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Can We Predict the Insulin Therapy Need and Early Postpartum Prediabetes in Patients with Gestational Diabetes Mellitus?

ABSTRACT

Objective: The authors aimed to identify risk factors for insulin therapy need and for the development of postpartum prediabetes in women with gestational diabetes mellitus (GDM).

Materials and methods: This was a prospective observational single-center study including pregnant women with GDM. Women with overt diabetes were excluded. Risk factors for insulin use and prediabetes were identified using logistic regression. Univariable analyses were performed to select factors for multivariable analysis. Stepwise logistic regression was used to create multivariable models.

Results: Among 135 women with GDM, 63 (46.7%) required insulin therapy. Multivariable analysis demonstrated that family history of diabetes, abnormal pre-pregnancy body mass index (> 25 kg/m^2), the performance of 75 g oral glucose tolerance test (OGTT) before 24 Hbd, fasting plasma glucose (FPG) at pregnancy diagnosis constitute predictive factors for further insulin therapy need. Thirteen women (9.6%) developed prediabetes shortly (6–12 weeks postpartum) after gestation. In multivariable analysis family history of diabetes, rapid weight gain, 1 h plasma glucose (PG) in OGTT, 2 h PG in OGTT and glycated hemoglobin (HbA1c) concentration were identified as independent risk factors for prediabetes postpartum.

Conclusions: Many easily-available parameters individually and combined in prediction models can be useful in assessing the risk of insulin therapy need and early postpartum prediabetes in women with GDM. Evaluation of the risk of above complications at GDM diagnosis is possible using metabolic parameters and family history of diabetes. (Clin Diabetol 2023; 12; 4: 223–231)

Keywords: gestation diabetes mellitus, insulin therapy, postpartum prediabetes, glycemia, OGTT

Introduction

Gestational diabetes (GDM) is the most common metabolic disorder diagnosed in pregnant women. GDM is a glucose intolerance that manifests itself for the first time during pregnancy as a varying degree hyperglycemia [1]. This condition is associated with maternal and fetal complications. When lifestyle modifications, i.e., diet and physical activities, do not lead to a desirable change in fasting and postprandial glycemia, insulin therapy is required [2]. Identification of factors associated with poor glycemic control with non-pharmacological intervention is clinically useful to timely initiate insulin therapy and prevent GDM complications.

Women with GDM are at increased risk of postpartum glucose intolerance and type 2 diabetes mellitus

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development (DM2) [1, 3, 4]. According to Sivaram et al. [5], within 5 years of GDM diagnosis, almost 7% of pregnant women, and within 10 years, more than 20% of pregnant women, will develop type 2 diabetes. A meta-analysis shows that one-third of women develop type 2 diabetes within 15 years after GDM [4]. Recent meta-analysis of 20 studies shows that women after GDM have nearly 10 times higher DM2 risk compared to healthy counterparts [6]. It should be noted that only a small fraction of patients will develop prediabetes and type 2 diabetes shortly after pregnancy [7, 8] including those with gestational diabetes mellitus (GDM. However, the prediction of these events and the assessment of risk factors are of significant clinical importance in order to apply appropriate prevention (diet and exercise) and to establish an appropriate diagnosis of carbohydrate disorders as soon as possible. Several predictive models were proposed to identify women at high risk of postpartum prediabetes [8, 9]. It has been shown that women with fasting and 2 h glucose values above GDM cut-offs are at high risk of postpartum prediabetes [8]. Another study provided evidence that age, family history of diabetes and glycated hemoglobin (HbA1c) at diagnosis are robust predictors of postpartum diabetes [10].

The aim of this study was to identify risk factors for the insulin therapy need and the development of postpartum prediabetes in women with GDM.

Materials and methods

Study design

This is a prospective observational single-center study. Pregnant women with diagnosed gestational diabetes mellitus, who were treated in the Diabetes Outpatient Clinic were included in the study. GDM was diagnosed based on abnormal glycemia in 75 g oral glucose tolerance test (75 g OGTT), accordingly with IADPSG 2010 criteria.

Study population

Before enrollment in the study, each pregnant woman had fasting blood glucose measured after the diagnosis of pregnancy. Patients with abnormal fasting glycemia and those with risk factors for the development of GDM were referred to the 75 g OGTT already in the first trimester of pregnancy. The remaining patients were screened for GDM with 75 g OGTT between 24 and 28 weeks of gestation. Meeting any of the criteria was an indication to start a GDM treatment. Patients with overt diabetes mellitus in pregnancy and previous history of diabetes mellitus were excluded from the study. Medical nutrition therapy was the first-line management and included dietary intervention and daily physical activity. Self-monitoring of glycemia using validated glucometer was recommended. Insulin therapy was implemented in pregnant women who failed to achieve metabolic control by diet and physical activity alone. After delivery (6–12 weeks) patients again underwent 75 OGTT to identify prediabetes and diabetes.

Data collection

Patients had regular appointments in diabetes and obstetrics outpatient clinic. HbA1c concentration and lipid profile [total cholesterol, low-density cholesterol (LDL), high-density cholesterol (HDL) and triglicerydes] were determined after GDM diagnosis (end of second trimester/beginning of third trimester). LDL, HDL, triglicerydes and total cholesterol were measured by spectrophotometry using Allinity analyzer. Reference range for total cholesterol was 115–190 mg/dL, for triglicerydes < 150 mg/dL and for LDL and HDL target values were dependent on cardiovascular risk. HbA1c was measured by enzymatic assay using Abbotts' reagents and Allinity analyzer with reference range 4.8–5.9%. The data about demographics, GDM risk factors, prior obstetric and medical history, pregnancy complications and delivery outcomes were collected during subsequent visits in the diabetes outpatient clinic.

Ethical considerations

The study was approved by the Ethics Committee of the Collegium Medicum at the Jan Kochanowski University. Each of the patients gave informed written consent to participate in the study.

Statistical analysis

Patients' characteristics were presented as the number of patients and percentage for categorized variables and median supplemented with interquartile range for continuous variables. Differences between groups were evaluated using Fisher's exact test and U-Mann Whitney test for frequencies and medians comparison respectively.

Risk factors for insulin use and prediabetes were identified using logistic regression. Univariable analyses were performed to select factors for multivariable analysis. Stepwise logistic regression was used to create multivariable models. Odds ratio (OR) and a 95% confidence interval (95% CI) were derived from logistic regression analyses. To evaluate model accuracy the area under the curve (AUC) was calculated. Two-sided p-value < 0.05 was adopted as the level of statistical significance for all analyses. All statistical analysis were performed using SAS system (version 9.4).

Results

Overall, 135 pregnant women with GDM were included in the analysis. Median of patients' age was 31 years and the majority of patients were multiparous (53.3%). For 56 women (41.5%) this was the first pregnancy, 45 (33.3%) were pregnant for the second time and in remaining 34 cases (25.2%) this was third or subsequent pregnancy. Thirty-one patients (23%) underwent 75 g OGTT before 24 weeks of gestation due to GDM risk factors and abnormal fasting glycemia in the first trimester. During 75 g OGTT median glycemia values were 88.5 (4.9), 182 (10.1) and 155 (8.6) mg/dL (mmol/L) in 0 h, 1 h, 2 h time points respectively.

Sixty-three patients (46.7%) required insulin therapy and 71 patients (53.3%) achieved glycemic control with medical nutritional therapy alone. Preterm labors [before 37 + 0 Hbd (< 259 days of gestation)] occurred in 16 cases (11.9%), 12 neonates (8.9%) were classified as large for gestational age (LGA), 66 cesarean sections (48.9%) were performed. Seven pregnancies were complicated by pregnancy-induced hypertension and another seven by gestational cholestasis.

Thirteen women (9.6%) developed prediabetes shortly after gestation, which was diagnosed by 75 g OGTT performed from six to twelve weeks postpartum. Among patients with postpartum prediabetes, eleven had impaired glucose tolerance [2 h plasma glucose (PG) ≥ 140 mg/dL (≥ 7.8 mmol/L)], whereas two had increased fasting glycemia [FPG ≥ 100 mg/dL (≥ 5.6 mmol/L)]. Cohort characteristics including GDM risk factors, metabolic profile, OGTT results, pregnancy complications and outcomes are presented in Table 1.

Patients requiring insulin therapy had higher median body mass index (BMI) before pregnancy, more frequently presented with FPG ≥ 92 mg/dL (5.1 mmol/L) at pregnancy diagnosis, FPG ≥ 92 mg/dL (5.1 mmol/L) during 75 g OGTT, family history of diabetes and performance of OGTT before 24 weeks of gestation (Tab. 2).

Univariable logistic regression identified family history of diabetes, pre-pregnancy BMI (> 25 kg/m^2), BMI before pregnancy, maximum BMI during pregnancy, performance of OGTT before 24 Hbd (week of pregnancy), fasting plasma glucose (FPG) in 75 g OGTT, FPG at pregnancy diagnosis, FPG ≥ 92 mg/dL (5.1 mmol/l) in OGTT, abnormal glycemia in all three points of OGTT as risk factors for insulin use. Nulliparity was associated with lower risk of insulin therapy requirement (Tab. 3). Two multivariable models were created, one of which includes only factors available already in the early pregnancy and second slightly more accurate based on factors known after performing OGTT (usually 24–28 weeks of gestation). First model included family history of diabetes, pre-pregnancy BMI

Table 1. Characteristics of Women with Gestational Diabetes Mellitus (N = 135)

Characteristics	N (%)	Median (IQR)
Gravida		
1	56 (41.5%)	
> 1	79 (58.5%)	
Parity		
Nullipara	63 (46.7%)	
Multipara	72 (53.3%)	
Age [years]		31 (29–35)
Age [years]		
< 35	102 (75.6%)	
≥ 35	33 (24.4%)	
Previous fetal macrosomia		
Yes	10 (7.4%)	
No	125 (92.6%)	
Prior GDM		
Yes	15 (11.11%)	
No	120 (88.89%)	
Hypertension before pregnancy		
Yes	7 (5.2%)	
No	128 (94.8%)	
Hirsutism		
Yes	9 (6.7)	
No	126 (93.3)	
BMI [kg/m^2]		24.5 (21.7–29.4)
BMI before pregnancy		
< 25 kg/m^2	73 (54.1%)	
> 25 kg/m^2	62 (45.9%)	
Obesity		
Yes	32 (23.7%)	
No	103 (76.3%)	
Family history of diabetes		
Yes	46 (34.1%)	
No	89 (65.9%)	
Rapid weight gain		
Yes	32 (23.7%)	
No	103 (76.3%)	
Low physical activity		
Yes	33 (24.4%)	
No	102 (75.6%)	
Smoking		
Yes	37 (27.4%)	
No	98 (72.6%)	
FPG in OGTT		
< 92 mg/dL (5.1 mmol/L)	78 (57.8%)	
≥ 92 mg/dL (5.1 mmol/L)	57 (42.2%)	
1 h PG in OGTT		
< 180 mg/dL (10 mmol/L)	58 (43%)	

→

Table 1 (cont.). Characteristics of Women with Gestational Diabetes Mellitus (N = 135)

Characteristics	N (%)	Median (IQR)
≥ 180 mg/dL (10 mmol/L)	77 (57%)	
2 h PG in OGTT		
< 153 mg/dL (8.5 mmol/L)	58 (43%)	
≥ 153 mg/dL (8.5 mmol/L)	77 (57%)	
FPG at pregnancy diagnosis		
< 92 mg/dL (5.1 mmol/L)	102 (75.6%)	
≥ 92 mg/dL (5.1 mmol/L)	33 (24.4%)	
OGTT before 24 HBD		
Yes	31 (23%)	
No	104 (77%)	
HbA1c [%]		5.1 (4.9–5.3)
OGTT performance (week)		24 (24–26)
Insulin therapy		
Yes	63 (46.7%)	
No	72 (53.3%)	
Delivery (week)		38 (38–39)
Delivery time		
In term (between 37 + 0	119 (88.1%)	
Hbd and 41 + 6 Hbd)		
Preterm (< 37 + 0 Hbd)	16 (11.9%)	
LGA		
Yes	12 (8.9%)	
No	123 (91.1%)	
Cesarean delivery		
Yes	66 (48.9%)	
No	69 (51.1%)	
Prediabetes		
Yes	13 (9.6%)	
No	122 (90.4%)	

BMI — body mass index; FPG — fasting plasma glucose; GDM — gestational diabetes mellitus; HbA1c — glycated hemoglobin; HBD — week of pregnancy; IQR — interquartile range; LGA — large for gestational age; OGTT — oral glucose tolerance test; PG — plasma glucose; rapid weight gain — gain of weight above 2 kg in the first trimester or/and above 0.5 kg per week in the second trimester

(> 25 kg/m^2), performance of OGTT before 24 Hbd, FPG at pregnancy diagnosis (AUC 0.813). Second alternative model included FPG ≥ 92 mg/dL (5.1 mmol/l) during 75 g OGTT instead of FPG at pregnancy diagnosis and was characterized by slightly lower AUC (0.797).

Family history of diabetes, rapid weight gain (gain of weight above 2 kg in the first trimester or/and above 0.5 kg per week in the second trimester), hyperglycemia at pregnancy diagnosis (FPG ≥ 92 mg/dL at first visit during pregnancy), 1 h PG in OGTT, 2 h PG in OGTT, HbA1c concentration, abnormal glycemia in all OGTT time points were identified as risk factors for prediabetes at 6–12 weeks postpartum (Tab. 4). Multivariable model for prediabetes prediction included family history of diabetes, rapid weight gain, 1 h PG in OGTT, 2 h PG in OGTT and HbA1c concentration. The model was characterized by an excellent accuracy (AUC 0.930).

Discussion

In the present study, the authors identified the risk factors for antenatal insulin therapy need and postpartum early prediabetes in patients with GDM. Both, antenatal insulin use and postpartum prediabetes constitute risk factors for diabetes mellitus development in the future [3, 11]. In the multivariate analysis carried out here, a model predicting the need for insulin therapy achieved good accuracy (AUC = = 0.813). Independent predictors of insulin use were the following: fasting glucose in 75g OGTT > 92 mg/dL (5.1 mmol/L), performance of 75 g OGTT before 24 weeks of gestation, increased BMI > 25 kg/m^2 and a family history of diabetes. The authors also created an alternative model including factors available already in the early pregnancy, which incorporated FPG at the beginning of pregnancy, instead of FPG during 75 g OGTT performance. Such model had similar prognostic accuracy and might be clinically useful for women with early GDM occurrence. FPG at diagnosis was also found as independent risk factor by other researchers [12–14].

A similar prediction model was created by Koning et al. [13], who included previous GDM, family history of diabetes, a previous infant weighing ≥ 4500 g, Middle-East/North-African descent, multiparity, pregestational BMI ≥ 30 kg/m^2, and an increased fasting glucose level ≥ 5.5 mmol/L (≥ 99 mg/dL) and 2h PG ≥ 9.4 mmol/L (≥ 169 mg/dL) at GDM diagnosis as insulin therapy risk factors.

Zhang et al. [14] created a model encompassing FPG in 75g OGTT, blood glucose level in 2h OGTT, and HbA1c concentration. They proved that higher fasting glucose levels and 2 h PG in OGTT and higher HbA1c increased risk of insulin use. Interestingly, Zhang et al. noted that the diagnostic value of FPG exceeded the diagnostic value of 2 h PG as well as the concentration of HbA1c. However, the authors did not observe the predictive role of 1 h and 2 h glycemia in OGTT for insulin use prediction. FPG seems to be the strongest determinant of subsequent insulin need. Therefore, only the fasting glucose was included the final model. In univariable analysis, the authors also showed that each 1 mg/dL (0.06 mmol/L) increase in fasting glucose in OGTT increases the risk of insulin use by 9.3%. This observation is of clinical importance and has also been made by other researchers [14, 15]. On the other hand,

Table 2. Differences between Women with Gestational Diabetes Mellitus Treated with Nutrition (N = 72) and Insulin Therapy (N = 63).

Characteristics	Nutrition therapy (N = 72)		Insulin and nutrition therapy (N = 63)		P
	N (%)	Median (IQR)	N (%)	Median (IQR)	
Gravida					
1	29 (40.3%)		27 (42.9%)		0.9
> 1	43 (59.7%)		36 (57.1%)		
Parity					
Primipara	39 (54.2%)		24 (38.1%)		0.1
Multipara	33 (45.8%)		39 (61.9%)		
Age [years]		32 (29–36)		31 (29–34)	0.4
Age [years]					
< 35	51 (70.8%)		51 (81%)		0.2
> 35	21 (29.2%)		12 (19%)		
Previous fetal macrosomia					
Yes	6 (8.3%)		4 (6.3%)		0.8
No	66 (91.7%)		59 (93.7%)		
Prior GDM					
Yes	11 (15.3%)		4 (6.3%)		0.2
No	61 (84.7%)		59 (93.7%)		
BMI before pregnancy		22.9 (20.4–27.1)		26.6 (22.8–30.5)	0.002
BMI before pregnancy					
< 25 kg/m^2	49 (68.1%)		24 (38.1%)		0.0006
> 25 kg/m^2	23 (31.9%)		39 (61.9%)		
Family history of diabetes					
Yes	19 (26.4%)		27 (42.9%)		0.048
No	53 (73.6%)		36 (57.1%)		
Rapid weight gain					
Yes	19 (26.4%)		13 (20.6%)		0.5
No	53 (73.6%)		50 (79.4%)		
FPG in OGTT					
< 92 mg/dL (5.1 mmol/L)	55 (76.4%)		23 (36.5%)		<0.0001
≥ 92 mg/dL (5.1 mmol/L)	17 (23.6%)		40 (63.5%)		
1 h PG in OGTT					
< 180 mg/dL (10 mmol/L)	32 (44.4%)		26 (41.3%)		0.7
≥ 180 mg/dL (10 mmol/L)	40 (55.6%)		37 (58.7%)		
2 h PG in OGTT					
< 153 mg/dL (8.5 mmol/L)	26 (36.1%)		32 (50.8%)		0.1
≥ 153 mg/dL (8.5 mmol/L)	46 (63.9%)		31 (49.2%)		
FPG at pregnancy diagnosis					
< 92 mg/dL (5.1 mmol/L)	60 (83.3%)		42 (66.7%)		0.029
≥ 92 mg/dL (5.1 mmol/L)	12 (16.7%)		21 (33.3%)		
OGTT before 24 HBD					
Yes	10 (13.9%)		21 (33.3%)		0.008
No	62 (86.1%)		42 (66.7%)		

BMI — body mass index; FPG — fasting plasma glucose; GDM — gestational diabetes mellitus; HBD — week of pregnancy; IQR — interquartile range; OGTT — oral glucose tolerance test; PG — plasma glucose; rapid weight gain — gain of weight above 2 kg in the first trimester or/and above 0.5 kg per week in the second trimester

Table 3. Factors Predicting the Need for Insulin Therapy in Woman with Gestational Diabetes Mellitus — Univariable and Multivariable Analysis

Risk factors	Univariable analysis OR (95% CI)	Multivariable analysis OR (95% CI)
Age > 35 years	0.59 (0.27–1.27)	
Primiparity	0.52 (0.26–1.04)	0.27 (0.11–0.67)
Prior GDM	0.38 (0.11–1.24)	
Family history of diabetes	2.09 (1.02–4.31)	2.52 (1.05–6.05)
Rapid weight gain	0.73 (0.32–1.62)	
BMI before pregnancy	1.14 (1.05–1.22)	
BMI > 25 kg/m^2 before pregnancy	3.46 (1.70–7.04)	3.48 (1.50–8.06)
Max. BMI during pregnancy	1.15 (1.06–1.24)	
OGTT before 24 HBD	3.10 (1.33–7.24)	2.95 (1.08–8.05)
FPG in OGTT	1.09 (1.05–1.14)	
1 h PG in OGTT	1.001 (0.99–1.02)	
2 h PG in OGTT	0.986 (0.97–1.00)	
HbA1c	3.18 (1.06–9.57)	
FPG at pregnancy diagnosis	1.07 (1.03–1.11)	
Hyperglycemia at pregnancy diagnosis (FPG ≥ 92 mg/dL)	2.50 (1.11–5.63)	
FPG ≥ 92 mg/dL (5.1 mmol/L) OGTT	5.63 (2.66–11.88)	4.27(1.88–9.72)
1 h PG ≥ 180 mg/dL (10 mmol/L) OGTT	1.14 (0.57–2.26)	
2 h PG ≥ 153 mg/dL (8.5 mmol/L) OGTT	0.55 (0.28–1.09)	
All abnormal PG OGTT	4.00 (1.22–13.13)	
AUC of the model = 0.813 AUC of alternative model = 0.797		

All significant variables from the univariable analyses were used for the stepwise selection with logistic regression to build a multivariable model. Two multivariable models were created, one of which includes only factors available already in the early pregnancy and the second slightly more accurate based on factors known after OGTT performance (usually 24–28 weeks of gestation). The first model included family history of diabetes, pre-pregnancy BMI (> 25 kg/m^2), performance of OGTT before 24 Hbd, FPG at pregnancy diagnosis (AUC 0.813) as independent risk factors. The second alternative model included FPG ≥ 92 mg/dL (5.1 mmol/L) during 75 g OGTT instead of FPG at pregnancy diagnosis and was characterized by slightly higher AUC (0.797)
AUC — area under the curve; BMI — body mass index; CI — confidence interval; FPG — fasting plasma glucose; GDM — gestational diabetes mellitus; HbA1c — glycated hemoglobin; HBD — week of pregnancy; OGTT — oral glucose tolerance test; PG — plasma glucose; rapid weight gain — gain of weight above 2 kg in the first trimester or/and above 0.5 kg per week in the second trimester

Wong et al. [2] reports that for each increase in fasting glucose by 9 mg/dL (0.5 mmol/L), the risk of insulin therapy increases almost threefold. Eleftheriades et al. [16] also found baseline blood glucose greater than 98 mg/dL (5.4 mmol/L) in OGTT next to overweight as increased risk for insulin treatment.

Notably, the authors identified two pre-gestational independent risk factors for insulin use — increased BMI > 25 kg/m^2 and a family history of diabetes. Several other researchers reported overweight women were at increased risk of insulin treatment [16–18]. In this study, factors that increase the risk of the need for insulin therapy have been comprehensively investigated. Knowing them can help stratify pregnant women into a group at risk of insufficient glycemic control with diet and exercise alone. The authors' observations are consistent with reports by other researchers that risk factors such as diagnosis of GDM in early pregnancy, obesity, family history of diabetes, excessive fetal growth, fasting blood glucose levels and glycated hemoglobin levels all increase the risk of insulin use [2, 15].

Interestingly, the authors also found that the abnormal glycemic result at all three points of the 75 g OGTT also increased (almost 4 times) the risk of using insulin therapy. These observations are partially confirmed by the results of Much et al. [21] who state that the combination of abnormal fasting blood glucose > 95 mg/dL (5.3 mmol/L) and 1h blood glucose > 200 mg/dL (11.1 mmol/L) in OGTT allows for the prediction of the implementation need of insulin therapy. Other researchers also indicate that HbA1c levels are an independent predictor of insulin use [14, 17, 20]. González-Quintero et al. [17] argue that HbA1c ≥ 6% at diagnosis is an independent predictor of insulin use. Bakiner et al. [12] suggested a cut-off of ≥ 5.485% for HbA1c to determine whether a pregnant woman requires insulin. The observations made

Table 4. Factors Predicting the Early Postpartum Prediabetes (6–12 Week after Delivery) in Woman with GDM — Univariable and Multivariable Analysis

Risk factors	Univariable analysis OR (95% CI)	Multivariable analysis OR (95% CI)
Age > 35 years	0.92 (0.24–3.66)	
Nullipara	1.38 (0.44–4.33)	
Family history of diabetes	5.17 (1.50–17.85)	6.42 (1.16–35.59)
Rapid weight gain	3.17 (0.98–10.23)	7.25 (1.27–41.40)
BMI > 25 kg/m^2 before pregnancy	1.01 (0.32–3.18)	
BMI before pregnancy	0.98 (0.88–1.11)	
Max. BMI during pregnancy	0.98 (0.86–1.11)	
OGTT before 24 HBD	1.56 (0.45–5.47)	
FPG at pregnancy diagnosis	1.06 (1.001–1.13)	
Hyperglycemia at pregnancy diagnosis (FPG ≥ 92 mg/dL)	3.02 (0.94–9.73)	14.78 (2.13–102.7)
FPG in OGTT	1.03 (0.99–1.06)	
1 h PG in OGTT	1.04 (1.01–1.08)	1.05 (1.001–1.10)
2 h PG in OGTT	1.05 (1.01–1.09)	1.06 (1.02–1.10)
HbA1c	24.01 (3.26–176.7)	32.79 (2.66–404.5)
FPG ≥ 92 mg/dL (5.1 mmol/l) OGTT	2.38 (0.73–7.72	
1 h PG ≥ 180 mg/dL (10 mmol/l)	4.67 (0.99–21.95)	
2 h PG ≥ 153 mg/dL (8.5 mmol/l)	2.74 (0.72–10.44)	
All abnormal PG OGTT	6.31 (1.76–22.63)	
Triglicerydes	0.995 (0.99–1.003)	
HDL	0.97 (0.93–1.01)	
LDL	0.99 (0.97–1.004)	
Cholesterol total	0.99 (0.98–1.002)	
AUC 0.93		

All significant variables from the univariable analyses were used for the stepwise selection with logistic regression to build a multivariable model. Multivariable model for prediabetes prediction included independent risk factors such as family history of diabetes, rapid weight gain, 1 h PG in OGTT, 2 h PG in OGTT and HbA1c concentration. The model was characterized by an excellent accuracy (AUC 0.930)
AUC — area under the curve; BMI — body mass index; CI — confidence interval; FPG — fasting plasma glucose; GDM — gestational diabetes mellitus; HbA1c — glycated hemoglobin; HBD — week of pregnancy; HDL — high-density lipoprotein; LDL — low-density lipoprotein; OGTT — oral glucose tolerance test; PG — plasma glucose; rapid weight gain — gain of weight above 2 kg in the first trimester or/and above 0.5 kg per week in the second trimester

in this paper are therefore consistent with the reports of other authors.

This observational study also identified women with GDM at risk of postpartum prediabetes. An important argument in favor of earlier prediabetes risk assessment is the reduced reporting of patients for OGTT after pregnancy. Reported compliance with recommended postpartum testing approximates 33% in one of systematic reviews [22]. In the observation of Werner et al. [23] only 42% of patients underwent a 75 g OGTT after pregnancy and socioeconomic factors seem to affect compliance. Therefore, the clinical relevance of the prediabetic prediction model is high.

The authors' analysis shows that the risk of prediabetes post pregnancy was higher in patients whose first-degree relatives had diabetes, in women with rapid gain of excess body weight, in women with abnormal blood glucose levels and with fasting hyperglycemia in the first trimester. In addition, the risk was more than 7 times higher when PG levels were abnormal at all three OGTT points. The need to use insulin therapy during pregnancy increased the risk of abnormal carbohydrate metabolism 3.6 times after pregnancy. Other researchers made similar observations [24]. Albareda et al. [24] indicate that independent risk factors for the development of type 2 diabetes include abnormal results in all values in OGTT, diagnosis of GDM before 24 weeks of pregnancy and pre-pregnancy BMI ≥ 26.4 kg/m^2.

This study shows that the risk of post-pregnancy prediabetes increases with an increase in glycemia in 1 h OGTT and 2 h OGTT. Moreover, high HbA1c is a strong risk factor for prediabetes. Benhalima et al. [25] similarly report an almost 5-fold increase in the risk of prediabetes when HbA1c increases by 1 unit. Kojima

et al. [26] also emphasize the relationship between the level of FPG and the risk of glucose intolerance after pregnancy, but in his analysis, insulinogenic index appeared to be the independent predictive factor. On the other hand, Akinci et al. [27] indicate that the strongest predictors of post-pregnancy diabetes are insulin requirements during pregnancy and glucose levels in antepartum 75 g OGTT. The dependencies observed by other researchers are consistent with the results of the authors' analysis.

In the multivariate model, the predictors of post-pregnancy prediabetes include family history of diabetes mellitus, fasting hyperglycemia upon diagnosis of pregnancy, rapid abnormal weight gain, glycemia in 1 h OGTT, glycemia in 2 h OGTT and glycated hemoglobin level. In the above model, the ROC curve with AUC = 0.8294 was obtained. Kojima et al. [26] developed a similar model to predict the occurrence of glucose intolerance after pregnancy using data from 123 pregnant women. They obtained the greatest discrimination using age, family history of diabetes, BMI ≥ 25 kg/m^2 and the use of insulin therapy in pregnancy (AUC = 0.725). Independent risk factors for glucose intolerance were the insulinogenic index, fasting immunoreactive insulin and total glycemia in OGTT during pregnancy [26].

Inoue et al. [28] indicate that high 2 h glycemia in 75 g OGTT, elevated HbA1c levels and complications in the perinatal period are good predictors of post-pregnancy glucose intolerance. The advantage of the authors' model compared to the Inoue model is the use of predictors that can be assessed shortly after GDM diagnosis.

In conclusion, several easily available risk factors (family history of diabetes, FPG > 92 mg/dL (5.1 mmol/L), timing of 75 g OGTT, BMI) might be used to identify patients who do not achieve satisfactory glycemic control with nutritional therapy and have a priori high risk of insulin therapy. It allows the stratification of pregnant women into risk groups and their faster referral to a diabetes clinic. Accurate prediction of postpartum prediabetes is possible using the following factors: a history of diabetes in a first-degree relative, the level of HbA1c, abnormal fasting blood glucose in first glycemia evaluation in the early pregnancy, rapid excessive weight gain before pregnancy or at the beginning of pregnancy and 1 h and 2 h glycemia during 75 g OGTT. The factors included in this model can be easily assessed in any pregnant woman with GDM. Stratification of patients to the group at high risk of developing prediabetes and possibly type 2 diabetes in longer follow-up may have an impact on making further therapeutic decisions.

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Conflict of interests

None declared.

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