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ORIGINAL ARTICLE

Modifiable risk factors for gestational diabetes recurrence

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Abstract The literature on risk factors for gestational diabetes mellitus recurrence is inconsistent and sometimes contradictory. The importance of inter-pregnancy interval and parity, remains unclear. We aimed to explore controversial risk factors for gestational diabetes mellitus recurrence, especially the modifiable ones, and to develop a prediction model in a cohort of women with gestational diabetes mellitus. A retrospective, population-based, cross-sectional cohort study was performed. The study included 788 women with gestational diabetes mellitus that delivered between 1991–2012 and had consecutive deliveries at a university affiliated hospital in Israel. Women with pre-existing diabetes were excluded. Factors associated with gestational diabetes mellitus recurrence were examined using log-binomial models to estimate prevalence ratios with 95 % confidence intervals. Multivariate analysis revealed that both inter-pregnancy interval and multiparity were significant risk factors for gestational diabetes mellitus recurrence. Other significant risk factors were maternal age, gestational diabetes mellitus diagnosis week, oral glucose tolerance test values, body mass index gain between pregnancies and insulin use; the latter and multiparity had the strongest effect size (PR $\geq$ 1.2). Among multiparous women, the association between inter-pregnancy interval and gestational diabetes mellitus recurrence was significantly lower ($P = 0.0004$) compared with primiparous women (PR = 1.11 [95 % CI 1.09–1.13] versus PR = 1.17 [95 % CI 1.15–1.20], respectively). The model we developed, predicts that reducing the inter-pregnancy interval and weight gain between pregnancies can reduce substantially the risk of gestational diabetes mellitus recurrence. The results suggest that weight gain and inter-pregnancy interval are modifiable risk factors for gestational diabetes mellitus recurrence. Our model could assist physicians in advising women with gestational diabetes mellitus in reducing the risk of recurrent gestational diabetes mellitus during subsequent pregnancies.

Keywords Gestational diabetes · Recurrence · Risk factors

Introduction

Gestational diabetes mellitus (GDM) is a common complication of pregnancy and is defined as "any degree of glucose intolerance with onset or first recognition during pregnancy" [1,2]. The prevalence of GDM has been found to be between 2 and 15 %, depending on the population and the diagnostic criteria [3,4]. GDM is associated with an increased risk of perinatal morbidity, maternal trauma, preeclampsia, eclampsia, and operative deliveries [2]. There are also long term complication of obesity and type 2 diabetes, for both the mother and the offspring [5].

GDM recurs in about 48 % of all women (95 % CI 41–54 %) [6] and GDM recurrence was found to be a

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significant predictor for type 2 diabetes [7,8]. While risk factors for GDM recurrence have been studied extensively, the literature is sometimes inconsistent [9]. For example, the role of inter-pregnancy interval (IPI) as a risk factor for GDM recurrence remains unclear. Two studies [10, 11] have found that shorter IPI was a significant risk factor for recurrent GDM, whereas two other studies [12,13] found that a longer IPI was a significant risk factor. The two studies that found longer IPI to be a significant risk factor for recurrent GDM [12,13], included only primiparous women, which may indicate an effect modification between multiparity and IPI. A recent meta-analysis found multiparity to be a significant predictor for GDM recurrence, but the analysis included only 128 multiparous women [6]. The interaction between parity and IPI in recurrence of GDM has not been reported [9].

A better understanding of the recurrence of GDM could help to distinguish genetic from environmental causes [14] and help to develop measures to prevent the impact on both maternal and child health. In this study we aimed to explore established and controversial risk factors for GDM recurrence. Since the studies that found longer IPI to be a risk factor for GDM recurrence included only primiparous women, we decided to explore the interaction between parity (primiparous versus multiparous) and IPI. Moreover, we aimed to develop a predictive model for GDM recurrence that may help physicians guide women with previous GDM.

Materials and methods

The study population consisted of women with first GDM diagnosis who delivered at Emek Medical Center in northern Israel, between 1991 and 2012, and had at least one consecutive birth at the same medical center. Those with preexisting diabetes mellitus in either pregnancy were excluded. Emek Medical Center serves a population of approximately 500,000 people from the cities, towns, and villages in the northeast of Israel, where the population is equally divided (50/50) between Jews and Arabs. For the last 20 years, the management of patients with GDM has been in the gestational diabetes clinic where women with GDM are closely monitored by specialist physicians in order to achieve appropriate glycemic control. As part of the National Health Insurance Law [15], Israeli residents are entitled to equality of health services (quality and quantity). The health maintenance organizations and hospitals are required to give equal medical care for all of the patients, regardless of socio-economic status (SES).

The approach at the Emek Medical Center for detecting GDM is to screen all pregnant women by performing a glucose challenge test (GCT). The women's plasma glucose is tested after a 50 g oral glucose load at 24 to 28 weeks of gestation. Women are referred for an oral glucose-tolerance test (OGTT) if the plasma glucose concentration 1 h later is ≥140 mg/dl. GDM is diagnosed when two or more abnormal values are presented on a 3-h 100-g OGTT using the Carpenter and Coustan criteria {0 h 95, 1 h 180, 2 h 155, 3 h 140 mg/dl} [16] or one abnormal value using the 1979 National Diabetes Data Group (NDDG) [17] {0 h 105, 1 h 190, 2 h 165, 3 h 145 mg/dl}. Since the difference between the two criteria is only in the OGTT interpretation we used them simultaneously and GDM diagnosis was established if at least one of them was fulfilled [18, 19]. GDM is also diagnosed with a GCT value of 200 mg/dl or higher. The criteria that were used to guide insulin therapy treatment were pre-prandial glucose ≥95 mg % or post-prandial glucose ≥120 mg %. These criteria were constant throughout the study period. Short acting regular insulin was given 30 min before meals and neutral protamine hagedorn (NPH) insulin was used before bed time. The study was approved by the Helsinki ethics committee of Emek Medical Center.

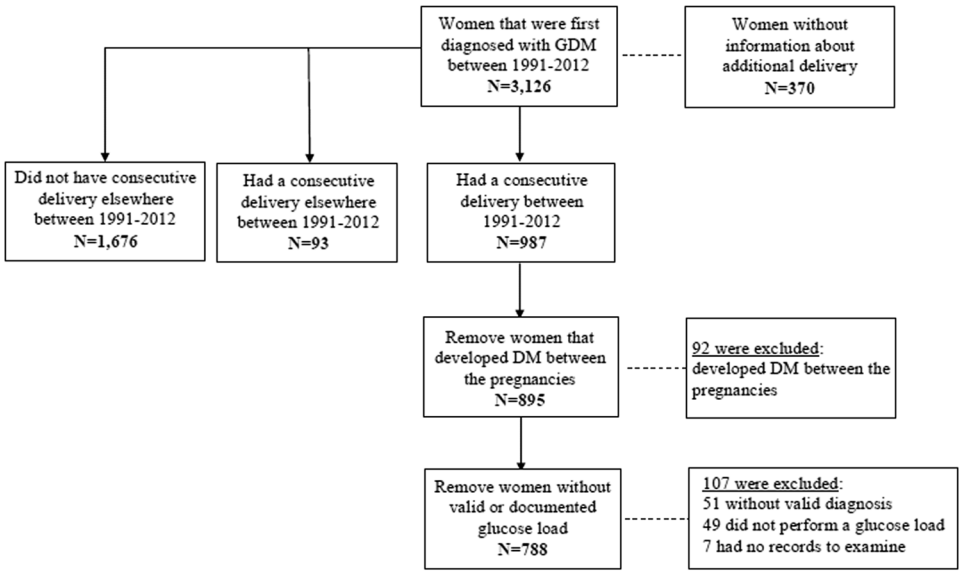
Data extraction

The list of women's ID's with at least one GDM diagnosis was extracted from the hospital records using the International Classification of Diseases, Ninth Revision, Clinical Modification (ICD9-CM) code 648.8 ("abnormal glucose tolerance of mother complicating pregnancy childbirth or the puerperium"). In order to exclude all the women with a diagnosis of preexisting diabetes we used the 250 and 648.0 codes ("Diabetes mellitus" and "Diabetes mellitus complicating pregnancy childbirth or the pueperium", respectively).

The women's medical files were then reviewed in order to verify GDM diagnosis. Women without documented and valid diagnostic tests (i.e., no GCT or OGTT values) in both pregnancies were excluded. Moreover, women without preexisting diabetes, who performed the OGTT during their first trimester and had extreme pathological results (i.e., fasting glucose >125 mg/dl and both 1 and 2 h post-100 g OGTT results exceeded 200 mg/dl), were also excluded.

All the information was obtained from the women's medical records, laboratory systems, gestational diabetes clinic files, and delivery records. HbA1c and Fructosamine measurements were extracted from the laboratory systems and GDM clinic records. For each woman the mean HbA1c and the mean Fructosamine were calculated (the measurements started approximately 1 week after the GDM diagnosis, and every 4 weeks until the delivery). SES was estimated according to the patient's (and her husband/partner's) occupation and place of work and by the social worker report. IPI was defined as the number of months

Fig. 1 Sample flowchart



between the date of delivery of the index pregnancy and the date of delivery of the subsequent pregnancy.

Statistical analyses

In order to estimate sample size, we assumed that the prevalence for GDM recurrence among women with short IPI (e.g., IPI $\leq$ 24 months) will be at least 1.25 times higher compared to women with longer IPI (>24 months). For a power of 80 % and two-sided alpha of 5 %, the minimal required sample size was 540 women (270 per group).

The statistical analyses included the following three main steps: First, we examined the distribution of maternal demographic/clinical and gestational characteristics by recurrent GDM (yes/no). Categorical variables (such as family history of diabetes, insulin use) were analyzed using Chi square test or Fisher's exact test (where 20 % or more of the cells in a χ^2 table will have an expected count less than 5). For continuous data, difference between the two groups (recurrent GDM vs. non-recurrent GDM) was assessed using *t*-test or Mann–Whitney U test when the data was not normally distributed.

Second, interactions and confounders were explored by stratifying the data and by using the log-binomial regression. When the model did not converge (a well-known problem of the log-binomial model), the COPY method was implemented [20]. Finally, univariate and stepwise multiple log-binomial regressions were implemented to assess which variables influence the probability of GDM recurrence and to present each variable's prevalence ratio with 95 % confidence intervals (CI). Multivariate logistic regression was then used in order to present the predictive probabilities for GDM recurrence and the model equation. The statistical analyses and the sample size computation were performed using SAS 9.2 software. Significance was set at $p < 0.05$.

Results

The sample flow-chart is presented in Fig. 1, showing a total of 3126 women who had a first GDM diagnosis between 1991 and 2012. Of them, 1676 (54 %) had no consecutive delivery in the study period. Ninety-three (3 %) women had a documented consecutive delivery at a different medical center. For 370 women (12 %), no information could be obtained to determine whether they had a consecutive delivery or not. Thus the analyses included 788 women.

The overall GDM recurrence rate was 55 %. Fifty one (6 %) women had normal OGTT results before the 24th gestational week (excluding pre-gestational diabetes). For these women the OGTT results after the 24th gestational week were not available and thus, we considered their GDM recurrence status as unknown. If we had considered these 51 women, the prevalence of GDM recurrence would become 52 %.

The women's characteristics and potential risk factors are presented in Tables 1 and 2 (Tables 1 and 2 here). During the index pregnancy, 8 (1.02 %) women had antepartum fetal death (6 of them had GDM recurrence; $P = 0.30$), 2 women (0.25 %) had shoulder dystocia (both of them had GDM recurrence; $P = 0.50$, and 394 women (50 %) did not receive any analgesia (227 had GDM recurrence; $P = 0.12$).

Smoking (passive or active), fertility treatments, neonatal gender, and multiple pregnancies were not associated with GDM recurrence (data not shown). Univariate analyses of the potential risk factors for GDM recurrence are presented

Table 1 Baseline characteristics of the women according to GDM recurrence

	No GDM recurrence $N = 356$	GDM recurrence $N = 432$	*P*-value	Prevalence ratio [95 % CI][a]
Age (years)	28.8 ± 4.8 [28.3]	30.4 ± 4.7 [30.5]	<.0001	1.15 [1.08–1.21][b]
Age				
<35 years	314 (47 %)	358 (53 %)		1
≥35 years	42 (36 %)	74 (64 %)	0.04	1.20 [1.03–1.40]
Pre-pregnancy BMI (kg/m²)[c]	25.8 ± 4.9 [25.1]	27.4 ± 4.9 [27.0]	<.0001	1.13 [1.07–1.19][b]
Parity				
Primiparous	205 (54 %)	177 (46 %)		1
Multiparous	151 (37 %)	255 (63 %)	<.0001	1.36 [1.19–1.55]
Parity	1.9 ± 1.5 [1]	2.5 ± 1.8 [2]	<.0001	1.05 [1.04–1.07]
Ethnicity				
Jews	196 (47 %)	220 (53 %)		1
Arabs	160 (43 %)	212 (57 %)	0.25	1.08 [0.95–1.22]
Past miscarriages				
No	252 (47 %)	281 (53 %)		1
Yes	104 (41 %)	151 (59 %)	0.09	1.12 [0.99–1.28]
Immigrant				
No	309 (46 %)	361 (54 %)		1
Yes	47 (40 %)	71 (60 %)	0.21	1.12 [0.95–1.31]
Employment[c]				
High income	81 (50 %)	80 (46 %)		1
Low income	110 (45 %)	134 (55 %)	0.31	1.11 [0.91–1.34]
Unemployed	156 (43 %)	209 (57 %)	0.12	1.15 [0.96–1.38]
Socio-economic status (SES)[c,d]				
High	83 (44 %)	106 (56 %)		1
Middle	97 (48 %)	107 (53 %)	0.47	0.94 [0.78–1.12]
Low	85 (43 %)	112 (57 %)	0.88	1.01 [0.85–1.54]
Family history of diabetes mellitus				
No	171 (52 %)	159 (48 %)		1
Yes	185 (40 %)	273 (60 %)	0.002	1.24 [1.08–1.42]

[a]CI = confidence interval

[b]for 5-unit increase

[c]Pre-pregnancy BMI: 7.9 % missing; Employment: 2.3 % missing; SES: 25 % missing

[d]Sensitivity analysis was performed for the extreme scenarios, where all the SES missing data belonged to women with low, moderate or high SES. Sensitivity analysis revealed no significant association between SES and GDM recurrence in all three scenarios ($P = 0.72$, $P = 0.65$ and $P = 0.67$ respectively)

Continuous variables are presented with mean ± standard deviation [median]

in Tables 1 and 2. Significant risk factors included: maternal age, pre-pregnancy BMI, parity, family history of diabetes, GDM diagnosis week, OGTT results (except the 3-h result), insulin use, hemoglobin A1c, IPI and BMI gain between the pregnancies.

IPI, parity and GDM recurrence

The study included 295 women with short IPI (i.e. IPI ≤ 24 months) and 493 women with longer IPI (i.e. IPI > 24 months) which increased the statistical power of the study hypothesis to 90 %. There was a significant association between IPI and GDM recurrence ($P = 0.01$). Thus, for women with IPI > 24 months, the risk for GDM recurrence is 1.18 [95 % CI 1.03–1.36] times higher compared with women that had IPI < 24 months. We also examined the IPI as a continuous variable, which was also significantly associated with GDM recurrence ($P < .0001$). For every 24 months increase in the IPI, the risk for GDM recurrence is 1.14 times higher [95 % CI 1.12–1.15] (Table 2).

Table 2 The GDM pregnancy characteristics, delivery outcomes and inter-pregnancy factors according to GDM recurrence

	No GDM recurrence $N = 356$	GDM recurrence $N = 432$	*P*-value	Prevalence Ratio [95 % CI][a]
GDM diagnosis week[b]	29.3 ± 4.6 [28.6]	28.3 ± 5.1 [27.9]	0.002	0.96 [0.95–0.97][c]
OGTT[a]: Fasting[b]	89 ± 14 [88]	93 ± 15 [91]	0.002	1.12 [1.07–1.18][d]
OGTT[a]: 1-h post glucose load[b]	194 ± 25 [195]	204 ± 25 [201]	<.0001	1.14 [1.10–1.19][d]
OGTT[a]: 2-h post glucose load[b]	157 ± 30 [159]	163 ± 33 [164]	0.002	1.07 [1.03–1.12][d]
OGTT[a]: 3-h post glucose load[b]	103 ± 38 [100]	104 ± 37 [99]	0.74	1.01 [0.97–1.04][d]
Insulin use				
No	269 (52 %)	250 (48 %)		1
Yes	87 (32 %)	182 (68 %)	<.0001	1.40 [1.24–1.59]
Hemoglobin A1c[b,e]	5.3 ± 0.6 [5.3]	5.4 ± 0.6 [5.4]	0.02	1.12 [1.04–1.20]
Fructosamine[b,e]	180 ± 18 [180]	183 ± 18 [182]	0.12	1.06 [0.99–1.13][d]
Mode of delivery				
Cesarean section	108 (49 %)	114 (51 %)		1
Vaginal	248 (44 %)	316 (56 %)	0.24	1.09 [0.94–1.26]
Neonatal birth weight[f]	3303 ± 485 [3325]	3313 ± 538 [3346]	0.24	1.01 [0.95–1.08][g]
Macrosomia[f]				
No	313 (44 %)	393 (56 %)		1
Yes	26 (46 %)	31 (54 %)	0.85	0.98 [0.76–1.25]
IPI[a] (months)	30.0 ± 15.6 [26.1]	36.5 ± 21.9 [31.9]	<.0001	1.14 [1.12–1.15][h]
Longer IPI (>24 months)				
No	150 (51 %)	145 (49 %)		1
Yes	206 (42 %)	287 (58 %)	0.01	1.18 [1.03–1.36]
BMI gain (kg/m²)[b]	0.7 ± 2.5 [0.4]	1.3 ± 2.3 [1.3]	0.002	1.04 [1.02–1.06]

[a]CI = confidence interval; IPI = inter-pregnancy interval; OGTT = oral glucose tolerance test

[b]Missing: BMI gain: 11.3 %; Fasting OGTT: 10.4 %; OGTT: 1-h post glucose load: 8.4 %; OGTT: 2-h post glucose load: 8.8 %; OGTT: 3-h post glucose load: 11.2 %; GDM diagnosis week: 2 %; Hemoglobin A1c: 35 %; Fructosamine: 37 %

[c]For every 2-week increase

[d]For every 20-unit increase

[e]For each woman the mean HbA1c and the mean Fructosamine were calculated (the measurements started approximately one week after the GDM diagnosis, and every 4 weeks until the delivery)

[f]Only singleton deliveries

[g]For every 500 gr increase

[h]For every 24-month increase

Continuous variables are presented with mean ± standard deviation [median]

We examined the association between IPI and GDM recurrence among primiparous and multiparous women separately. For primiparous women, the association between IPI (for two-year increase) and GDM recurrence was significant ($P < .0001$) and the prevalence ratio was 1.17 [95 % CI 1.15–1.20], whereas among multiparous women, the association was significant ($P < .0001$), but the effect size was lower with a prevalence ratio of 1.11 [95 % CI 1.09–1.13]. We wanted to examine whether the difference between the prevalence ratios was significant. Therefore, a multivariate analysis which included the variables IPI, multiparity (Yes/No) and the interaction term between IPI and multiparity was performed. The interaction term was significant ($P = 0.0004$), reflecting that for primiparous women, the IPI effect is significantly stronger compared with multiparous women.

SES and GDM recurrence

SES had no significant effect on the risk for GDM recurrence (Table 1), and no confounding effects between SES

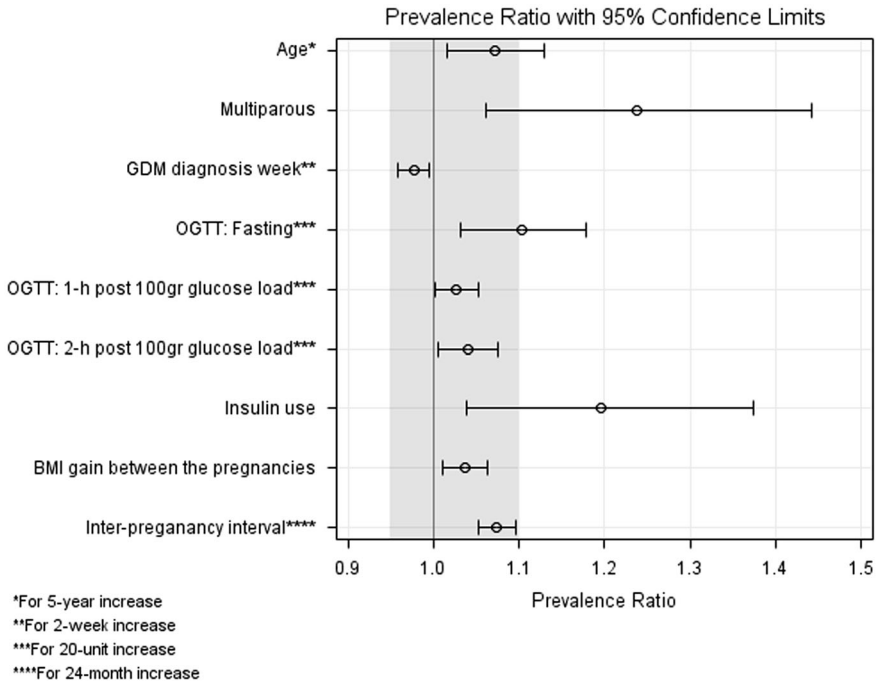


Fig. 2 Adjusted prevalence ratio with 95 % confidence intervals of the final log-binomial model for GDM recurrence

and the rest of the potential risk factors were found. However, according to the medical records, the information regarding this parameter was missing for approximately 25% of the women and therefore potentially created a bias in the results. In order to overcome this problem we examined whether the missing data were associated with GDM recurrence and found that the percentage of women with missing data is similar in women with GDM recurrence compared with women without GDM recurrence (24.8% versus 25.6% respectively $P = 0.80$). Additionally, we performed a sensitivity analysis that examined the hypothesis that all the missing data belonged to a single group. The results demonstrate that even in such an extreme scenario SES is not associated with GDM recurrence.

Risk factors for GDM recurrence

Multiple log-binomial regression analysis was performed for the study population. The model was estimated in order to obtain the independent risk factors for GDM recurrence. Figure 2 presents the adjusted prevalence ratio with 95 % CI of the final models. The model was estimated in order to obtain the independent risk factors for GDM recurrence.

Multiparity and insulin therapy at the index pregnancy were the risk factors with the largest effect size (prevalence ratio ≥ 1.2), while the fasting OGTT result and maternal age had moderate effect sizes (prevalence ratios 1.10 and 1.07, respectively). The rest of the significant risk factors had rather small effect sizes (Fig. 2).

In order to evaluate the predictive probability, the multivariate logistic regression was also implemented using the same variables in the log-binomial multivariate regression. The model equation was: $Logit\ (P[GDM\ recurrence]) = -6.426 + (0.055 \times maternal\ \ age) + (0.556 \times multiparous) + (-0.048 \times GDM\ diagnosis\ week) + (0.020 \times fasting\ OGTT) + (0.011 \times OGTT\ \ after\ \ 1\ \ hour) + (0.007 \times OGTT\ \ after\ \ 2\ \ hours) + (0.676 \times insulin\ \ use) + (0.021 \times IPI) + (0.129 \times BMI\ gain)$.

In order to demonstrate the role of IPI and BMI gain between the pregnancies, we calculated two scenarios: 1) IPI = 48 months and BMI gain = 1.5 kg/m^2 and 2) IPI = 24 months and BMI gain = −0.5 kg/m^2. We explored these scenarios for a fixed information (maternal age = 28;GDM diagnosis week = 25 weeks; Fasting OGTT = 95 mg/dl; 1-h post 100 g glucose load = 190 mg/dl; 2-h post 100 g glucose load = 150 mg/dl) and with different combinations of the main risk factors (insulin use: yes/no and multiparity: yes/no). The results are presented in Fig. 3. Thus, by losing weight between the pregnancies (a reduction of 0.5 BMI units) instead of gaining weight (increase of 1.5 BMI units), and waiting one year between the pregnancies (instead of two years), the woman will have a decrease of 15–19 % in the probability of GDM recurrence.

Discussion

Risk factors for GDM recurrence can be divided into two groups when family planning is considered: factors that are uncontrolled (such as age, parity, family history of diabetes, insulin use) and factors that may be controlled (such as IPI

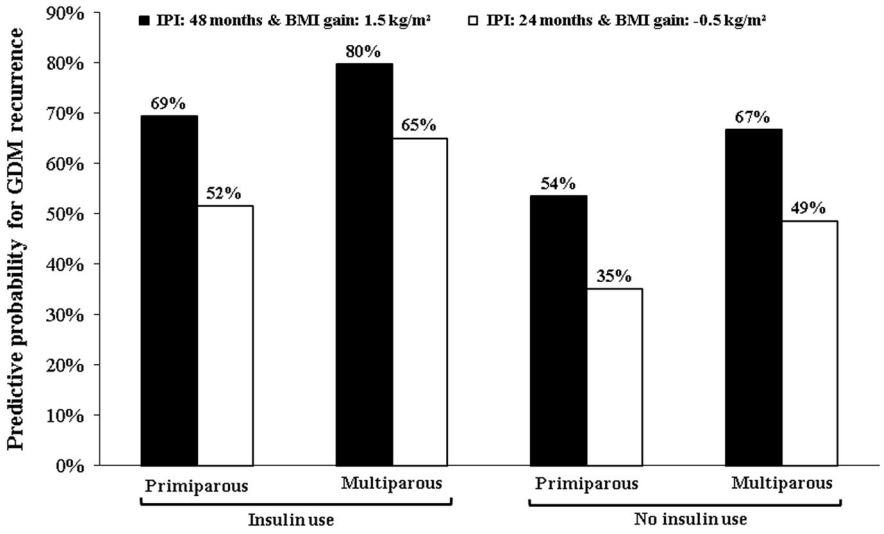


Fig. 3 Predictive probabilities from the multivariate logistic regression model, where maternal age = 28 years; GDM diagnosis week = 25 weeks; Fasting OGTT = 95; 1-h post 100 g glucose load = 190; 2-h post 100 g glucose load = 150. Model equation: Logit (P(GDM recurrence)) = −6.426 + (0.055 × maternal age) + (0.556 × multiparity) + (−0.048 × GDM diagnosis week) + (0.020 × fasing OGTT) + (0.011 × OGTT after 1 h) + (0.007 × OGTT after 2 hs) + (0.676 × insulin use) + (0.021 × IPI) + (0.129 × BMI gain). Hosmer and Lemeshow Goodness-of-Fit Test $P = 0.8568$

and weight gain between the pregnancies). This study supports the significance of IPI as a risk factor for GDM recurrence. In both primiparous and multiparous women, shorter IPI was preferable. A possible explanation could be that among women who suffered from GDM, the β-cell reserves are already diminished and therefore longer IPI suggests a longer time in which the reserve is decreased even further. Moreover, in this study we emphasize the importance of shorter IPI among primiparous compared with multiparous women. A possible explanation might be that multiparous women have cumulative damage in every additional pregnancy when their β-cell reserves are diminished [21], and therefore are at increased risk for GDM recurrence. However, primiparous women did not suffer from previous diminishing of their β-cell reserve, and in their case, the IPI can play a more significant role.

In a recent meta-analysis [9] it was found that insulin use, BMI, multiparity, macrosomia and weight gain between pregnancies are strong risk factors for GDM recurrence (as was found in the current study). Due to the contradiction in the literature regarding the importance of IPI, the meta-analysis showed no significant effect. In two small studies ($N = 30$–78 women), short IPI was shown to increase the risk for GDM recurrence [10, 11]. However, multivariate analysis was not done in the study of Nohira et al. [11] and in the study of Major et al. [10] the follow-up was up to 5 years and approximately 47 % of the sample had an IPI of less than 24 months. On the contrary, in two larger cohorts with longer follow-up duration long IPI was shown to increase the risk for GDM recurrence [12, 13] similarly to the current study. In addition, the current study demonstrated that by applying the physician recommendations regarding the reduction in IPI and the weight between the pregnancies, a meaningful reduction in the probability of GDM recurrence could be achieved.

In this study the overall GDM recurrence rate was 55 %, which is slightly higher than the reported average (48 %) [6]. This finding is reasonable since the studies that presented the prevalence of GDM recurrence did not exclude women with invalid OGTT testing, thus resulting in an underestimation of the GDM recurrence rate.

No association between ethnicity and GDM recurrence was found in this study. Three studies previously examined the association between different ethnic groups and GDM recurrence. Philipson et al. [22] did not find ethnicity to be statistically significant; this study is limited due to small sample size (30 women). Getahun et al. [23] revealed that Caucasians have a much lower recurrence risk of GDM than Hispanics and Asian/Pacific Islanders. Ehrlich et al. [24] also found ethnicity to be significantly associated with GDM recurrence where the odds for GDM recurrence among mixed ethnicities (Hispanic, African American, Asian and other) were twice that of Caucasian women. The common denominator of these studies is that they all were performed in the USA (both of the largest studies in California) where ethnicity has a strong association with SES [25] and no National Health Insurance Law exists. In addition, past systematic reviews [6, 26, 27] have pointed out that there are large differences in the prevalence of GDM recurrence among non-Hispanic white women compared to other ethnicities (Hispanic, African-American, etc.). Thus, one can argue that the dependence between ethnicity and GDM recurrence could partially represent the dependence between SES and GDM recurrence. However, we must acknowledge that the genetic differences between Arab and Jewish Israeli women are much smaller compared to the differences between Hispanic, African-American and Caucasian Americans. In addition, Lindquist et al. [28] found that the risk of severe maternal morbidity among women in Australia is significantly increased by social

disadvantage. This study demonstrated that when we neutralize the ability of women to receive good health insurance, SES does not influence the risk for GDM recurrence.

This study had several limitations. A potential source of selection bias could have been due to a small portion of the eligible women were excluded from the database due to the fact that they delivered their consecutive birth at a different medical center. The main reason for changing the delivery facility in our region is because the woman changed her address between births. Women who were excluded, since they had consecutive delivery at a different medical center (93 women), did not differ from the 788 included women in all of the risk factors that were considered in the analyses, but there was a slight overrepresentation of women with family history of diabetes ($P = 0.03$).

Another potential selection bias could have been a result of missing data on the postpartum test result that determines whether or not a woman became diabetic after her GDM pregnancy. The postpartum screening test for diabetes has a low compliance rate, resulting in misdiagnosis of women with preexisting diabetes as women with GDM. This situation may cause an overestimation of the recurrence rate and, as a result, we have excluded women with extreme values in the OGTT. Like most retrospective studies, we experienced information bias due to missed/unclear documentation. It should be noted that GDM diagnosis was established using the Carpenter and Coustan criteria and the 1979 NDDG as was accepted during the study period for GDM diagnosis. The more recent IADPSG and ADA new recommendations [29] require the use of 75 g glucose load while in the current study, the women had 100 g glucose load, making a retroactive analysis with the IADPSG unfeasible. Nevertheless, it was reported that the prevalence of GDM when implementing the IADPSG criteria is 17.8 % (an increment of 10–15 % in GDM diagnosis) [30], resulting in a larger amount of mild GDM women. Therefore, we assume that the estimators for the association between the established risk factors and the probability for GDM recurrence, that were found in this study, may be stronger than those that would have been found among a cohort of women diagnosed with the IADPSG criteria.

Conclusion

This study examines a large and diverse sample of women during a 22-year period, which led to a variety of IPIs. It allowed us to show that a shorter IPI is better when we aim to avoid GDM recurrence, which was a controversial conclusion in the past. In addition, we concluded that older multiparous women, who were diagnosed with GDM early during the pregnancy with high OGTT results and were treated with insulin, are at increased risk for GDM recurrence. Our prediction model can easily demonstrate the yield of the modifiable risk factors for GDM recurrence. During a family planning consult, physicians should emphasize the importance of weight reduction and short IPI in order to avoid GDM recurrence. Physicians may simulate the individual predictive probability for GDM recurrence by using our model equation.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interests.

Ethical approval Emek medical center ethics committee approval number EMC0061-13.

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