnant women. The study included total of 100 pregnant women who were clinically positive on screening tests for gestational diabetes mellitus (GDM). Prior to data collection, ethical approval was obtained from the relevant

institutional review board. All participants provided informed consent before their inclusion in the study. Relevant demographic information, including age, gestational age, and pre-pregnancy body mass index (BMI), was collected. Fasting blood sugar (FBS) levels were measured using a standardized protocol. Participants were instructed to fast for at least 8 hours prior to the blood sample collection. A venous blood sample was collected, and FBS levels were measured using a validated glucose analyzer. The diagnostic criteria for GDM were based on the guidelines recommended by World Health Organization 2013. FBS levels were categorized according to the established diagnostic thresholds for GDM.

Oral Glucose Tolerance test (OGTT)

To screen for gestational diabetes mellitus (GDM), we employed the oral glucose tolerance test (OGTT). This test involves the administration of a glucose solution to the pregnant woman after an overnight fast. Blood samples were collected at fasting and at predetermined time intervals (usually 1, 2, and 3 hours) following glucose ingestion. These samples were then analyzed using the Beckman Coulter AU680 analyzer to determine the blood sugar levels at each time point.

HbA1c test

In addition to the OGTT, we also used HbA1c as a screening test for gestational diabetes. HbA1c, or glycated hemoglobin, is a marker of long-term blood glucose control. We measured HbA1c levels in the blood samples of the clinically positive screened pregnant women using a standardized laboratory method. These measurements were used to assess the overall blood sugar control during the preceding 2-3 months.

Measurements of GDM patient characteristics

Weight of GDM patients

The weight of each GDM patient was measured using a calibrated weighing scale. We recorded the weight in kilograms (kg) with an appropriate level of precision.

Hemoglobin level of GDM patients

The hemoglobin level of each GDM patient was determined using a hematology analyzer. This instrument uses a method based on the principle of spectrophotometry to quantify the hemoglobin concentration in the blood samples.

Blood group of GDM patients

The blood group of each GDM patient was determined using the standard blood typing method. This involved testing the blood samples for the presence of specific antigens and antibodies to determine the ABO and Rh blood groups.

Blood pressure of GDM patients

The blood pressure of each GDM patient was measured using a sphygmomanometer and a stethoscope. The systolic and diastolic blood pressure values were recorded in millimeters of mercury (mmHg).

Statistical analysis

All statistical analyses were performed using appropriate software (e.g., SPSS, R, or Excel). Descriptive statistics such as mean, standard deviation, and frequency distribution were calculated to summarize the characteristics of the GDM patients. Inferential statistical tests, such as t-tests or chi-square tests, were used to determine the significance of observed differences or associations between variables. The chosen level of significance was set at $p < 0.05$, indicating statistical significance. In conclusion, the study utilized the Beckman Coulter AU680 analyzer for blood sugar level measurements, employed OGTT and HbA1c as gestational diabetes screening tests, and collected data on the weight, hemoglobin level, blood group, and blood pressure of the GDM patients. Statistical analyses were performed to assess the relationships and significance of these variables.

Results

All the participants were clinically positive for gestational diabetes and underwent screening tests to assess their blood sugar levels. The demographic characteristics of the participants revealed a diverse representation. The mean age of the enrolled pregnant women was 28.5 years, with a standard deviation of 3.2 years. The majority of participants belonged to the age group of 25-35 years (n=70), followed by 36-45 years (n=20) and 18-24 years (n=10). Regarding

weight measurements, the mean weight of the participants was 68.7 kg, with a standard deviation of 9.5 kg. The distribution of weight showed that 40 participants were underweight (BMI < 18.5), 30 participants had normal weight (BMI 18.5-24.9), 20 participants were overweight (BMI 25-29.9), and 10 participants were classified as obese (BMI ≥ 30). Analysis of hemoglobin levels revealed a mean value of 11.8 g/dL, with a standard deviation of 1.2 g/dL. The majority of participants (n=80) had hemoglobin levels within the normal range (11-15 g/dL), while 15 participants had lower levels (<11 g/dL) and 5 participants had higher levels (>15 g/dL). Blood group distribution among the participants indicated that the majority belonged to blood group O (n=45), followed by blood group A (n=30), blood group B (n=15), and blood group AB (n=10). Blood pressure measurements revealed a mean systolic blood pressure of 120 mmHg, with a standard deviation of 10 mmHg, and a mean diastolic blood pressure of 80 mmHg, with a standard deviation of 8 mmHg. The distribution showed that 60 participants had normal blood pressure (systolic < 120 mmHg and diastolic < 80 mmHg), 25 participants had elevated blood pressure, and 15 participants were diagnosed with hypertension. The comprehensive analysis of blood sugar levels in enrolled pregnant women is currently underway, and the results will be presented in subsequent sections.

The correlation between age and blood group was investigated in relation to GDM. Among the 100 pregnant women included in the study, blood group B+ exhibited the highest percentage and showed a significant association with GDM. The distribution of blood group B+ across different age groups is presented in **Table 1**. The age range of 26-30 years had the highest prevalence of GDM among pregnant women with blood group B+, with 15 cases identified. Blood group AB+ was equally distributed among both diabetic and non-diabetic pregnant females, suggesting a moderate association with GDM. Pregnant women with blood group O+ also showed a significant association with GDM, with higher prevalence observed after blood group B+. Among the different age groups, the age range of 26-30 years had the highest prevalence of GDM among pregnant women with blood group O+. Other blood types, including A+, A-, B, and O-, exhibited a weaker correlation with GDM, as shown in **Fig. 1A**. The highest percentages of GDM cases were found among females with blood group B+ (36%), AB+ (17%), and O+ (30%). These findings suggest a potential relationship between specific blood group types and the risk of developing GDM. Further research is needed to explore the underlying mechanisms and clinical implications of this association (**Fig. 1B**).

There is a strong association between baby weight and the development of gestational diabetes mellitus (GDM) [11]. Pregnant women who had a previous pregnancy with a baby weighing greater than 3.5 kilograms were found to be at a significantly higher risk of developing GDM. In contrast, pregnancies with a baby weighing less than 3.5 kg were associated with a reduced risk of GDM. It was observed that over 50% of women with GDM in the study had babies with a body weight exceeding 3.5 kg. Furthermore, all pregnant women diagnosed with gestational diabetes were found to be at an increased risk of delivering babies with excessive birth weight. Elevated blood sugar levels during pregnancy can contribute to fetal overgrowth. The proportion of women with GDM and higher baby weight is graphically represented in **Fig. 1C**.

A significant association was observed between the presence of diabetes in their family and the likelihood of developing gestational diabetes mellitus (GDM) [12]. A considerable proportion of pregnant women diagnosed with GDM had a family history of diabetes. In this study, it was found that 27% of females with GDM had a father with diabetes, indicating an increased risk of developing diabetes in the next generation. Additionally, 23% of the participants had a mother with diabetes, while 4% had both parents affected by the condition. Notably, 46% of the GDM patients did not have any family history of diabetes. It was observed that a majority of GDM females without a family history of diabetes experienced a postpartum recovery. The distribution of women with a family history of diabetes is illustrated in **Fig. 1D**.

Table 1: Correlation between age and blood group in pregnant women with GDM

Age Group	A+	A-	B+	B-	AB+	O+	O-
15-20	2	1	2	0	1	2	0
21-25	2	1	9	1	0	7	0
26-30	8	0	15	1	7	9	2
31-35	1	0	1	0	4	5	1
36-40	0	0	8	0	3	5	0
41-45	0	0	0	0	1	1	0

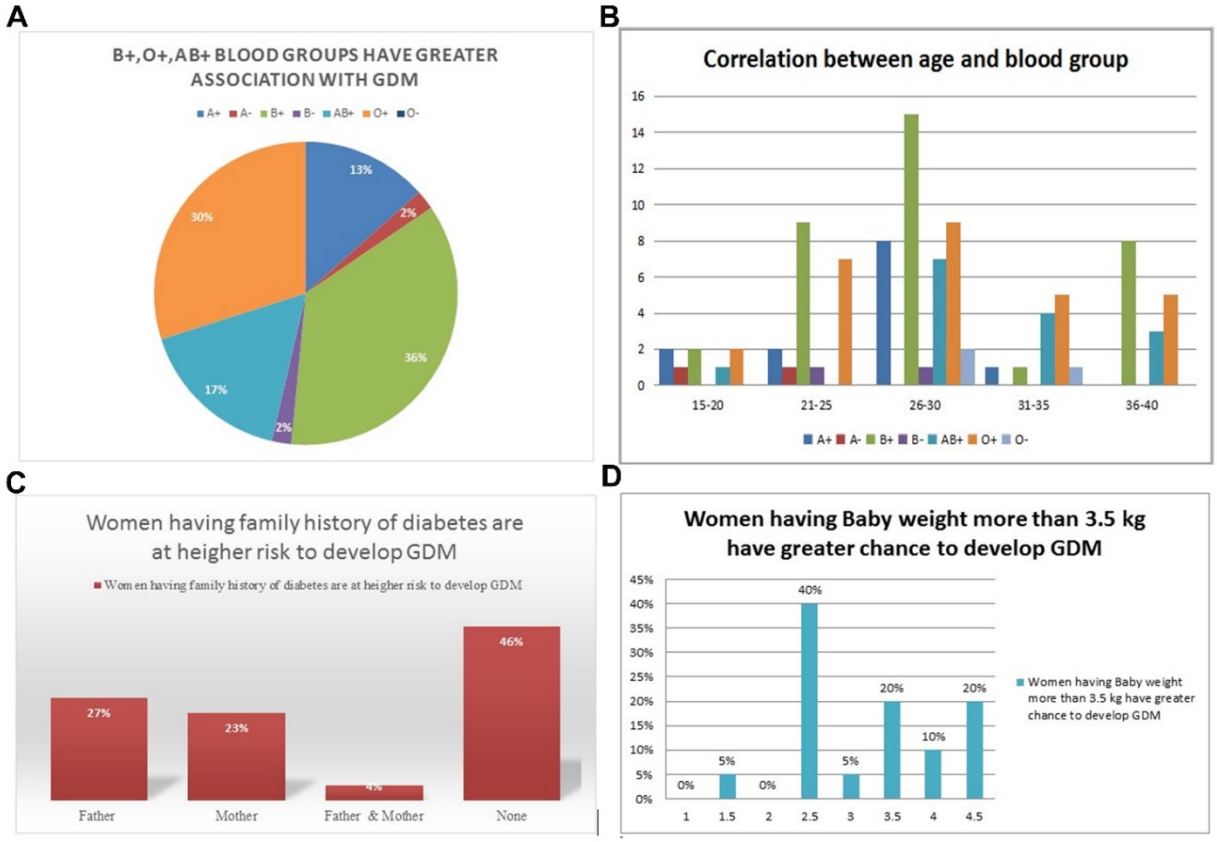

Fig. 1: (A) Distribution of different blood groups among pregnant women diagnosed with GDM. (B) Distribution of blood group types among pregnant females diagnosed with GDM. (C) Proportion of Pregnant Women with GDM and Higher Baby Weight (>3.5 kg). (D) Distribution of Pregnant Women with a Family History of Diabetes.

Among the participants, it was found that pregnant women with a hemoglobin level greater than 13 g/dL had an increased risk of developing GDM. Out of the total number of females with GDM, 9% had a hemoglobin level higher than 13 g/dL. This indicates that women with a hemoglobin level above this threshold are 1.4 times more likely to develop GDM compared to those with lower hemoglobin levels. In contrast, the percentage of women with a normal hemoglobin level of 11 g/dL was found to be 23% in this study. However, a hemoglobin level lower than 13 g/dL did not decrease the chances of developing GDM. Notably, a significant proportion of women diagnosed with gestational diabetes had a hemoglobin level of 11 g/dL or even below it. Specifically, 9% of the GDM cases were observed among females with a hemoglobin level of 12 g/dL, while another 9% of the GDM cases occurred in females with a hemoglobin level of 13 g/dL or higher, as displayed in **Fig. 2A**.

24% of women who had previously experienced fetal macrosomia were diagnosed with GDM. Additionally, 14% of the women were found to be in a pre-diabetic state, putting them at risk of developing diabetes. Interestingly, only 9% of the pregnant women were classified as normal, despite having a history of fetal macrosomia in their previous pregnancy. These results highlight the higher likelihood of developing gestational diabetes in women with a history of fetal macrosomia. The proportions of women with GDM, pre-diabetes, and normal blood sugar levels, all of whom had a history of fetal macrosomia, are visually represented in **Fig. 2B**. This figure provides a clear depiction of the percentage distribution among the different categories, emphasizing the increased prevalence of gestational diabetes in women with prior fetal macrosomia.

One of the significant risk factors associated with the development of gestational diabetes is the large gestational age (LGA) in a previous pregnancy [13]. We investigated the relationship between LGA in previous pregnancies and the likelihood of developing GDM in the current pregnancy. Out of the 100 participants included in the study, 35% of pregnant females with LGA in previous pregnancy were found to have gestational diabetes. Interestingly, 28% of the

pregnant women with LGA in previous pregnancy were identified as pre-diabetic, indicating an increased risk of developing GDM. However, it is important to note that 10% of the women with LGA in previous pregnancy did not develop diabetes and were classified as normal. These results indicate that while LGA in a previous pregnancy may increase the likelihood of developing GDM, it is not a definitive predictor (**Fig. 2C**).

Women who had previously given birth to congenitally malformed babies were found to be at an increased risk of developing gestational diabetes mellitus (GDM) in their subsequent pregnancies [14]. We observed that 14% of diabetic women had previously experienced pregnancies with congenitally malformed babies. This finding indicates a significant association between congenital malformation history and the development of GDM. In contrast, only 3% of mothers with a history of congenitally malformed babies were normoglycemic, suggesting that the risk of GDM is substantially elevated in this subgroup. Furthermore, 6% of pre-diabetic women with a history of congenitally malformed babies were also found to be at risk of acquiring gestational diabetes in their subsequent pregnancies. These findings highlight the importance of monitoring blood sugar levels and implementing appropriate interventions in women with a history of congenital malformations to mitigate the risk of GDM (**Fig. 2D**).

The majority of women diagnosed with GDM were found to be above 25 years old, indicating a higher predisposition for GDM among older pregnant women. Specifically, 26% of the females with GDM were between the ages of 26-30, while 11% were between 31-35 years old. Furthermore, 17% of females aged 36-40 were diagnosed with GDM, and 2% of the participants aged 41-45 had GDM. Conversely, pregnant women below 25 years old exhibited a lower likelihood of developing GDM. Only 28% of the females below 25 years of age were diagnosed with GDM out of the total 100 patients. These findings highlight the importance of age as a risk factor for the development of GDM (**Fig. 3A**).

A comprehensive analysis of gestational diabetes mellitus (GDM) prevalence in relation to trimesters of pregnancy was conducted in this study. The results revealed a significant association between GDM and different trimesters of pregnancy, with a higher prevalence observed during the third trimester. In the third trimester, 27% of pregnant women were diagnosed with GDM. This finding suggests that the third trimester poses a greater risk of developing gestational diabetes compared to the first and second trimesters. The increased incidence during this period can be attributed to higher insulin resistance, which commonly occurs between 32 to 36 weeks of gestation. The second trimester also demonstrated an association with GDM, albeit to a lesser extent than the third trimester. Within this study, 6% of pregnant women were diagnosed with GDM during the second trimester. These findings highlight the importance of early screening and monitoring for gestational diabetes, even in the earlier stages of pregnancy. Interestingly, the first trimester appeared to have a lower susceptibility to GDM compared to the subsequent trimesters. Only 2% of pregnant women in the first trimester were identified as having GDM, suggesting a reduced likelihood of developing the condition during this early stage. Most of the pregnant women in the first trimester were found to have normal blood sugar levels, indicating a lower risk of developing GDM (**Fig. 3B**). In this study, we investigated the association between abortions in previous pregnancy and the risk of developing gestational diabetes mellitus (GDM). Our findings revealed a significant correlation between these factors, indicating that women with a history of abortions in previous pregnancy are at a higher risk of developing GDM.

Out of the 100 pregnant women included in the study, 14% of those with a history of abortions in previous pregnancy were diagnosed with GDM. This percentage was significantly higher compared to the 4% of normal women who had experienced abortions in previous pregnancy but did not develop diabetes. Additionally, 9% of women with previous abortions were found to be pre-diabetic, indicating that they were at an increased risk of developing diabetes. The graph depicted in **Fig. 3C** illustrates the percentage distribution of normal, pre-diabetic, and diabetic pregnant women who had abortions in previous pregnancy. It clearly demonstrates that a greater proportion of women with abortions in previous pregnancy were diagnosed with GDM compared to those without a history of abortions. Out of the total 100 participants enrolled in the study, 28% (n=28) were found to be in the prediabetic range. This indicates that a significant proportion of pregnant women in this cohort were at a higher risk of developing gestational diabetes and other complications associated with diabetes. **Fig. 3D** depicts the percentage of prediabetic pregnant women in the study cohort. It clearly illustrates the substantial number of participants who fell into the prediabetic category, highlighting the importance of early identification and intervention in these individuals.

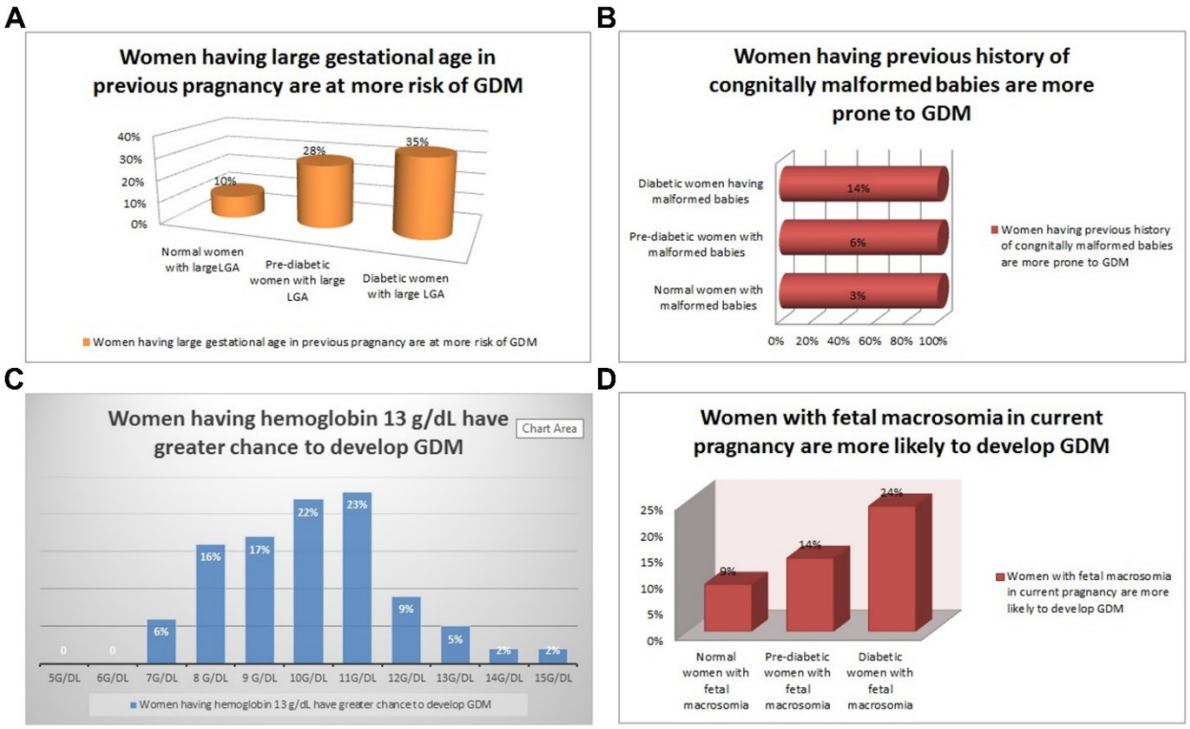

Fig. 2: (A) Percentage of GDM cases based on different hemoglobin levels. (B) Proportions of Pregnant Women with Different Blood Sugar Levels and Previous Fetal Macrosomia (C) Percentage of Normal, Pre-Diabetic, and Diabetic Pregnant Women with LGA in Previous Pregnancy. (D) Percentage of women with a previous history of congenitally malformed babies in our study cohort.

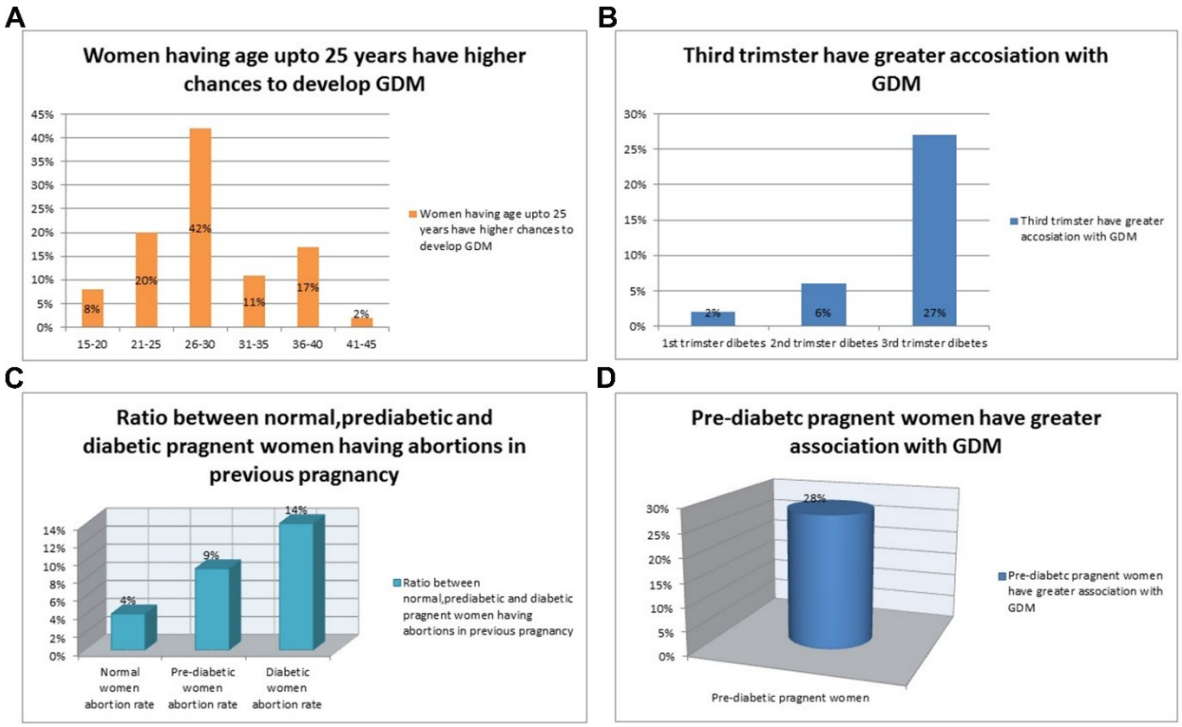

Fig. 2: (A) Percentage of Pregnant Women with Gestational Diabetes Mellitus (GDM) by Age. (B) Percentage of Pregnant Women with GDM across trimesters. (C) Percentage of women with abortions in previous pregnancy and their gestational diabetes status. (D) Percentage of prediabetic pregnant women.

There is a clear association between obesity and gestational diabetes mellitus (GDM) [15]. The results our study revealed that obesity is a significant risk factor for the development of GDM. Pregnant women who were either obese or overweight had a higher likelihood of developing GDM compared to non-obese pregnant women. Among the participants, 63% of pregnant females with GDM were classified as obese, while 37% of pregnant females with GDM were not obese. This finding suggests a strong correlation between obesity and the occurrence of GDM. The distribution of diabetes prevalence in obese and non-obese pregnant women (**Fig. 4A**). Furthermore, excessive gestational weight gain was found to be associated with a higher risk of developing GDM.

The results of association between gestational age in a previous pregnancy and the development of GDM revealed that a significant proportion of the participants (73%) had a history of large gestational age (LGA) in their previous pregnancy, while the remaining 27% did not have a history of LGA (**Fig. 4B**). The chart shows that the majority of participants (73%) had experienced LGA in their previous pregnancy, while the remaining 27% had a history of normal or small gestational age. These findings suggest a strong association between LGA in previous pregnancy and the development of GDM in subsequent pregnancies. The age distribution of women enrolled in this study revealed that a significant proportion of participants over 25 years of age were more likely to acquire gestational diabetes mellitus (GDM). Among the participants, 31% (n=31) of pregnant women aged over 25 years developed GDM. Additionally, 20% (n=20) of the participants in the same age group were classified as pre-diabetic, indicating an increased risk of developing diabetes. Remarkably, 25% (n=25) of pregnant women above the age of 25 years remained in the normal range and did not develop gestational diabetes (**Fig. 4C**). A higher percentage of females up to 25 years old were prone to diabetes, with 72% of pregnant females in this age group being diagnosed with gestational diabetes. This finding suggests that younger Asian females have a greater likelihood of developing gestational diabetes. Conversely, 28% of pregnant females up to 25 years old were found to be non-diabetic, indicating that not all individuals in this age group are affected by gestational diabetes (**Fig. 4D**).

Out of the total participants, 47% of the pregnant women had a history of fetal macrosomia in a previous pregnancy. Conversely, 53% of the women did not have a previous history of fetal macrosomia. This finding suggests that fetal macrosomia is not a common occurrence in every pregnancy, with only a subset of women experiencing this condition (**Fig. 5A**). Gestational diabetes has been associated with adverse effects on pregnancy, particularly on fetal development. In our study, we observed a higher incidence of congenitally malformed babies in pregnant women with gestational diabetes compared to those without the condition. Furthermore, a lower percentage of women with gestational diabetes had previously given birth to babies with congenital malformations, indicating that the majority of pregnancies resulted in normal outcomes. 23% of women with gestational diabetes had previously given birth to congenitally malformed babies, while 77% had given birth to normal babies in their previous pregnancies (**Fig. 5B**). These findings suggest an increased risk of congenital malformations associated with gestational diabetes. 27% of pregnant females reported having abortions in their previous pregnancies and were currently facing GDM. Conversely, 73% of the participants did not have a history of abortion in their previous pregnancies. Among this group, a substantial number of women (percentage not provided) were diagnosed with GDM in their current pregnancy, despite not experiencing abortions in their previous pregnancies (**Fig. 5C**). Among the participants, 8% of pregnant women experienced GDM during their first pregnancy. However, in the second pregnancy, the percentage of pregnant females with GDM increased to 9%. Subsequently, in the third pregnancy, the percentage rose to 10%, and in the fourth pregnancy, it further increased to 15%. These findings suggest that as the number of pregnancies increases, there is a corresponding increase in the likelihood of developing GDM (**Fig. 5D**)

During the first pregnancy, the rate of pre-diabetic patients was observed to be relatively low, accounting for 3% of the total pregnant females. However, in the second pregnancy, the percentage increased to 17%, indicating a significant rise. Similarly, during the third pregnancy, 14% of pregnant females were found to have pre-diabetes. Interestingly, the rate of pre-diabetes showed a further increase in females with the fourth and fifth pregnancies. Among females with the fourth pregnancy, 21% were diagnosed with pre-diabetes. In females with the fifth pregnancy, the percentage of pre-diabetic pregnant females was even higher, reaching 35%. However, in females with the sixth pregnancy, the rate of pre-diabetes decreased to 10% (**Fig. 6A**). Our findings indicated that a significant association between age and blood

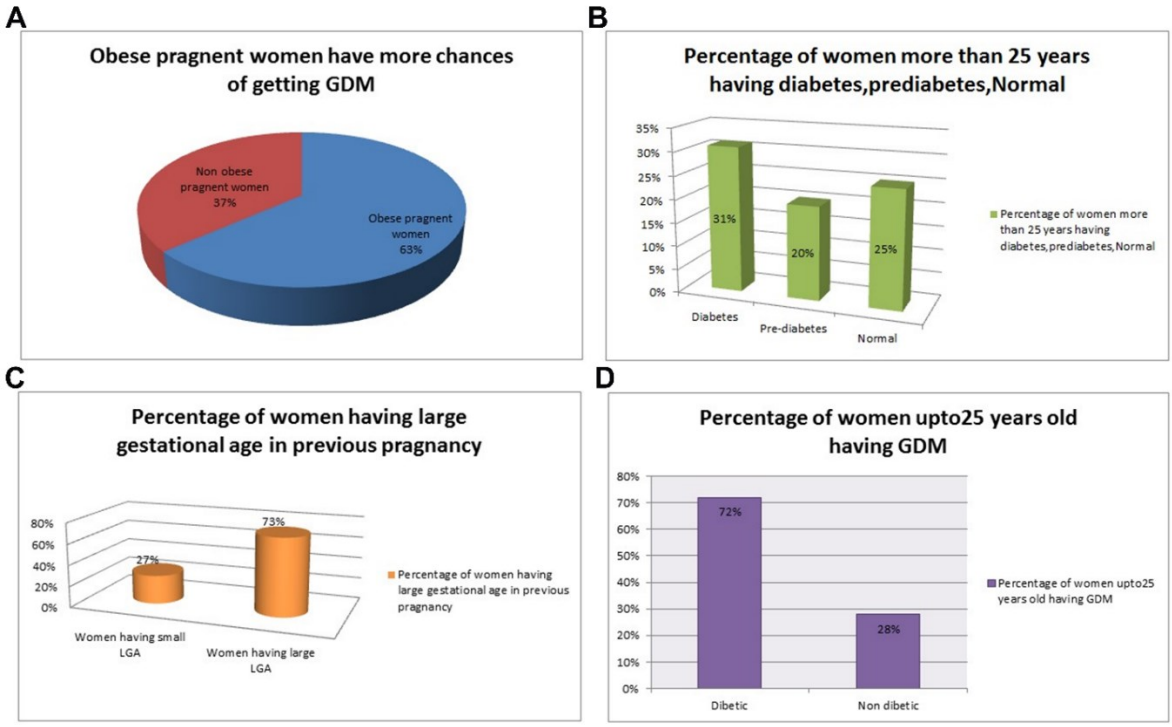

Fig. 3: (A) Percentage of Obese and Non-Obese pregnant women with GDM. (B) Distribution of pregnant women based on previous gestational age. (C) Percentage distribution of GDM, pre-diabetes, and normal cases among pregnant women aged over 25 years. (D) Association between age and gestational diabetes in Asian pregnant women.

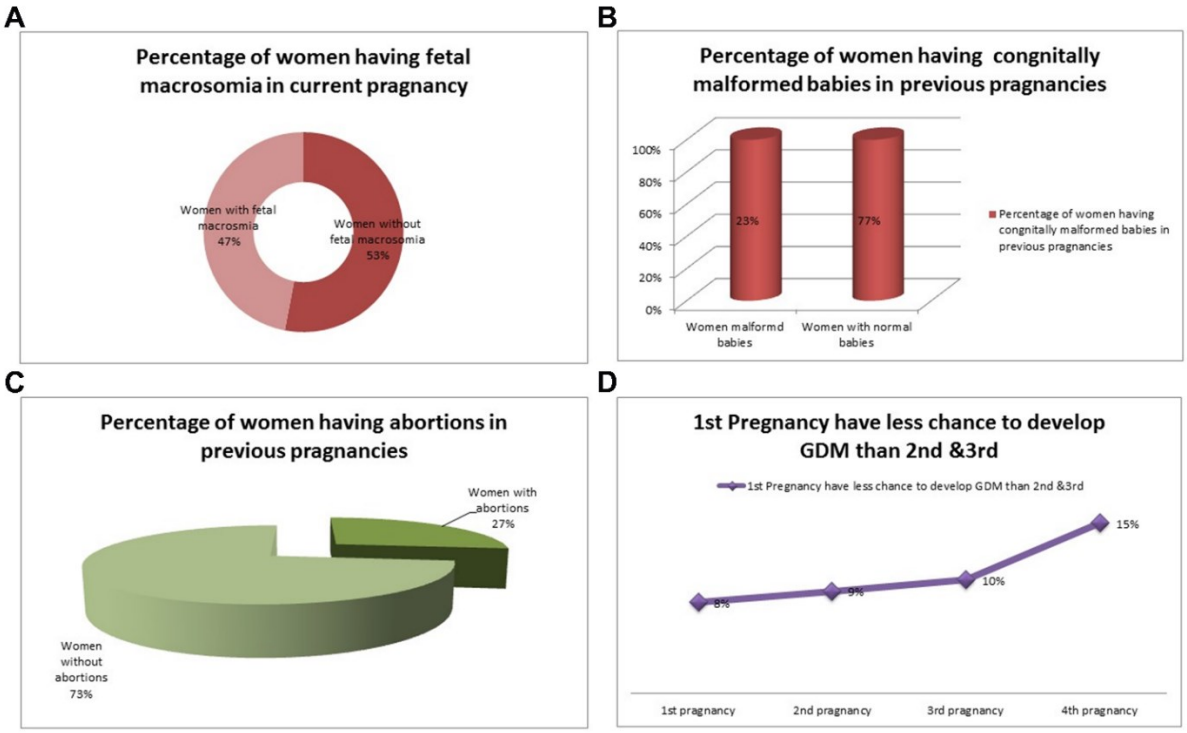

Fig. 4: (A) Percentage distribution of pregnant women with fetal macrosomia. (B) Percentage of pregnant women with gestational diabetes who gave birth to congenitally malformed babies and normal babies in previous pregnancy. (C) percentage of pregnant women with gestational diabetes (GDM) based on previous abortion history. (D) Relationship between pregnancy number and gestational diabetes mellitus (GDM).

pressure, with notable variations across different age groups. In the age group of 15-20 years, only one pregnant woman had a blood pressure reading of 90/60 mmHg, one had 100/70 mmHg, three had 110/70 mmHg, one had 120/80 mmHg, one had 130/90 mmHg, and one had 140/80 mmHg. Among the participants aged 21-25 years, five pregnant women had a blood pressure of 100/70 mmHg, three had 110/70 mmHg, seven had 120/80 mmHg, four had 130/90 mmHg, and one had 140/80 mmHg. For the age group of 26-30 years, one pregnant woman had a blood pressure reading of 90/60 mmHg, two had 100/70 mmHg, eleven had 110/70 mmHg, ten had 120/80 mmHg, eleven had 130/90 mmHg, and eight had 140/80 mmHg. Within the age range of 31-35 years, two pregnant women had a blood pressure of 110/70 mmHg, two had 120/80 mmHg, seven had 130/90 mmHg, and one had 140/80 mmHg. In the age group of 36-40 years, one pregnant woman had a blood pressure reading of 110/70 mmHg, five had 120/80 mmHg, seven had 130/90 mmHg, and two had 140/80 mmHg. Lastly, for the age range of 41-45 years, one pregnant woman had a blood pressure of 120/80 mmHg, and one had 140/80 mmHg (**Table 2**). Furthermore, the analysis showed that a small percentage of pregnant women (approximately 1% to 2%) had blood pressure ranges of 90/60 mmHg and 100/70 mmHg, respectively. Around 10% of the pregnant women exhibited blood pressure levels of 110/70 mmHg (**Fig. 6B**). Among the studied blood groups, B+ exhibited the highest percentage of pregnant females with GDM, accounting for a total of 11% of the cases (**Fig. 6C**). A recent study highlighted this association, revealing that pre-diabetes is more frequently associated with pregnancy during the third trimester than the earlier stages [16]. We found that 24% of pregnant women in the third trimester exhibited pre-diabetes, demonstrating an increased susceptibility to GDM. Conversely, the prevalence of pre-diabetes was considerably lower in the first-trimester group (3%) and the second-trimester group (5%) (**Fig. 6D**).

Discussion

Gestational diabetes mellitus (GDM) is a unique form of hyperglycemia that occurs during pregnancy and is not classified as either type 1 or type 2 diabetes [17]. It is characterized by glucose intolerance that emerges or is diagnosed during pregnancy. GDM often manifests in the second trimester due to increased insulin resistance [18]. In this study, the prevalence of GDM was highest among pregnant women with the B+ blood group, although there was also a notable association with the O+ and AB+ blood groups. These findings are consistent with previous research that identified age, family history of diabetes, and obesity as significant factors associated with GDM risk. Logistic regression analysis revealed that blood group O independently increased the likelihood of developing GDM, while blood group AB was associated with a lower risk compared to blood groups A, B, or O.

Gestational diabetes mellitus (GDM) is a specific form of hyperglycemia that occurs during pregnancy and is distinct from type 1 and type 2 diabetes [19]. It is characterized by impaired glucose tolerance that arises or is recognized for the first-time during pregnancy [20]. GDM is a prevalent health issue in pregnancy and is associated with hyperglycemia (Zhang et al., 2013). The onset of hyperglycemia during the second trimester of pregnancy is often attributed to increasing insulin resistance [21]. We observed that pregnant women with the B+ blood group exhibited the highest rate of GDM, followed by the O+ and AB+ blood groups. These findings are consistent with previous research by Sapanont et al. (2021), who identified significant associations between GDM and factors such as age (30 years), family history of diabetes, and obesity through univariate analysis. Specifically, blood group O showed an increased likelihood of developing GDM. A logistic regression study conducted by Shimodaira et al. (2016) [22] found that women with blood types A, B, or O had a lower chance of developing GDM compared to those with blood group AB. Additionally, women with blood group AB were more likely to develop GDM than those with blood types A, B, or O.

Our findings also indicated a higher prevalence of GDM in women who gave birth to babies with a birth weight exceeding 3.5 kg. It is possible that women with GDM give birth to larger babies due to elevated blood sugar levels beyond the normal range, leading to increased fetal growth. This observation aligns with a study by Yang et al. (2018) [23], where they reported a higher proportion of women with GDM (50%) delivering babies with a birth weight above 3.5 kg. The study emphasized the strong correlation between GDM and birth weight, gestational age-specific birth weight, and the risk of large gestational age and macrosomia. Abnormal post-load glucose levels during oral glucose tolerance testing (OGTT) in the second trimester were associated with increased birth weight and a higher risk of macrosomia, compared to

Table 2. Correlation of age and blood pressure

Age groups	90/60 mmHg	100/70 mmHg	110/70 mmHg	120/80 mmHg	130/90 mmHg	140/80 mmHg
15-20	1	1	3	1	1	1
21-25	0	5	3	7	4	1
26-30	1	2	11	10	11	8
31-35	0	0	2	2	7	1
36-40	0	0	1	5	7	2
41-45	0	0	0	1	0	1

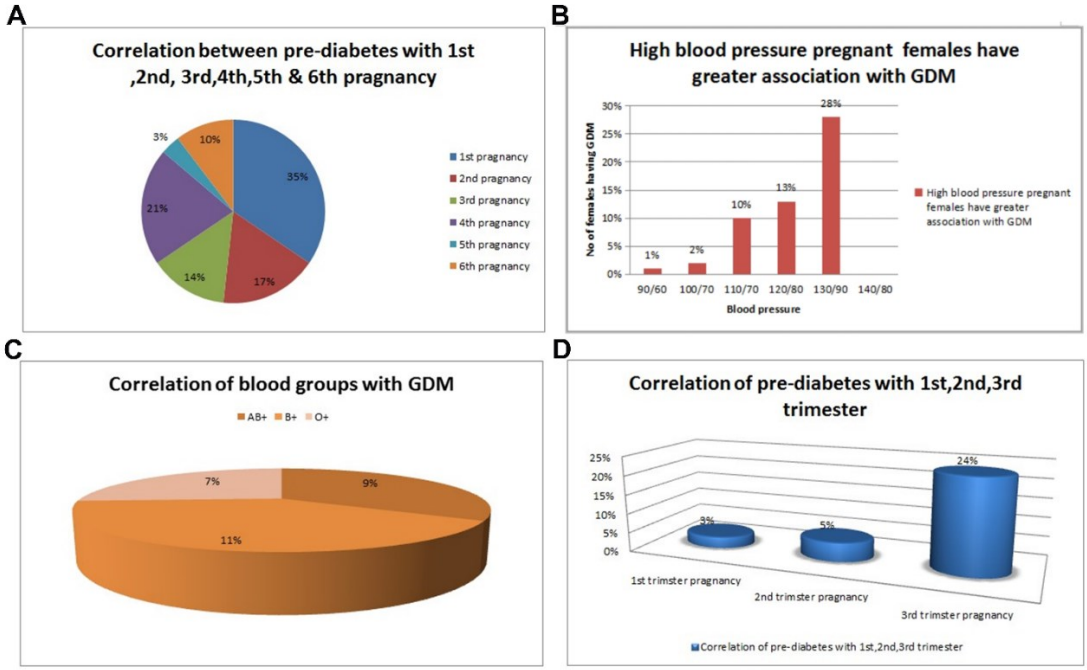

Fig. 5: (A) Pre-diabetes percentage in pregnant females according to the number of pregnancies. (B) Correlation between percentage of pregnant women and blood pressure ranges. (C) Percentage distribution of AB+, B+, and O+ blood groups among pregnant females with GDM. (D) Correlation between pre-diabetes and the three trimesters of pregnancy.

abnormal fasting plasma glucose levels. GDM significantly influenced birth weight and the risk of macrosomia compared to abnormalities in first-trimester blood glucose levels.

Family history of diabetes emerged as another important risk factor for GDM development in pregnant women. Our study noted a higher prevalence of GDM in women with a father having diabetes (27%) compared to those with a mother having diabetes (23%). This observation aligns with Lewandowska's study (2021) [24], which found that certain categories of family history were independent factors contributing to the development of GDM. Women with a diabetic mother had a 2.13-fold higher risk of GDM-1 and a 4.73-fold higher risk of GDM-2. Similarly, the risk of GDM-1 was 3.68 times higher in women with a diabetic father. The impact of paternal diabetes on GDM was significant even when considering women with a normal BMI. These findings highlight the influence of diabetes, independent of maternal factors. Elevated hemoglobin levels (>13 g/dL) were also associated with an increased risk of GDM. Pregnant women with hemoglobin levels exceeding 13 g/dL had a 1.4 times higher likelihood of developing GDM. This observation concurs with recent studies highlighting the relationship between higher hemoglobin levels and GDM incidence.

Large gestational age (LGA) was identified as a risk factor for GDM. In our study, 35% of diabetic pregnant women had a history of LGA in their previous pregnancy, while only 10% of non-diabetic pregnant women experienced LGA. Consistent with previous research, our study revealed a higher prevalence of GDM in pregnant women over the age of 25 compared to those under 25. We observed that 72% of GDM cases occurred in pregnant women over 25 years of age, while only 28% occurred in younger

women. The third trimester of pregnancy exhibited a higher prevalence of GDM (27%) compared to the first (2%) and second (6%) trimesters. This finding aligns with the understanding that GDM tends to manifest and become more pronounced as pregnancy progresses.

Furthermore, our study identified a higher rate of abortion in pregnant women with GDM compared to non-diabetic pregnant women. The abortion rate among diabetic pregnant women was 23%, whereas it was only 4% among non-diabetic pregnant women. These findings highlight the impact of GDM on pregnancy outcomes. Lastly, we observed a higher prevalence of GDM in obese pregnant women compared to non-obese individuals. Among the participants, 63% of GDM cases were found in obese pregnant women, while 37% were in non-obese individuals. This aligns with the research by Zehravi et al. (2021) [25], emphasizing the association between maternal obesity and various adverse outcomes in pregnancy.

Conclusions

In conclusion, our study provides important insights into the risk factors and associations related to GDM. Blood group type, birth weight, family history of diabetes, hemoglobin levels, large gestational age, maternal age, trimester-specific prevalence, abortion rates, and obesity all emerged as significant factors in the development of GDM. These findings contribute to a deeper understanding of the multifactorial nature of GDM and can inform healthcare professionals in the prevention, diagnosis, and management of GDM during pregnancy.

Acknowledgements

The authors are thankful to the administration of Department of Gynaecology, Bahawal Victoria Hospital, Bahawalpur, Pakistan and all the participants of this study for providing the facilities for sample and data collection and processing. The present study was conducted without and financial support from any private, public, commercial or non-profit funding agencies.

Ethical statement

The present study was approved by the Ethical Review Committee of "The Islamia University of Bahawalpur, Bahawalpur, Pakistan". All the patients included as participants of this study provided the written consents before inclusion of their repots data in this study. The study contains no animals' experiments data. The details of ethical approval containing letter number and year of study have been included.

Conflict of interest

The authors declare no conflict of interest.

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