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Identifying gestational diabetes mellitus and assessing risk factors in affected women: a comprehensive study

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Abstract. – OBJECTIVE: Gestational diabetes mellitus (GDM) is a prevalent pregnancy complication associated with adverse health outcomes for both mothers and offspring. This study aimed to identify risk factors for GDM, a condition with a rapidly increasing global prevalence.

PATIENTS AND METHODS: A study involving 474 pregnant women who attended the obstetrics outpatient clinic of Kafkas University Faculty of Medicine Hospital was conducted between January 2022 and June 2023. Risk factors for GDM were assessed based on criteria recommended by the American Diabetes Association and the Committee on Practice of the American College of Obstetricians and Gynecologists. Statistical analyses, including descriptive statistics, Chi-square tests, Mann-Whitney U tests, and multivariate logistic regression.

RESULTS: Individuals with GDM (mean age: 31.26±6.09 years) were significantly older than those without GDM (mean age: 28.36±4.89 years; $p<0.001$). Obesity prevalence was higher in the GDM group (32.5%) compared to the non-GDM group (14.3%; $p<0.001$). Individuals with GDM had higher rates of pre-diabetes (3.3% *vs.* 0.3%; $p=0.007$), a history of gestational diabetes (25.2% *vs.* 5.7%; $p<0.001$), high blood sugar in previous pregnancies (13.8% *vs.* 1.4%; $p<0.001$), and diabetes mellitus in 1st-degree relatives (40.7% *vs.* 20.3%; $p<0.001$). GDM was associated with increased pregnancies ($p<0.001$), preterm births ($p<0.001$), macrosomic babies ($p=0.026$), congenital anomalies ($p=0.011$), high cholesterol ($p=0.036$), and polyhydramnios ($p=0.001$) in previous pregnancies, as well as polyhydramnios in the index pregnancy ($p=0.008$). Regular exercise in previous pregnancies differed significantly based on GDM presence ($p=0.037$).

CONCLUSIONS: Recognizing modifiable risk factors is crucial for preventing GDM and reducing associated health risks. Healthcare providers should be vigilant, especially among those with a family history of GDM, previous GDM, advanced maternal age, and other risk factors. Early lifestyle interventions show promise. Further research is needed for accurate GDM prediction.

Key Words:

Antenatal care, Gestational diabetes mellitus, Gestational diabetes mellitus prediction, Lifestyle interventions, Maternal health, Pregnancy complications, Risk factors, Screening.

Introduction

Gestational diabetes mellitus (GDM) is a prevalent pregnancy complication, defined as glucose intolerance with the onset of pregnancy, in women with no previous diabetes history prior to pregnancy[1,2].

Although there is a common misconception suggesting that GDM disappears after delivery, it is important to recognize that GDM serves as an indicator symptom of future potential type 2 diabetes mellitus (T2DM), cardiovascular disease (CVD), and metabolic syndrome risks, as well as it has significant short-term adverse outcomes both for the fetus and the mother[3].

The adverse outcomes affecting both mothers and infants during the periods before, during, and after childbirth include conditions like pregnancy-induced hypertension, preeclampsia, polyhydramnios, macrosomia, higher rates of cesarean sections, shoulder dystocia, birth injuries, and stillbirth, among other[4]. Besides, these offspring are believed to be more likely to suffer from metabolic syndrome, T2DM, obesity, and hypertension in their later lives[5]. Risk factors and groups should be identified, and conduct screening with the idea that many such adverse consequences might be avoided with proper management and treatment. Risk assessment for the potential development of GDM should be diligently conducted during the very first prenatal appointment or even before.

The prevalence of GDM differs worldwide, influenced by factors such as the demographic

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traits of the population in question and the specific diagnostic criteria employed. The prevalence of GDM varies from 1% to 14% among pregnancies in the United States each year, contingent on the specific attributes of the population under examination, as well as the methods of diagnosis and measurement utilized[6]. An analysis of data published in the last ten years revealed that the Middle East and North Africa had the highest reported prevalence, with a median estimate of 13%. In contrast, Europe had the lowest with a 5.8% reported median prevalence[7].

As a result, the worldwide prevalence of gestational diabetes has reached concerning levels. This increase can be attributed to factors such as a sedentary lifestyle, rising obesity rates linked to unhealthy diets before conception and during pregnancy, and the advanced age of women due to delayed maternal age, among other contributing factors. The International Diabetes Federation predicts a serious increase in the number of people with diabetes within 25 years, from 382 million to 590 million[8]. By 2030, the number of deaths resulting from diabetes-related complications is foreseen to be doubled compared with 2005 records, according to the WHO[9]. So it is rather obvious that the impact of the disease is out of discussion besides it is being continuous to be a prominent preventable non-communicable disease. The etiology of GDM is complex and has not been fully elucidated yet, though multiple risk factors are thought to contribute to its development. Recognizing risk factors and vulnerable groups and implementing screening is crucial, as appropriate management and treatment can potentially prevent many of the negative outcomes of GDM.

This study aimed to determine the risk factors for GDM, a serious health problem with rapidly increasing prevalence worldwide.

Patients and Methods

Study Design and Participants

This research was designed to investigate risk factors identified by various international committees. The study incorporated data obtained from Oral Glucose Tolerance Tests (OGTT), which were conducted as part of routine antenatal examinations for 474 pregnant women visiting the obstetrics outpatient clinic at Kafkas University Faculty of Medicine Hospital from January 2022 to June 2023. Approval was obtained from the Ethics Committee of Kafkas University Faculty of Medicine (80576354-050-99/04).

The 2020 American Diabetes Association (ADA) was used and Committee on Practice B-O (2018) risk factors definitions for GDM, which both the ADA and the American College of Obstetricians and Gynecologists (ACOG) recommend using to screen[10]. While these factors significantly contribute to an elevated risk of GDM, it is important to note that diagnostic accuracy is restricted when relying solely on any one of these factors[11]. Patients who refused to be screened or answer the study's survey questions were excluded. Guidelines, based on recent reviews, lack consensus on whether to conduct universal screening or risk-based screening. ADA defines women at low risk as those younger than 25 years, not belonging to an ethnic group, with a body mass index (BMI) <25 kg/m^2, no history of previous abnormal glucose tolerance or adverse obstetric outcomes, and no known history of glucose metabolism abnormalities in first-degree relatives. ADA recommends against screening these women since it provides no additional benefit[10]. Advancing age, elevated BMI, a previous history of GDM or impaired glucose metabolism, a family history of diabetes, a history of stillbirth, preterm delivery, macrosomia, or polyhydramnios, as well as conditions such as PCOS, contribute to the risk factor-based screening group.

Statistical Analysis

The conformity of the continuous variables in the study to normal distribution was evaluated graphically and by the Shapiro-Wilks test. It was determined that none of the continuous variables fit the normal distribution. Mean±SD (standard deviation) and Median (Minimum-Maximum) values were given in the descriptive statistics of the variables.

Cross tabulations were created, and number (n), percentage (%), and Chi-square (χ^2) test statistics were given in the comparison of categorical variables according to GDM status.

Mann-Whitney U test was used to compare age, body mass index (BMI), number of pregnancies, number of births, number of survivors, gestational week, own birth weight, and HBA1c values according to GDM status.

Multivariate logistic regression analyses analyzed potential risk factors associated with GDM status. Results were presented as Odds ratio [Exp(B)] and 95% confidence interval.

IBM SPSS Statistics 21.0 (IBM Corp., Armonk, NY, USA) and MS-Excel 2007 programs were used. The statistical significance level was accepted as $p<0.05$.

Results

The findings from this study, in which commonly recognized risk factors of GDM were examined as follows.

The mean age of individuals without GDM was 28.36±4.89 years, and that of individuals with GDM was 31.26±6.09 years. A statistically significant difference was found between the age values of the individuals according to GDM status ($p<0.001$). In addition, 23.2% (n=81) of the individuals without GDM were <25 years old and 76.8% (n=268) were ≥25 years old, while 12.2% (n=15) of the individuals with GDM were <25 years old and 87.8% (n=108) were ≥25 years old. A statistically significant difference was found in the distribution of age groups according to GDM status ($p=0.009$).

The mean BMI of individuals without GDM was 25.45±3.91 kg/m^2, and the mean BMI of individuals with GDM was 28.08±5.93 kg/m^2. A statistically significant difference was found between the BMI values of the individuals according to having GDM ($p<0.001$). In addition, a statistically significant difference was found in BMI classification according to GDM status ($p<0.001$). While 14.3% (n=50) of individuals without GDM were obese, 32.5% (n=40) of individuals with GDM were obese.

A statistically significant difference was found in the distribution of being pre-diabetic before pregnancy according to GDM status ($p=0.007$). It was determined that 0.3% (n=1) of individuals without GDM and 3.3% (n=4) of individuals with GDM had pre-diabetes.

While 5.7% (n=20) of individuals without GDM had a history of gestational diabetes, 25.2% (n=31) of individuals with GDM had a history of gestational diabetes. A statistically significant difference was found in the distribution of gestational diabetes mellitus according to GDM status ($p<0.001$).

A statistically significant difference was found in the distribution of high blood glucose or impaired fasting glucose in previous pregnancies according to GDM status ($p<0.001$). It was determined that 1.4% (n=5) of individuals without GDM and 13.8% (n=17) of individuals with GDM had high blood sugar or impaired fasting glucose in previous pregnancies.

While 20.3% (n=71) of individuals without GDM had diabetes mellitus in 1st-degree relatives, 40.7% (n=50) of individuals with GDM had diabetes mellitus in 1st-degree relatives. A statistically significant difference was found in the distribution of diabetes in 1st-degree relatives according to GDM status ($p<0.001$).

The median number of pregnancies of individuals without GDM was 2.0, and that of individuals with GDM was 3.0. A statistically significant difference was found between the number of pregnancies of individuals according to GDM status ($p<0.001$).

A statistically significant difference was found between the number of births of individuals according to GDM status ($p=0.001$). The median value of the number of births of individuals with GDM was higher than that of individuals without GDM. A statistically significant difference was found between the living child values of individuals according to GDM status ($p<0.001$). The median value of the number of living individuals with GDM is higher than that of individuals without GDM.

While 6.3% (n=22) of individuals without GDM had a history of preterm birth, 19.5% (n=24) of individuals with GDM had a history of preterm birth. A statistically significant difference was found in the distribution of preterm birth history according to GDM status ($p<0.001$).

While 4.9% (n=17) of individuals without GDM had a macrosomic baby (>4 kg), 10.6% (n=13) of individuals with GDM had a macrosomic baby (>4 kg). A statistically significant difference was found in the distribution of having a macrosomic baby (>4 kg) according to GDM status ($p=0.026$).

While 0.3% (n=1) of individuals without GDM had a history of having a baby with congenital anomaly, 3.7% (n=4) of individuals with GDM had a history of having a disabled baby. There was a statistically significant difference in the distribution of having a history of giving birth to a disabled baby according to GDM status ($p=0.011$).

A statistically significant difference was found in the distribution of high cholesterol according to GDM status ($p=0.036$). 2.2% (n=8) of individuals without GDM and 6.4% (n=7) of individuals with GDM had high cholesterol.

A statistically significant difference was found in the distribution of polyhydramnios in previous pregnancies according to GDM status ($p=0.001$).

While 3.7% (n=13) of individuals without GDM had a history of polyhydramnios in previous pregnancies, 15.4% (n=19) of individuals with GDM had a history of polyhydramnios in previous pregnancies.

While 12.1% (n=42) of individuals without GDM had polyhydramnios in their index pregnancy, 22.0% (n=27) of individuals with GDM had polyhydramnios in their index pregnancy. There was a statistically significant difference in the distribution of polyhydramnios in this pregnancy according to GDM status (p=0.008).

A statistically significant difference was found in the distribution of regular exercise in previous pregnancies according to the presence of GDM (p=0.037). It was determined that 34.6% (n=119) of individuals without GDM and 24.4% (n=30) of individuals with GDM exercised regularly.

The comparison results and descriptive statistics of other parameters according to GDM status are summarized in Table I.

The results of the multivariate logistic regression model including age, gravida, parity, number of alive children, BMI, preterm birth history, history of delivering a baby with congenital anomaly, blood glucose levels before pregnancy, history of GDM, history of polyhydramnios in previous pregnancies, high blood glucose or impaired fasting glucose history in previous pregnancies, history of T2DM in 1st-degree relatives, regular exercise, polyhydramnios in the present pregnancy variables whose effect on GDM status was investigated are given in Table II.

According to the results of multivariate logistic regression analysis, age (OR: 1.079, 95% CI: 1.026-1.135) and BMI (OR: 1.106, 95% CI: 1.050-1.165) increased the risk of having GDM. Those with preterm birth were more likely to have GDM than those without (OR: 2.537, 95% CI: 1.160-5.547), those with impaired fasting glucose or high blood glucose were more likely to have GDM than other individuals (OR: 26.776, 95% CI: 2.494-287.422), those with a history of gestational diabetes were more likely to have GDM than those without (OR: 3. 803, 95% CI: 1.761-8.213), and those with first-degree relatives with diabetes compared to those without (OR: 1.830, 95% CI: 1.078-3.105) (p<0.05) (Table II).

In 24.0% (n=12) of the individuals with GDM who had diabetes in their first-degree relatives, BMI classification was normal, 34.0% (n=17) were pre-obese, and 42.0% (n=21) were obese. A statistically significant difference was found in the distribution of BMI classification according to the presence of diabetes in first-degree relatives in individuals with GDM (p=0.017) (Table III).

Discussion

The global incidence of gestational diabetes has been steadily rising. According to various estimates, over the past two decades, the prevalence of gestational diabetes in women has increased by anywhere from 10% to 100%, particularly in highly developed countries. In 2019, hyperglycemia was diagnosed in approximately 16% of pregnancies worldwide, with gestational diabetes accounting for 84% of all cases[12,13]. This concerning trend is anticipated to lead to a significant increase in perinatal complications. Consequently, researchers are actively working to identify factors that may contribute to these complications and increase the financial burden on patients, aiming to mitigate these risks[5].

The development of GDM can be attributed to shifts in hormonal activity. As pregnancy advances, insulin sensitivity diminishes, leading to elevated fasting glucose levels. In response, the body augments insulin secretion to uphold proper glucose regulation. GDM arises when the body cannot effectively acclimate to these changes, resulting in inadequate insulin production by the endocrine system[14].

Identifying the risk factors for GDM within societies is crucial. It enables the identification of women at risk, facilitating early diagnosis and the implementation of intensive lifestyle modifications and medical interventions to manage blood glucose levels and reduce the risk of GDM-related complications from worsening. This approach may contribute to preventing or improving adverse outcomes associated with GDM.

The incidence of GDM is influenced by several factors encompassing diet, lifestyle, genetics, and the distinctive features of each pregnancy. Women with established risk factors for GDM, such as belonging to a high-risk ethnic group, obesity, or having a family history of diabetes in first-degree relatives, would benefit from universal screening with the diagnostic criteria recommended by the International Association of Diabetes and Pregnancy Study Group (IADPSG)[6].

Most guidelines[15], including the 2016 recommendations from the ADA, suggest universal screening for GDM during the second trimester. However, other organizations, like The National

Table I. Comparison of parameters according to GDM status.

	GDM		
	Negative (n = 349) n (%)	Positive (n = 123) n (%)	*p*
Age			**< 0.001***
Median (Min-Max)	28.0 (18.0-42.0)	31.0 (17.0-47.0)	
BMI Classification			**< 0.001****
Lean	10 (2.9)	0 (0.0)	
Normal	165 (47.3)	48 (69.0)	
Pre-obese	124 (35.5)	35 (28.5)	
Obese	50 (14.3)	40 (32.5)	
Gravida			**< 0.001***
Median (Min-Max)	2.0 (1.0-13.0)	3.0 (1.0-8.0)	
Parity			**< 0.001***
Median (Min-Max)	1.0 (0.0-6.0)	2.0 (0.0-6.0)	
Abortus			0.063**
Yes	81 (23.2)	39 (31.7)	
Singleton/Multiple Pregnancy			0.371**
Singleton pregnancy	336 (96.3)	117 (95.1)	
Multiple pregnancy	13 (3.7)	6 (4.9)	
Multiple Pregnancy			-
Twin Pregnancy	10 (2.9)	6 (4.9)	
Gestational Week			0.511*
Median (Min-Max)	24.0 (22.0-30.0)	24.0 (23.0-28.0)	
Chronic Drug Use			0.895**
Yes	41 (11.7)	15 (12.2)	
Chronic Disease			0.950**
Yes	39 (11.2)	14 (11.4)	
Person's Own Birthweight			0.388*
Median (Min-Max)	3,200 (1,050-6,000)	3,000 (1,000-5,100)	
History of Preterm Birth			**< 0.001****
Yes	22 (6.3)	24 (19.5)	
History of stillbirth			0.364**
Yes	13 (3.7)	3 (2.4)	
Neonatal Death			0.527**
Yes	13 (3.7)	5 (4.1)	
History of Hypertension in Previous Pregnancies			0.104**
Yes	15 (4.3)	10 (8.1)	
Macrosomia (> 4 kg)			**0.026****
Yes	17 (4.9)	13 (10.6)	
History of having a baby with congenital anomalies			**0.018****
Yes	1 (0.3)	4 (3.3)	
History of Poor Pregnancy			0.301**
Yes	42 (12.1)	19 (15.8)	
Conception with Treatment			0.687**
No	319 (91.7)	110 (89.5)	
IVF	26 (7.5)	11 (8.9)	
IUI	3 (0.8)	2 (1.6)	
Hypertension			0.169**
Yes	9 (2.6)	6 (4.9)	
Hypercholesterolemia			0.066**
Yes	8 (2.3)	7 (5.7)	
History of Embolism			0.616**
Yes	9 (2.6)	3 (2.4)	
Pre-pregnancy blood glucose levels			0.007**
Unknown	305 (87.6)	96 (78.0)	
Normal	42 (12.1)	23 (18.7)	
Pre-diabetic	1 (0.3)	4 (3.3)	

Continued

Table I (*Continued*). Comparison of parameters according to GDM status.

	GDM		
	Negative (n = 349) n (%)	Positive (n = 123) n (%)	p
History of GDM			< 0.001**
Yes	20 (5.7)	31 (25.2)	
Treatment for those diagnosed with GDM			0.642**
Diet	8 (61.5)	22 (66.7)	
İnsulin	5 (38.5)	10 (30.3)	
Treatment refusal	0 (0.0)	1 (3.0)	
HBA1c			0.118*
Median (Min-Max)	5.4 (4.3-7.2)	5.2 (4.4-6.3)	
History of delivering a baby > 4,5 kg			0.073**
Yes	12 (3.4)	9 (7.3)	
History of polyhydramnios in previous pregnancy			< 0.001**
Yes	13 (3.7)	19 (15.4)	
History of high blood glucose or impaired fasting glucose in previous pregnancy			< 0.001**
Yes	5 (1.4)	17 (13.8)	
History of diabetes in 1st-degree relatives			< 0.001**
Yes	71 (20.3)	50 (40.7)	
GDM history in sisters			0.285**
No	312 (90.4)	105 (85.4)	
Yes	15 (4.4)	9 (7.3)	
No sisters	18 (5.2)	9 (7.3)	
Regular Exercise			0.037**
Yes	119 (34.6)	30 (24.4)	
Weight Gained During Pregnancy			0.182**
Unknown	41 (11.8)	15 (12.2)	
0-6 kg	80 (23.1)	38 (30.9)	
7-12 kg	135 (38.9)	48 (39.0)	
> 12 kg	91 (26.2)	22 (17.9)	
Polyhydramnios in existing pregnancy			**0.008****
Yes	42 (12.1)	27 (22.0)	
PCOS			0.216**
No	306 (87.9)	109 (88.6)	
Yes	34 (9.8)	14 (11.4)	
Do not know	8 (2.3)	0 (0.0)	
Acanthosis Nigricans			0.219**
Yes	39 (11.2)	19 (15.4)	
Insulin Resistance			0.142**
No	329 (94.5)	111 (90.2)	
Yes	7 (2.0)	7 (5.7)	
Do not know	12 (3.5)	5 (4.1)	
Vitamin D Deficiency Diagnosis in Pregnancy			0.218**
Yes	226 (64.9)	86 (71.1)	
Vitamin Usage			0.756**
Yes	301 (86.5)	106 (87.6)	
Smoking			0.788**
Yes	15 (4.3)	6 (4.9)	
Alcohol use			0.545**
Yes	2 (0.6)	0 (0.0)	
Physical Activity			0.315**
3 days a week for less than 30 minutes	170 (48.9)	65 (54.2)	
3 days a week for more than 30 minutes	178 (51.1)	55 (45.8)	

*Mann-Whitney U Test, **Chi-square Test.

Institute for Health and Care Excellence (NICE) in 2015, recommend screening for GDM based on risk factors during the initial booking appointment. The risk factors identified by NICE in 2015 include having a BMI of ≥30, a family history of diabetes, previous gestational diabetes, a history

Table II. Potential risk factors associated with GDM status in the multivariable logistic regression model.

Variables	β	Standard error	Wald	p	Exp(B)	Confidence interval for Exp(B) 95%	
						Under	Over
Constant	-6.491	0.988	43.188	< **0.001**	0.002		
Age	0.076	0.026	8.750	**0.003**	1.079	1.026	1.135
BMI	0.101	0.026	14.555	< **0.001**	1.106	1.050	1.165
Gravida	-0.238	0.212	1.259	0.262	0.788	0.521	1.194
Parity	0.348	0.362	0.923	0.337	1.416	0.696	2.881
Alive	-0.005	0.269	0.001	0.984	0.995	0.587	1.685
Preterm Labor	0.931	0.399	5.438	**0.020**	2.537	1.160	5.547
History of delivering a baby with congenital anomaly	1.977	1.288	2.354	0.125	7.218	0.578	90.132
Pre-pregnancy high blood glucose	3.288	1.211	7.370	**0.007**	26.776	2.494	287.422
GDM history	1.336	0.393	11.559	**0.001**	3.803	1.761	8.213
History of Polyhydramnios in previous pregnancies	0.936	0.483	3.761	0.052	2.551	0.990	6.571
High Blood Glucose or Impaired Fasting Glucose in Previous Pregnancies	0.549	0.657	0.698	0.403	1.732	0.477	6.283
Diabetes in First Degree Relatives	0.604	0.270	5.007	**0.025**	1.830	1.078	3.105
Regular Exercise	-0.292	0.275	1.128	0.288	0.747	0.436	1.280
Polyhydramnios in current Pregnancy	0.198	0.355	0.312	0.576	1.219	0.608	2.446

of macrosomia (birth weight of 4.5 kg and more), or belonging to an ethnic minority group with a high prevalence of gestational diabetes, such as South Asian and Middle Eastern populations[15,16].

Maternal age is a well-established risk factor for GDM, yet there is a lack of consensus regarding the precise relationship between age and the heightened risk of GDM[17]. ADA recommends screening for GDM as early as possible, setting the lowest age cut-off at ≥25 years[18]. This study revealed that advanced maternal age increased the risk of GDM by 1.026 times, according to the multivariate logistic regression analysis results.

Table III. Comparison of BMI groups in individuals with GDM according to diabetes in 1st-degree relatives.

BMI (body mass index)	Diabetes in 1st degree relatives		
	No n (%)	Yes n (%)	p
Normal	36 (49.3)	12 (24.0)	
Pre obese	18 (24.7)	17 (34.0)	**0.017**
Obese	19 (26.0)	21 (42.0)	

These findings align with previous research[19], underscoring the higher predictive value of screening for GDM among individuals aged 25 years and older, particularly when accompanied by other risk factors.

GDM exhibits a notable heritability, with a significant prevalence of positive family history for T2DM among affected women. Additionally, individuals with a history of GDM are more susceptible to developing T2DM as they age. According to Yang et al[20], women with a history of T2DM demonstrated a twofold increased risk of developing GDM compared to those without a family history. Kim et al[21] found a strong association between a family history of type 2 diabetes and an increased likelihood of having a history of GDM. Their research suggested that having a family history of diabetes from one parent could double or even triple the risk of developing GDM compared to individuals with no diabetes. In their study, Rhee et al[22] uncovered that the risk of GDM was doubled when there was a parental history of T2DM, increased fivefold in the presence of a sibling with T2DM, and rose to 6.5-fold when both parental and sibling histories were present. Previous stud-

ies[23,24] indicate that a family history of diabetes, particularly in a first-degree relative, elevates the risk of GDM. This observation implies a genetic predisposition to GDM development. This study showed that those with a family history of GDM in first-degree relatives were 1.078 times more likely to develop GDM than those without, according to the multivariate logistic regression analysis results. In this context, this study results are consistent with the literature[15,25].

Obesity is a primary factor contributing to the development of both diabetes and GDM, as noted in previous studies[6]. BMI is a widely employed metric to assess the degree of obesity and is commonly utilized in risk-based screening for GDM. The prevalence of GDM is positively associated with increasing pre-pregnancy BMI[6]. A study[26] found that women who are overweight or obese face a significantly increased risk of developing GDM, regardless of their ethnic background. However, the cut-off point for diagnosing obesity differs between Western and Asian countries[27].

For example, among Asian women, the prevalence of GDM was highest in those with a BMI ≥30 kg/m^2 (13.78%), followed by BMI ≥25 kg/m^2 (10.22%), and BMI ≥20 kg/m^2 (6.09%)[27].

According to the literature, a BMI ≥25 kg/m^2 is considered more suitable for use among African-American women, as it offers higher sensitivity (46.2%) and specificity (81.5%)[27].

In a meta-analysis carried out by Chu et al[28], it was shown that the risk of GDM doubled among overweight women with a BMI of 25.0-30.0 kg/m², quadrupled for those with a BMI of 30.0-35.0 kg/m² and octupled for those with a BMI over 35 kg/m²[28]. As outlined by Glazer et al[29], obese women who gained a minimum of 4.5 kg between pregnancies experienced a 47% increase in the risk of GDM. Conversely, those who lost at least 4.5 kg saw a 37% reduction in risk compared to individuals with stable weight. Villamor et al[30] found that among women who experienced two consecutive pregnancies, an inter-pregnancy weight gain increasing to 3 or more BMI units was associated with a twofold increase in GDM risk. They also noted that this increased risk was more significant among women who were not overweight during their first pregnancy. This proposition suggests that the association with the rate of weight gain had the greatest impact on women who were not initially overweight. These findings suggest that even minor weight gain in women who are not initially overweight can increase the risk of GDM. Obesity creates an unfavorable metabolic environment early in gestation. Hence, initiating weight loss interventions during pregnancy might not be adequate to prevent or reverse adverse outcomes. This suggestion emphasizes the importance of implementing weight management strategies before conception[31,32]. ACOG, NICE, and The International Organization for Migration (IOM) guidelines stress the importance of integrating lifestyle modifications in preconceptional weight, weight gain during pregnancy, physical activity, and nutrition as crucial elements in preventing and managing GDM[1,33]. NICE guidelines encompass precise instructions for adopting a nutritious diet, adhering to a low-fat eating regimen, and engaging in moderate physical activity before, during, and following pregnancy[34].

These results are consistent with previous studies[15,35]. The mean BMI of individuals without GDM was 25.45±3.91 kg/m^2, and the mean BMI of individuals with GDM was 28.08±5.93 kg/m^2. A statistically significant difference was found between the BMI values of the individuals according to having GDM (p<0.001). In addition, a statistically significant difference was found in BMI classification according to GDM status (p<0.001). While 14.3% (n=50) of individuals without GDM were obese, 32.5% (n=40) of individuals with GDM were obese.

Lifestyle interventions are believed to be effective in preventing GDM. However, adopting a new lifestyle can be a daunting undertaking, and it can be even more challenging for expectant mothers. Pregnancy often presents unique challenges, including nausea and fatigue, making adhering to a healthy diet and regular physical activity more difficult. Nevertheless, the period encompassing pregnancy and family planning can be seen as an ideal opportunity to promote a healthier lifestyle for the entire family. This proposal is because women during these specific life stages are generally more motivated to follow guidance to improve pregnancy outcomes and their infants' well-being[36]. However, findings of intervention studies[37,38] on GDM are inconsistent; the majority report either statistically non-significant findings or negative besides certain protective effects. The negative findings could mostly be due to the small sample size or interventions to be implemented in the late trimester, which might not provide adequate time for the interventions to be effective. The studies that showed a significant benefit from physical activity, diet, and lifestyle changes started before conception or early in the

first trimester. Two recent meta-analyses have indicated that physical activity interventions can effectively prevent GDM, particularly when the intervention extends throughout pregnancy[39,40]. The interventions employed varied, encompassing activities such as yoga, aerobic exercises, or resistance training, and targeting various dietary aspects. These results are consistent with previous studies[41,42].

According to Lewandowska's study[43], parental diabetes mellitus was significantly associated with an increased risk of GDM, and this relationship was further exacerbated by pre-pregnancy obesity and/or overweight. When categories of family history of diabetes coincided with pre-pregnancy obesity or overweight, the risk of GDM was approximately twice as high compared to pregnant women with a normal BMI. 16% of women developed GDM, with 29.7% having a pre-pregnancy BMI ≥ 25 kg/m^2 and 10.8% classified as obese. Women who developed GDM were statistically older, and the percentage of women with pre-pregnancy obesity was significantly higher (21.9% *vs.* 8.6%). This study highlighted how obesity and being overweight can magnify the impact of genetic factors. Considering that obesity is an independent risk factor for GDM, the campaigns should focus on optimizing women's weight before pregnancy by promoting healthy lifestyles, including improvements in nutrition and physical activity[43]. A study by Shirazian et al[44] showed that complications related to GDM increase when BMI exceeds 30, age exceeds 30 years, and there is a family history of diabetes. According to the multivariate logistic regression analysis results, BMI increased the risk of GDM by 1.050 times. In this context, the results are consistent with the literature.

Another significant risk factor for GDM is having a previous pregnancy with GDM, as GDM has a recurrence rate ranging from 30% to 84% in subsequent pregnancies[45]. To summarize, women who have previously experienced GDM face an elevated likelihood of GDM recurrence, with ethnicity emerging as a significant predictive factor. In summary, women with a history of GDM have an increased risk of GDM recurrence, and ethnicity is a significant predictive factor. This study revealed that individuals with a history of previous GDM are 1.761 times more likely to develop GDM than those without such a history. This result aligns with previous research findings[6,46].

Some authors[47] suggest improving the diagnostic accuracy of risk factors by adding some risk indicators, such as fasting plasma glucose and some biochemical markers**.**

The International Diabetes Federation (IDF) reported that 16.7% (21.1 million) of live births to women in 2021 had some form of hyperglycemia in pregnancy. Of these, 80.3% were due to gestational diabetes mellitus[5,48]. Literature suggests the history of macrosomia and pregnancy-induced hypertension have 4 times and 3 times for odds to have higher insulin resistance[15,49]. This study measured the individuals' Hba1c and blood cholesterol values. The results were not statistically significant for HbA1c but significant for blood cholesterol values.

Studies[50] revealed a negative correlation between plasma vitamin D concentration and the frequency of GDM. Overweight and vitamin D-deficient women exhibited an approximately fivefold increased risk of developing GDM compared to lean individuals with normal weight and sufficient vitamin D levels. This study results are consistent with the literature.

A meta-analysis[15] demonstrated that the risk factors of GDM include congenital anomalies within other risk factors. This study showed a statistically significant difference between individuals with and without GDM with a history of having a baby with congenital anomalies. This finding aligns with prior research[51].

GDM often leads to a significant complication known as fetal macrosomia, which increases the risk of birth-related complications, including shoulder dystocia, clavicle fractures, and brachial plexus injuries. Consequently, there is an elevated admissions rate to neonatal intensive care units (NICUs)[5,6]. GDM women who underwent treatment exhibited lower rates of macrosomia, preeclampsia, and emergency cesarean section[52]. Among the various factors associated with GDM, Anzaku and Musa's research[53] highlighted that a previous history of macrosomia in a woman's pregnancy is the sole independent risk factor for developing GDM in subsequent pregnancies. These results underscore the importance of monitoring and managing GDM, particularly in cases with a history of macrosomia, which was similar to this study results.

Polycystic ovarian syndrome is a common endocrine, multifactorial lifelong disorder harming women's metabolic and reproductive health. Although one of the major problems of PCOS is infertility due to anovulatory cycles, the ones who are fortunate enough to conceive unfortunately face an elevated risk of pregnancy-related compli-

cations such as GDM. GDM and PCOS are strongly interconnected and often co-occur[54]. A nutraceutical supplement containing vitamin D may decrease the risk of diabetes and its complications. When examining the relationship between PCOS and GDM in the literature, the use of myoinositol during pregnancy is suggested to prevent gestational diabetes and its fetal consequences (such as large gestational age), improving the metabolic profile[55,56]. According to the results, women with PCOS have a higher risk of developing GDM[15]; in contrast, any strong link between GDM and PCOS. This is believed to be related to the small sample size of the study group.

Conclusions

Understanding risk factors, especially modifiable ones, is important to prevent GDM and improve the intrauterine environment, which can reduce the risk of adverse health outcomes associated with GDM in mothers and offspring. Clinicians should be aware of these common risk factors to show additional attention to high-risk cases of GDM in pregnancy. Well-established risk factors for GDM encompass a family history of diabetes, a history of previous GDM, belonging to a high-risk ethnicity, advanced maternal age, delivering a macrosomic baby, being overweight or obese, and smoking. Taken together, when it comes to the question of whether GDM is preventable or not, the answer remains optimistic. Although not all GDM events can be prevented, lifestyle interventions introduced early in pregnancy or, even better, before pregnancy can potentially prevent GDM development, at least among some women. The promising findings from large observational studies support this. Modulating diet, promoting physical activity, and pharmacotherapy, including insulin, may hold the hope of interrupting the vicious circle involving maternal GDM, childhood obesity, and diabetes, ultimately stopping or delaying the onset of diabetes. Changing behavior/lifestyle is always challenging. Pregnant women, in particular, may face additional barriers to eating healthily and doing regular physical activity because of pregnancy symptoms such as nausea and fatigue. However, the time around pregnancy or family planning may represent an ideal opportunity to advocate a healthy lifestyle for the family, as women in these specific time windows of their lives are generally better motivated to follow advice to improve pregnancy outcomes and infant health. Until now, definitive biochemical markers that could predict GDM with certainty have not been pinpointed. Comprehensive screening tests involving a combination of clinical and biochemical factors are intricate and have yet to be verified in external cohorts. Affirmation of the role of the family history of diabetes as an independent risk factor for GDM is important as this information is available even before pregnancy.

Hence, clinical risk factors could potentially hold significance in predicting GDM early, facilitating the timely initiation of monitoring and preventive measures.

Conflict of Interest

The author declares no conflict of interest concerning this article's authorship and/or publication.

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The data generated and analyzed during the study are available from the corresponding author. They are not available publicly.

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The patients who participated in the study were given detailed information about the study, and consent for participation was obtained.

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