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Efficacy of a phone reminder to improve adherence to post-partum glucose tolerance testing after gestational diabetes and clinical predictors of post-partum follow-up compliance

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ABSTRACT

Aim: To assess the effectiveness of a phone reminder to improve adherence to post-partum glucose tolerance testing in women with gestational diabetes mellitus (GDM) and to identify clinical predictors of adherence to post-partum follow-up.

Methods: Retrospective study including 543 women with GDM. We assessed the adherence rate to post-partum glucose tolerance testing in women who received a phone reminder (n = 297) compared to women not alerted (n = 246). Demographic and clinical variables were collected to identify the predictors of adherence to the post-partum oral glucose tolerance test (OGTT).

Results: The adherence to post-partum OGTT was higher in women who received the phone reminder compared to those not alerted (60.6 % vs. 35.4 %, $p < 0.001$). Women less compliant compared to those more compliant, had a higher pre-pregnancy body mass index (BMI) (29.3 ± 7.9 vs. 27.0 ± 6.1 Kg/m^2, $p = 0.03$). The adherence was lower in pre-pregnant obese compared to non-obese women (42.7 % vs. 52.0 %, $p < 0.05$), in women with only one, compared to multiple OGTT alterations during pregnancy (44.5 % vs. 57.8 %, $p < 0.05$), and in women non-insulin treated compared to those insulin-treated (40.0 % vs. 57.1 % vs, $p < 0.001$).

Conclusions: The phone reminder improved post-partum follow-up adherence. Pre-pregnancy BMI, number of OGTT alterations and type of therapy could identify poorly adherent women.

1. Introduction

Gestational diabetes mellitus (GDM) is the first diagnosis of abnormal blood glucose levels occurring during the second or third trimester of pregnancy and represents the most common metabolic complication in pregnancy [1].

In the last decades, the rising prevalence of overweight worldwide, advanced maternal age, and the spread of unhealthy lifestyles have resulted in an increase in pregnancies complicated by GDM. The prevalence varies across countries, depending on the different screening modalities, reaching about 15–20 % in the most recent series [2]. Early detection and treatment of hyperglycaemia are mandatory to reduce the risk for both maternal and foetal–neonatal adverse outcomes (e.g., gestational hypertension, preeclampsia, foetal macrosomia, shoulder dystocia, caesarean delivery, and neonatal hypoglycaemia) [3–7].

Women with GDM also are at increased risk for developing varying impaired glucose tolerance after delivery [8–10]. The risk for type 2 diabetes (T2D) ranges from 2 to 70 % depending on the studied population and the follow-up duration [11–13]. Early identification of diabetes is crucial to avoiding the short and long-term consequences of unrecognized diabetes, maintaining women's health and reducing healthcare costs. Nevertheless, despite the current guidelines indicating a post-partum OGTT in women with previous GDM, the adherence rate to this recommendation remains unsatisfactory, being widely below 50 % [14–17]. Several barriers to post-partum screening have been reported at different levels, including the inadequacy of educational resources to improve women's awareness of the health consequences of missed screening, the lack of responsibility coordination for follow-up

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screening among health care providers, and enhanced reminder systems [18,19]. In the previous two decades, a small number of studies evaluating the efficacy of different reminder systems (e.g. phone, text message, e-mail, and postal reminders), adopted with various modalities and timing, produced encouraging, although not univocal, results [20,21].

Our study aimed to assess the efficacy of a phone recall placed two weeks before the date of the scheduled post-partum visit, in order to enhance adherence to post-partum diabetes screening in women with GDM. We also aimed to identify the potential clinical predictors that during pregnancy could be associated with these women's attitude to carry out the post-partum glucose tolerance evaluation

2. Subjects, material and methods

We retrospectively analysed data of all pregnant women affected by GDM (n = 543) who referred to the medical service dedicated to the management of diabetes in pregnancy of the Diabetes, Obesity and Dietetic Centre of the Garibaldi-Nesima Hospital (Catania, Italy) between January 2013 and December 2020.

The International Association of Diabetes and Pregnancy Study Groups criteria for GDM diagnosis were adopted [22]. According to Italian recommendations, the 75-g oral glucose tolerance test (OGTT) was performed at 16-18th or 24-28th weeks of gestation, depending on the women's risk factors [23]. GDM women were regularly followed, every 2–3 weeks until delivery, to monitoring the therapy effect (lifestyle alone or in addiction, insulin) on glucose level (self-monitoring capillary glucose measurement), maternal weight and foetal growth. At the last visit before delivery, all women were informed about the importance of post-partum follow-up and a visit 3–6 months after delivery was scheduled to assess glucose tolerance.

Since January 2017 until December 2020, we planned to remind women of their scheduled post-partum visit with a phone call. Women (n = 297) received a phone call from the medical staff, 10–14 days before the scheduled visit, to remind them both to perform the OGTT and the control visit. Women whose post-partum visit was scheduled between January 2013 and December 2016 (n = 246) did not receive the telephone reminder (Fig. 1A). The following data were retrospectively collected from the electronic medical records routinely used to storage clinical variables in our centre (Smart Digital Clinic 10.12.20, Meteda s. r.l.): demographic, anthropometric, and biochemical characteristics (first trimester fasting plasma glucose, glucose and insulin at pregnancy OGTT, and glycosylated haemoglobin - HbA1c), weight gain during pregnancy, type of therapy, and the occurrence of gestational hypertension or preeclampsia.

All women included in this study were addressed to perform the assays for HbA1c and plasma glucose and insulin of the OGTT (both during pregnancy and at post-partum glucose tolerance evaluation) in the centralized laboratory analysis of our hospital. Plasma glucose was enzymatically analysed (glucose–hexokinase method), serum insulin was measured using a chemiluminescent micro-particle immunoassay, and IFCC-standardized glycated hemoglobin was determined in total blood by high-performance liquid chromatography (HPLC) of the gradient ionic exchange.

Women who attended the post-partum glucose tolerance testing were classified, according to glucose values at 75-g OGTT, in the following groups: normal glucose tolerance (NGT), fasting glucose <

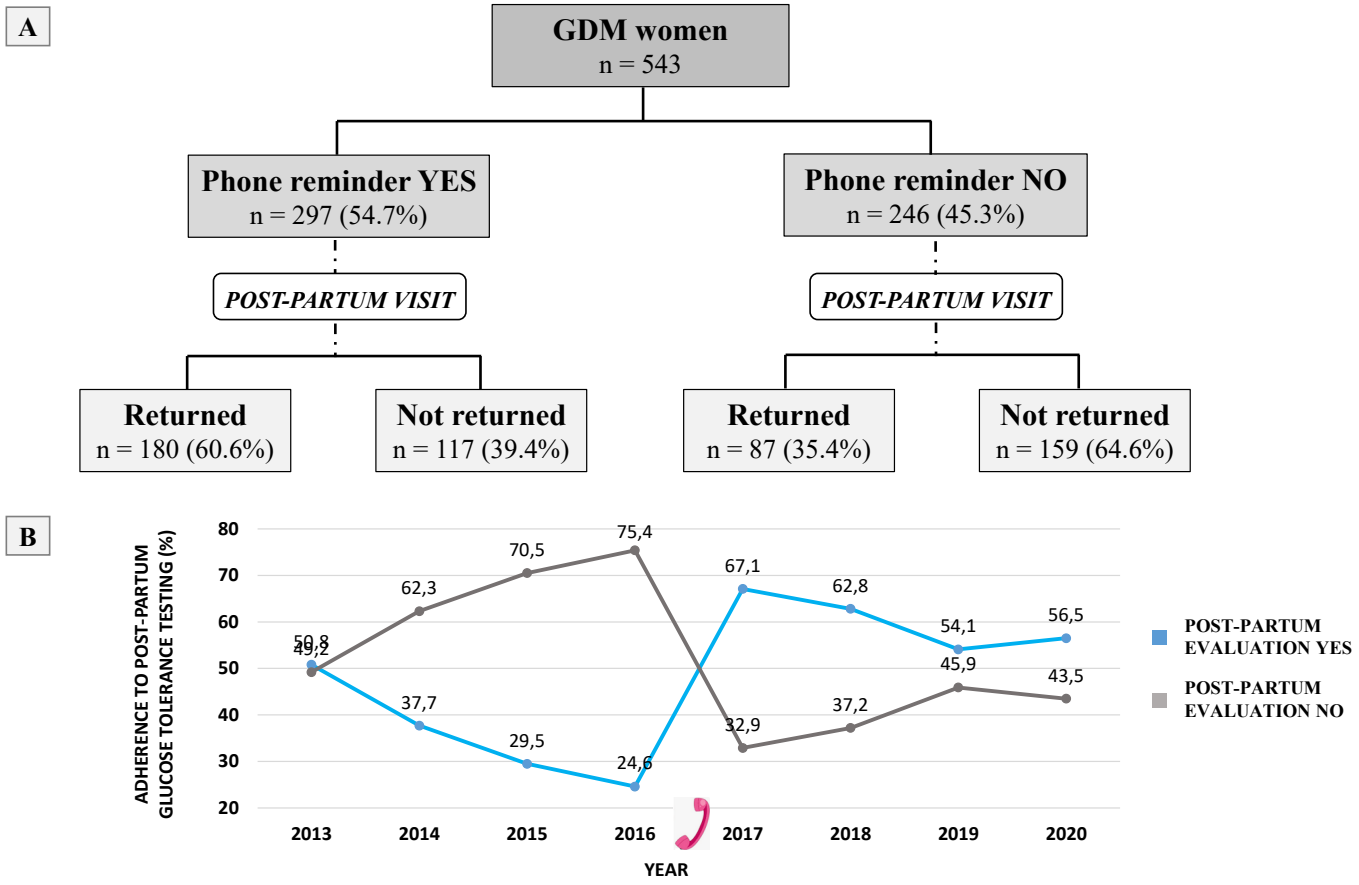

Fig. 1. Distribution of women with gestational diabetes according to whether or not they received the telephone reminder and having or not undertaken the post-partum visit for glucose tolerance assessment (A) and year-by-year graphical representation of the adherence rate to post-partum follow-up (B) (the pink phone symbol indicates the start, from January 2017, of the telephone reminder). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

100 mg/dl and 2 h glucose < 140 mg/dl; impaired fasting glucose (IFG), fasting glucose 100–125 mg/dl and 2 h glucose < 140 mg/dl; impaired glucose tolerance (IGT), fasting glucose < 100 mg/dl and 2 h glucose 140–199 mg/dl; IFG + IGT, fasting glucose 100–125 mg/dl and 2 h glucose 140–199 mg/dl; diabetes mellitus (DM), fasting glucose ≥ 126 mg/dl or 2 h glucose ≥ 200 mg/dl. In the last condition, to confirm the diagnosis, HbA1c was also evaluated [1].

The study was conducted in accordance with the ethical principles of the Declaration of Helsinki and its later amendments. All subjects gave their consent to process the personal and clinical data contained in the electronic medical records used in our diabetes centre. Data were anonymously analysed.

2.1. Sample size and statistical analysis

We estimated the minimum number of women to be recruited in order to obtain a statistical power of 90 % and an estimated α error of 0.01, according to previous studies [24,25], a difference in the rate of adherence to post-partum follow-up of 20 % between the two study groups (reminder yes vs. no). The post-hoc power estimate indicated that the population sample of our study (543 women: 297 in the group that received the reminder and 246 in the group that did not receive the alert), would have a power of 100 % to detect the observed difference of 25.2 % between the two groups with a defined α error of 0.01.

Shapiro-Wilk and Kolmogorov-Smirnov tests were applied to explore continuous variables distribution, and, in case of not perfectly concordant results, we performed additional investigations (graphic analyses of histogram, Q-Q normality graph and asymmetry/standard error or kurtosis/standard error ratio) to support the continuous variables distribution exploration.

Continuous, normally distributed variables were presented as mean ± standard deviation (SD) and compared by using the *t* test for independent samples or univariate analysis of variance, with Bonferroni post-hoc analysis, for comparison among three or more groups. An F-test was preliminarily performed to examine the homogeneity of the variance. Continuous, not normally distributed variables were presented as median and interquartile range (IQR) and were compared by using the Mann-Whitney or Kruskal-Wallis test.

The percentage of dichotomous outcomes is expressed as number and percentage. Yates' χ^2 test was applied to detect differences of percentage between groups and multivariate logistic regression models were used for considering all potential confounders. Hosmer- Lemeshow post estimation test was used to assess the model performance.

A two-sided p value < 0.05 was considered statistically significant. Statistical analyses were performed using IBM SPSS Statistics software version 20 (IBM Corp., Armonk, NY).

3. Results

Our analysis included 543 women affected by GDM. Demographic, anthropometric, and biochemical characteristics of the study population are summarized in Table 1. The mean age at pregnancy OGTT was 33.7 ± 5.3 years, and most of women (59.3 %) were overweight or obese before pregnancy (BMI 28.2 ± 7.0 kg/m^2).

3.1. Adherence to post-partum glucose tolerance testing according to the phone reminder

Less than half of women (49.3 %) adhered to the post-partum visit and to the glucose tolerance assessment. Among the 543 women, 297 (54.7 %) received the reminder for the post-partum glucose tolerance evaluation whereas 246 (45.3 %) did not receive the reminder (Fig. 1A). These subgroups were similar for the most relevant clinical features (Table 2). We observed a significantly higher prevalence, almost doubled, of attendance to the post-partum glucose tolerance evaluation in women who received the reminder compared to those who did not (60.6 % vs. 35.4 %, p < 0.001), indicating the effectiveness of the phone reminder to improve the adherence rate to post-partum glucose tolerance assessment. Fig. 1B illustrates the year-by-year distribution of the adherence rate to post-partum follow-up, indicating an early improvement of the adherence rate since the starting of the phone reminder at the beginning of 2017.

Table 1
Demographic, clinical, and biochemical characteristics of the 543 GDM women.

Ethnicity (%)	
Caucasian	95.1
Asian	3.5
Black	0.4
Age (years)	33.7 ± 5.3
Pre-pregnancy body weight (Kg)	72.0 ± 18.7
Pre-pregnancy BMI (Kg/m^2)	28.2 ± 7.0
Overweight or obese (%)	59.3
Weight at the end of pregnancy (Kg)	83.6 ± 18.0
Weight gain at the end of pregnancy (Kg)	9.1 ± 5.2
HbA1c at diagnosis (%) (mmol/mol)	5.41 ± 0.49 (36 ± 5)
Average HbA1c during pregnancy (%) (mmol/mol)	5.48 ± 0.98 (36 ± 10)
Average fasting plasma glucose at first trimester (mg/dl)	91.6 ± 12.1
Gestational week at diagnostic OGTT (weeks)	25.0 (22.0–25.0)
Gestational period at diagnostic OGTT (%)	
16–18 weeks	19.7
24–28 weeks	80.3
Plasma glucose values at pregnancy OGTT (mg/dl)	
Fasting	92.2 ± 13.4
1-h	182.4 ± 32.8
2-h	144.0 ± 35.9
Plasma insulin values at pregnancy OGTT (μU/ml)	
Fasting	11.5 ± 7.6
1-h	125.2 ± 57.3
2-h	108.6 ± 64.0
Two or more OGTT alteration (%)	37.3
Insulin therapy during pregnancy (%)	56.7
Insulin dose (U/Kg)	0.37 ± 0.23
Basal insulin dose (U/Kg)	0.14 ± 0.16
Pre-gestational hypertension (%)	3.1
Gestational hypertension (%)	6.1
Preeclampsia (%)	1.0
Returned at post-partum follow-up (%)	49.3

Continuous normally distributed variables are presented as mean ± standard deviation, continuous not-normally distributed variables are presented as median and interquartile range (IQR), dichotomous variables are presented as a percentage (%) of the total subjects.
Abbreviations: GDM, gestational diabetes mellitus; BMI, body mass index; HbA1c, glycosylated haemoglobin; OGTT, oral glucose tolerance test.

3.2. Clinical predictors of post-partum glucose tolerance testing compliance

The cohort was subdivided and analysed into four subgroups based on the phone reminder (yes or no) and the post-partum evaluation (yes or no). While age, HbA1c at diagnosis of GDM, and total gestational weight gain (GWG) were similar among the subgroups, pre-pregnancy BMI was higher in women who failed to comply with the post-partum evaluation compared to adherent women (Table 3). In particular, pre-pregnancy BMI was significantly higher in the least compliant women (missing post-partum visit despite the reminder) compared to the most compliant ones (adherent to post-partum evaluation without reminder) (29.3 ± 7.9 vs. 27.0 ± 6.1 Kg/m^2, p = 0.03). In addition, we also found an inverse relation between pre-pregnancy BMI and the adherence rate to post-partum glucose screening. Fig. 2 illustrates the adherence to post-partum glucose tolerance assessment according to BMI classes. We found that the prevalence of women returning to the post-partum visit was significantly lower in obese compared to non-obese women (42.7 % vs. 52.0 %, p < 0.05) (Fig. 2).

Furthermore, multiple alterations at pregnancy OGTT (two or more) and insulin therapy during pregnancy could be predictors of better

Table 2
Demographic, clinical, and biochemical characteristics of the study population subdivided according to receiving the phone reminder for glucose tolerance evaluation in the post-partum.

	CALL REMINDER YES (*n* = 297)	CALL REMINDER NO (*n* = 246)	P
Age (years)	33.8 ± 5.1	33.5 ± 5.6	*0.44*
Pre-pregnancy body weight (Kg)	72.2 ± 18.7	71.6 ± 18.9	*0.71*
Pre-pregnancy BMI (Kg/m^2)	28.3 ± 7.0	28.0 ± 7.0	*0.61*
Overweight or obese (%)	61.4	57.4	*0.34*
Weight at the end of pregnancy (Kg)	83.0 ± 16.8	84.3 ± 19.6	*0.56*
Weight gain at the end of pregnancy (Kg)	9.0 ± 5.2	9.1 ± 5.3	*0.83*
HbA1c at diagnosis (%) (mmol/mol)	5.5 ± 0.5 (37 ± 8)	5.4 ± 0.5 (36 ± 8)	*0.31*
Average HbA1c during pregnancy (%) (mmol/mol)	5.6 ± 1.3 (38 ± 13)	5.4 ± 0.5 (36 ± 8)	*0.41*
Average fasting plasma glucose at first trimester (mg/dl)	89.7 ± 12.8	92.1 ± 15.3	*0.18*
Gestational week at diagnostic OGTT (weeks)	25.0 (21.0–27.0)	25.0 (23.0–28.0)	*0.10*
Plasma glucose values at pregnancy OGTT (mg/dl)			
Fasting	91.9 ± 13.4	92.6 ± 13.5	*0.51*
1-h	181.4 ± 34.6	183.6 ± 30.5	*0.47*
2-h	144.7 ± 36.3	143.1 ± 33.0	*0.65*
Plasma insulin values at pregnancy OGTT (μU/ml)			
Fasting	11.7 ± 7.8	11.3 ± 7.3	*0.75*
1-h	123.4 ± 59.8	130.4 ± 52.2	*0.74*
2-h	106.8 ± 63.4	113.6 ± 68.9	*0.78*
Two or more OGTT alteration (%)	41.5	32.6	*0.04*

Continuous normally distributed variables are presented as mean ± standard deviation, continuous not-normally distributed variables are presented as median and interquartile range (IQR), dichotomous variables are presented as a percentage (%) of the total subjects.
Abbreviations: GDM, gestational diabetes mellitus; BMI, body mass index; HbA1c, glycosylated haemoglobin; OGTT, oral glucose tolerance test.

adherence to post-partum assessment (Fig. 3A). Indeed, the adherence to post-partum visit was significantly higher in women with two or more alterations at the OGTT during pregnancy compared to only one (57.8 % vs. 44.5 %, $p < 0.05$) (Fig. 3A). Analysing the subgroups according to the phone intervention, the prevalence of multiple alterations at pregnancy OGTT was significantly higher ($p = 0.01$) in women who returned (with reminder 44.6 %, without reminder 41.9 %) than in those who did not return to the post-partum visit for glucose tolerance assessment (with reminder 36.6 %, without reminder 27.6 %) (Table 3).

A similar within the groups distribution was observed according to the need for insulin therapy during pregnancy: the prevalence of attendance to post-partum visit was significantly higher in women treated with insulin during pregnancy than in those who achieved optimal glucose control with lifestyle alone (57.1 % vs. 40.0 %, $p < 0.001$) (Fig. 3B). In addition, the insulin use rate was significantly higher ($p = 0.001$) in women who returned (with reminder 68.2 %, without reminder 59.3 %) than in those not returned at post-partum diabetes screening (with reminder 48.6 %, without reminder 48.1 %) (Table 3).

These results allow us to identify subgroups particularly at risk of non-adherence to post-partum follow-up, based on pre-pregnancy obesity, single alterations of the OGTT in pregnancy, and no insulin use. These findings were further confirmed by comparing the group of women with these three unfavourable characteristics (low-adherent group) with the group without these characteristics (high-adherent group). The adherence rate to the post-partum evaluation was significantly higher in the high-adherent group than in the low-adherent group (63.4 % vs. 30.3 %, OR 3.98, $p < 0.001$) (Fig. 3C).

3.3. Multivariate analysis of all predictors of post-partum glucose tolerance testing compliance

To assess the relative efficacy on the post-partum follow-up adherence of both the phone reminder and all the clinical predictors, we created a multivariate logistic regression model including all possible confounders (Table 4): the phone reminder determined a three-fold statistically significant increase in the adherence rate to post-partum follow-up. Clinical variables (pre-pregnancy BMI, multiple OGTT alterations in pregnancy, and insulin use) significantly predict the adherence to post-partum glucose tolerance assessment with a lower predictive value than the telephone intervention (Table 4).

3.4. Post-partum glucose tolerance evaluation

We also assessed glucose tolerance in the women who returned to the post-partum visit. Most of the women (77.2 %) had normal glucose tolerance, while the remaining part had various degrees of impaired glucose tolerance, with a diagnosis of diabetes mellitus established in 3.9 % of the returned women (Fig. 4). At multivariate logistic regression model, we found that fasting (OR 1.11, $p < 0.001$, 95 % CI 1.06–1.17) and 2-h (OR 1.02, $p < 0.05$, 95 % CI 1.004–1.03) glucose value at pregnancy OGTT are significantly related to any degree of post-partum glucose tolerance impairment.

4. Discussion

Our study evaluated, to our knowledge for the first time in Italian women affected by GDM, the effectiveness of a post-partum reminder to improve adherence to post-partum screening for glucose tolerance.

The prevention and early diagnosis of T2D are crucial for the start of lifestyle or pharmacological intervention and prevent its onset and complications [26]. Women with GDM have a seven-fold increased risk for T2D after delivery, and the cumulative incidence is estimated to reach 60 per cent within 10 years [8,27]. Despite current guidelines emphasizes the importance of post-partum glucose tolerance evaluation in GDM women, the adherence rate remains unsatisfactory. In our series of GDM women, all of them managed in a tertiary level diabetes centre encompassing a medical service for diabetes in pregnancy, participation at the post-partum glucose tolerance assessment in women not alerted by the telephone reminder was about 35 %, despite the post-partum visit was scheduled at the last visit before delivery. Conversely, this prevalence significantly increased (60.6 %, $p < 0.001$) in women who received the phone call about two weeks before the scheduled post-partum visit, suggesting the effectiveness of our phone intervention (Fig. 1A).

To date, few studies evaluated the efficacy of different reminder systems, comparing an intervention and a control group, with conclusions that are not always univocal [20,21]. Similar to our study, Soffer and colleagues observed a significant improvement in the rate of adherence to post-partum glucose tolerance assessment (from 17 % to 36 %) in women who received a phone reminder [24], while some randomised trials did not demonstrate the efficacy of the phone call [28] or SMS reminder [29]. Other reminder modalities, addressed to women or physicians, have been tested [25,30]. Clark and colleagues achieved a significant increase in post-partum screening for diabetes mellitus by sending to the patient or to the physician or both a postal reminder three months after delivery [25]. Lega and colleagues evaluated the effect of having a checklist in the clinical chart, to remember physicians to schedule post-partum diabetes screening for women with GDM and observed a beneficial effect of this reminder [30].

In our study, despite the phone reminder allowed us to significantly increase the adherence rate to post-partum glucose tolerance assessment, a high prevalence of GDM women, close to 40 percent, continued to escape from screening. Therefore, our analysis focused on identifying subgroups particularly at risk of non-adherence to post-partum follow-

Table 3
Demographic, clinical, and biochemical characteristics of the study population subdivided according to receiving the phone reminder and the adherence to post-partum visit for glucose tolerance evaluation.

	CALL REMINDER YES (*n* = 297)		CALL REMINDER NO (*n* = 246)		
	POST-PARTUM EVALUATION		POST-PARTUM EVALUATION		
	YES (*n* = 180)	NO (*n* = 117)	YES (*n* = 87)	NO (*n* = 159)	*P*
Age (years)	34.1 ± 4.9	33.4 ± 5.3	34.2 ± 5.2	33.1 ± 5.8	*0.22*
Pre-pregnancy body weight (Kg)	70.5 ± 15.9	75.0 ± 22.2[a]	68.4 ± 15.7	73.4 ± 20.2	*0.04*
Pre-pregnancy BMI (Kg/m^2)	27.7 ± 6.4	29.3 ± 7.9 [a]	27.0 ± 6.1	28.6 ± 7.5	*0.03*
Overweight or obese (%)	61.6	61.2	52.9	59.9	*0.23*
Weight at the end of pregnancy (Kg)	81.5 ± 14.9[b]	86.5 ± 20.3	80.0 ± 14.5	97.3 ± 22.2	*0.04*
Weight gain at the end of pregnancy (Kg)	9.4 ± 5.2	8.4 ± 5.2	8.6 ± 4.8	9.4 ± 5.6	*0.31*
HbA1c at diagnosis (%) (mmol/mol)	5.47 ± 0.47 (36 ± 5)	5.44 ± 0.41 (36 ± 4)	5.32 ± 0.51 (35 ± 5)	5.38 ± 0.55 (35 ± 6)	*0.14*
Average HbA1c during pregnancy (%) (mmol/mol)	5.50 ± 0.43 (37 ± 4)	5.69 ± 0.48 (39 ± 5)	5.35 ± 0.50 (35 ± 5)	5.41 ± 0.52 (36 ± 5)	*0.09*
Average fasting plasma glucose at first trimester (mg/dl)	90.5 ± 11.5	88.3 ± 14.5	91.4 ± 12.7	92.5 ± 16.7	*0.41*
Gestational week at diagnostic OGTT (weeks)	25.0 (20.0–28.0)	25.0 (22.0–27.0)	25.0 (23.0–28.0)	25.0 (22.0–29.0)	*0.39*
Gestational period at diagnostic OGTT (%)					
16–18 weeks	27.5[c]	17.5	15.7	11.0	*0.03*
24–28 weeks	72.5[c]	85.5	84.3	89.0	*0.03*
Plasma glucose values at pregnancy OGTT (mg/dl)					
Fasting	92.4 ± 12.5	91.0 ± 14.7	90.8 ± 12.5	93.7 ± 13.9	*0.27*
1-h	182.9 ± 35.6	179.1 ± 33.1	188.4 ± 26.8	180.7 ± 32.2	*0.23*
2-h	146.9 ± 37.8	141.4 ± 33.9	148.4 ± 34.6	140.3 ± 31.8	*0.24*
Plasma insulin values at pregnancy OGTT (μU/ml)					
Fasting	11.2 ± 7.9	8.1 ± 3.1	10.7 ± 6.2	15.2 ± 12.4	*0.24*
1-h	128.0 ± 58.7	63.9 ± 52.3	156.6 ± 35.0	69.4 ± 24.2	*0.055*
2-h	108.1 ± 64.2	89.6 ± 70.2	130.1 ± 76.9	75.0 ± 20.4	*0.63*
Two or more OGTT alteration (%)	44.6	36.6	41.9	27.6 [d]	*0.01*
Insulin therapy during pregnancy (%)	68.2[e]	48.6	59.3	48.1	*0.001*
Insulin dose (U/Kg)	0.42 ± 0.22	0.40 ± 0.32	0.34 ± 0.16	0.29 ± 0.17	*0.92*
Basal insulin dose (U/Kg)	0.16 ± 0.11	0.19 ± 0.30	0.11 ± 0.9	0.10 ± 0.08	*0.06*
Pre-gestational hypertension (%)	2.8	4.0	1.1	3.8	*0.64*
Gestational hypertension (%)	7.9	5.9	5.7	4.5	*0.63*
Preeclampsia (%)	0.6	0.0	2.3	1.3	*0.38*

Continuous normally distributed variables are presented as mean ± standard deviation, continuous not-normally distributed variables are presented as median and interquartile range (IQR), dichotomous variables are presented as a percentage (%) of the total subjects.
Abbreviations: GDM, gestational diabetes mellitus; BMI, body mass index; HbA1c, glycosylated haemoglobin; OGTT, oral glucose tolerance test.
[a]Indicates statistical significance vs. call reminder no/post-partum evaluation yes.
[b]Indicates statistical significance vs. call reminder no/post-partum evaluation no.
[c]Indicates statistical significance vs. the other three groups.
[d]Indicates statistical significance vs. call reminder yes/post-partum evaluation yes and call reminder no/post-partum evaluation yes.
[e]Indicates statistical significance vs. call reminder yes/post-partum evaluation no and call reminder no/post-partum evaluation no.

up. We found that a higher pre-pregnancy BMI, together with a single alteration at pregnancy OGTT, and no insulin use during pregnancy, were significantly related with a four-fold increased risk of non-adherence to screening procedures (Fig. 3). Surprisingly, pre-pregnancy BMI was higher in women who did not adhere to post-partum evaluation and an inverse relation was found between pre-pregnancy BMI and the adherence rate to post-partum screening (Fig. 2). Evidence from previous reports investigating the predictive role of pre-pregnancy BMI on adherence to post-partum diabetes screening in women with GDM is few and not univocal [31–33]. Similarly to our data, Ferrara and colleagues observed that obesity is independently correlated with lower screening performance in a large sample including more than 14.000 women with GDM [31]. These findings could be explained by the lack of awareness of the link between excess adiposity and lifetime risk of diabetes or, conversely, the fear of negative consequences of living with diabetes (e.g., the necessity to be engaged in diabetes daily management, diabetes-related social stigma, etc.) whose diagnosis is more likely in obese women [20]. Conversely, other studies with smaller sample did not observe a relationship between BMI and the adherence to post-partum glucose tolerance assessment [14,32,33].

We found a better adherence to post-partum diabetes screening in women with multiple abnormalities of the OGTT in pregnancy, while women with only one abnormal value were less likely to adhere to screening (Fig. 3A). A prospective cohort study conducted by Hunt and colleagues on 707 women with GDM showed a relationship between higher glucose values at the diagnostic OGTT and a reduced adherence to post-partum glucose evaluation [32], while Ferrara and colleagues found no such tendency [31]. To our knowledge our study is the first observing that the number of abnormal glucose values at OGTT in pregnancy could predict the adherence to post-partum glucose tolerance assessment. The improved adherence to post-partum follow-up in women treated with insulin during pregnancy confirms what previous studies have shown, suggesting a probable increase in the fear of persistence or recurrence of diabetes risk arising from insulin use during pregnancy [14,21,31–33].

We observed no relationship between maternal age and gestational weight gain with the likelihood of meeting the post-partum glucose tolerance assessment (Table 3). Few conflicting data arose from previous studies about the role of maternal age. The studies of Ferrara and colleagues [31] and Lawrence and colleagues [15] described that older maternal age may increase the rate of adherence to post-partum screening, conversely other studies, like our data, indicate a neutral role [14,32,33]. Regarding gestational weight gain, Cho and colleagues observed, in a Korean cohort, a greater weight gain during pregnancy in women who were less likely to perform a post-partum glucose test [33].

A considerable percentage of women (22.8 %) who performed the post-partum OGTT presented some degree of dysglycaemia, with T2D diagnosed in 3.9 % of them (Fig. 4). These data enhance the importance

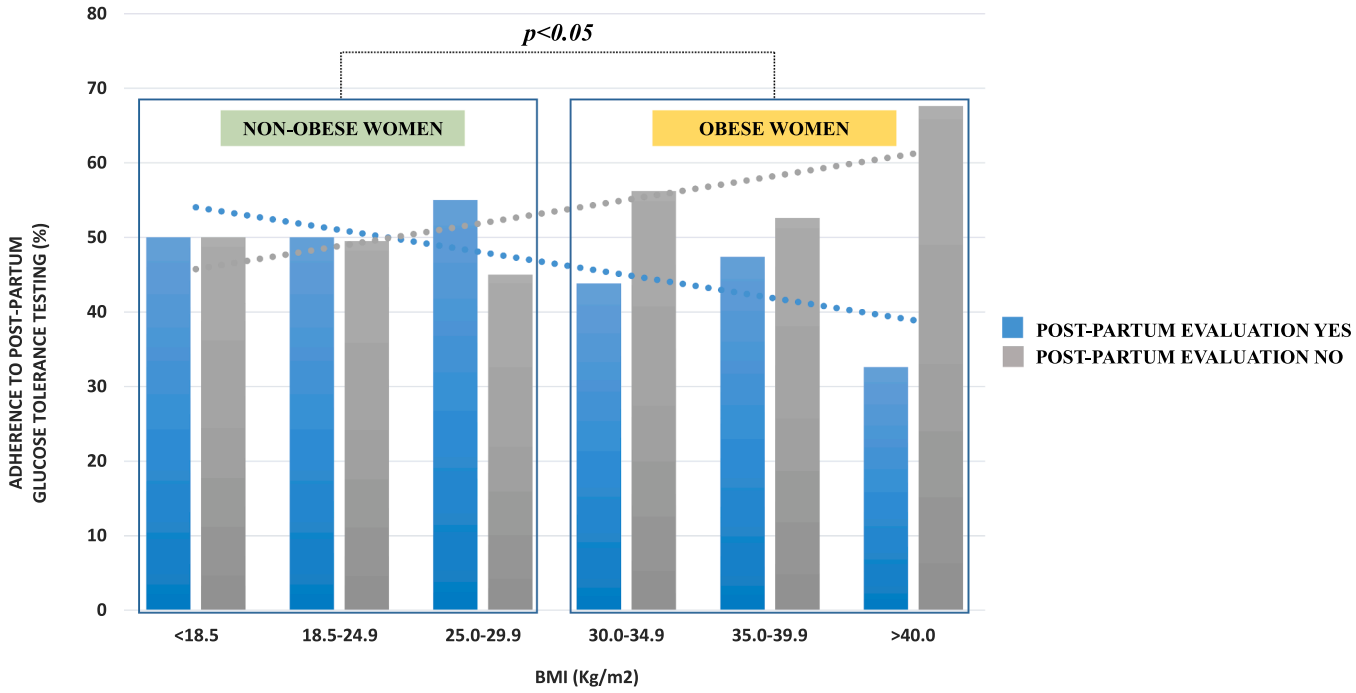

Fig. 2. Adherence rate to post-partum glucose tolerance evaluation in subgroups according pre-pregnancy body mass index and comparison among non–obese and obese women. Dotted lines illustrate the trend of post-partum follow-up prevalence across BMI classes.

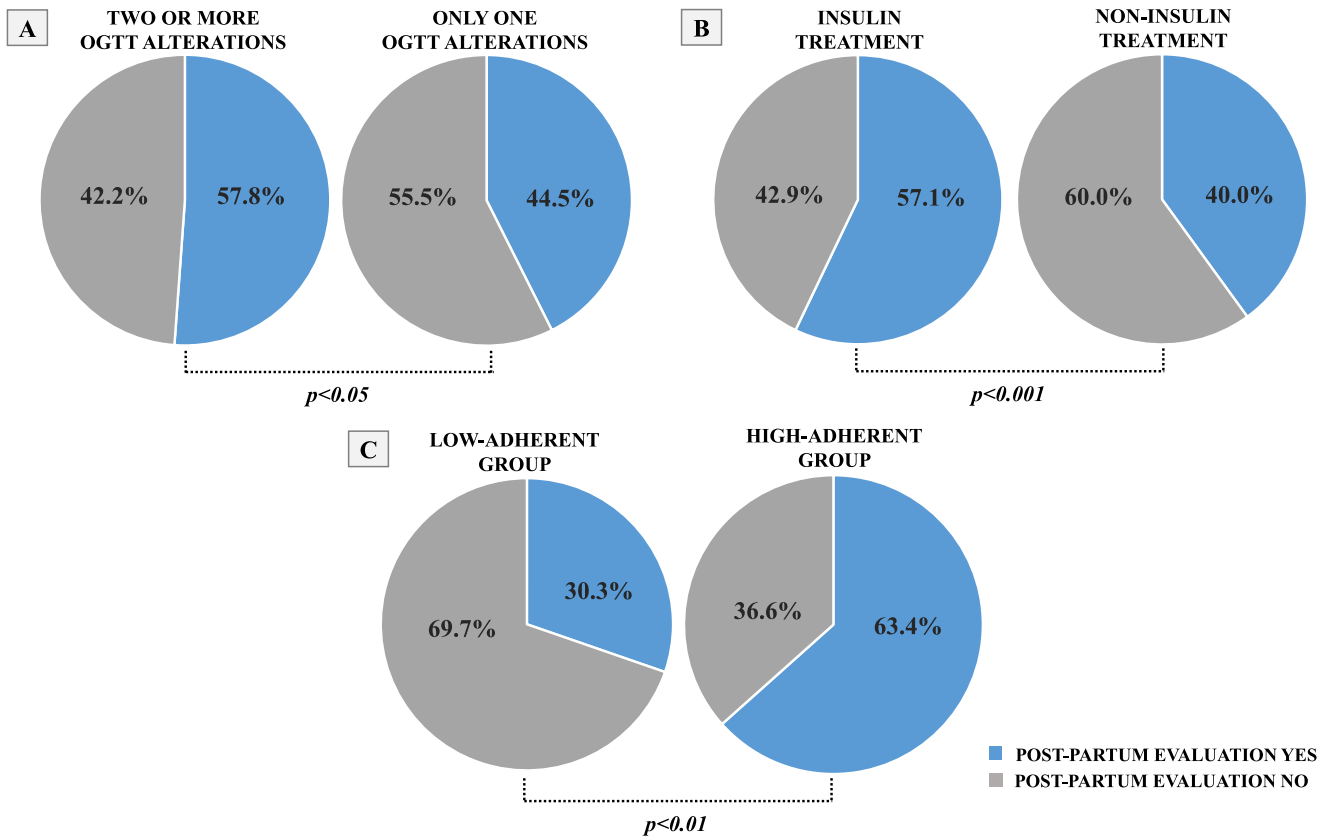

Fig. 3. Adherence rate to post-partum glucose tolerance evaluation in women with only one compared to multiple abnormal glucose values at pregnancy OGTT (A), in women treated with insulin compared to non-insulin-treated women during pregnancy (B), and in low-adherent group (pre-pregnancy BMI $\geq$ 30 Kg/m^2, only-one alteration at pregnancy OGTT, and non-insulin therapy) compared with high-adherent group (pre-pregnancy BMI $<$ 30 Kg/m^2, multiple alterations at pregnancy OGTT, and insulin therapy) (C).

Table 4
Multivariate logistic regression model exploring the association among clinical parameters and phone reminder and the adherence to post-partum glucose tolerance assessment.

	B	SE	Wald	OR (95 % CI)	P
Groups based on phone reminder (no/yes)	1.13	0.20	32.5	**3.03** (2.1–4.55)	**<0.001**
Pre-pregnancy BMI	−0.04	0.02	8.0	**0.96** (0.93–0.99)	**<0.01**
Two or more OGTT alteration	0.43	0.21	4.4	**1.54** (1.03–2.31)	**<0.05**
Insulin therapy during pregnancy	0.64	0.21	9.6	**1.89** (1.26–2.83)	**<0.01**
Age	0.03	0.02	1.7	1.03 (0.98–1.06)	0.19
HbA1c at diagnosis	−0.11	0.20	0.3	0.89 (0.61–1.33)	0.59
Pre-gestational hypertension	−0.77	0.61	1.6	0.47 (0.14–1.53)	0.21
Gestational hypertension	0.64	0.42	2.4	1.90 (0.84–4.3)	0.12
Preeclampsia	0.80	1.14	0.5	2.22 (0.24–20.9)	0.48

Abbreviations: B, regression coefficient; SE, standard error; OR, odds ratio; CI, confidence interval; BMI, body mass index OGTT, oral glucose tolerance test; HbA1c, glycated hemoglobin.

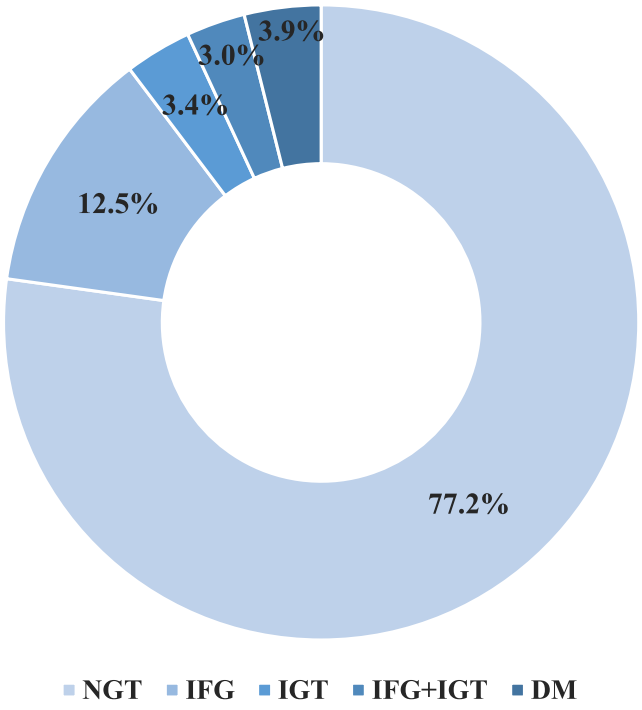

Fig. 4. Prevalence of glucose alterations at post-partum OGTT.

of the post-partum glucose assessment, and the prevalence of post-partum glucose alteration (23 percent) observed in our sample is similar to that found in the STRONG cohort, an Italian multicentre observational study including 2736 women with recent GDM [14]. Other studies reported a variable post-partum prevalence of 5–14 % for T2D, 3–6 % for IFG, and up to 30 % for IGT, depending on the country, ethnicity, timing and mode of post-partum screening [8,34,35].

Our study has some limitations that could be addressed in future research. First, the retrospective analysis of the data and the lack of information regarding socioeconomic status, educational level, parity, previous GDM, family history of diabetes and reasons why women might not return for post-partum glucose testing. Second, the lack of data on perinatal and post-partum outcomes for women who did not return for the post-partum visit despite the telephone reminder.

We conclude that, among women with GDM, a simple and inexpensive phone reminder significantly improves the adherence to post-partum diabetes screening, although the reached adherence rate is not fully satisfying. We believe that our reminder system, tested in a diabetes centre provided with a medical service dedicated to the management of diabetes in pregnancy, could be generalizable to other medical contexts, also involving healthcare providers other than physicians (nurses, case managers or other administrative staff). Nevertheless, the applicability should be evaluated according to the contextual ability to provide human resources and continuity to women's care.

Post-partum diabetes evaluation is mandatory for its early diagnosis and management, as well as to begin, in women particularly at risk (e.g., obese, family history, prediabetes, etc.), a lifestyle or pharmacologic intervention to prevent its future onset. Besides, the assessment of post-partum glucose tolerance, in women during reproductive age, reduces, in future offspring, the risks associated with exposure to a diabetic intrauterine environment during early pregnancy (e.g., congenital abnormalities and miscarriage). Understanding the reasons for low screening uptake is essential for developing effective strategies to improve screening rates. Reasons contributing to poor screening rates involve both GDM women and gaps in healthcare transition strategies [19]. During pregnancy, women are usually strongly motivated to make positive behaviour, driven by the instinct of pursuing the newborn health, while, after delivery, the possible lifelong health consequences deriving from an unrecognized glucose impairment are underestimated. From the healthcare side, barriers to post-partum diabetes screening are provider misconceptions, and barriers to reliable healthcare transitions. Pre-pregnancy overweight or obesity and the need for insulin therapy during pregnancy are risk factors for diabetes later in life [36–38]. In our cohort, the 61.2 % of women with pre-pregnancy overweight or obesity and the 48.6 % of those requiring insulin therapy did not adhere to the post-partum glucose tolerance evaluation, thus requiring a greater attention. Further strategies involving, for example, the general practitioner are needed to prevent these at-risk women from escaping follow-up. This approach, along with the improvement of women's education and awareness of the post-partum sequelae of GDM, and the enhancement of national strategies clarifying the multidisciplinary responsibility of post-partum screening for diabetes, could reduce, for both GDM mother and their offspring, the long-life health burden related to unrecognised impairment of glucose tolerance.

CRediT authorship contribution statement

Agostino Milluzzo: Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lucia Manuella:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Lucia Frittitta:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Data curation. **Laura Sciacca:** Conceptualization, Investigation, Methodology, Project administration, Supervision, Validation, Writing – original draft, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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References

[1] ElSayed NA, Aleppo G, Bannuru RR, Bruemmer D, Collins BS, Ekhlaspour L, et al. 2. diagnosis and classification of diabetes: *Standards of Care in Diabetes—2024*. Diabetes Care 2024;47:S20–42. https://doi.org/10.2337/dc24-S002.

[2] ACOG Practice Bulletin No. 190: Gestational Diabetes Mellitus. Obstetrics & Gynecology 2018;131:e49–64. 10.1097/AOG.0000000000002501.

[3] Pintaudi B, Fresa R, Dalfrà M, Dodesini AR, Vitacolonna E, Tumminia A, et al. The risk stratification of adverse neonatal outcomes in women with gestational diabetes (STRONG) study. Acta Diabetol 2018;55:1261–73. https://doi.org/10.1007/s00592-018-1208-x.

[4] Lowe LP, Metzger BE, Dyer AR, Lowe J, McCance DR, Lappin TRJ, et al. Hyperglycemia and adverse pregnancy outcome (HAPO) study. Diabetes Care 2012;35:574–80. https://doi.org/10.2337/dc11-1687.

[5] Milluzzo A, Tumminia A, Scalisi NM, Frittitta L, Vigneri R, Sciacca L. Insulin degludec in the first trimester of pregnancy: report of two cases. J Diabetes Investig 2018:9. https://doi.org/10.1111/jdi.12721.

[6] Tumminia A, Scalisi NM, Milluzzo A, Ettore G, Vigneri R, Sciacca L. Maternal diabetes impairs insulin and IGF-1 receptor expression and signaling in human placenta. Front Endocrinol (Lausanne) 2021:12. https://doi.org/10.3389/fendo.2021.621680.

[7] Tumminia A, Milluzzo A, Festa C, Fresa R, Pintaudi B, Scavini M, et al. Efficacy of flash glucose monitoring in pregnant women with poorly controlled pregestational diabetes (FlashMom): a randomized pilot study. Nutr Metab Cardiovasc Dis 2021:31. https://doi.org/10.1016/j.numecd.2021.03.013.

[8] Bellamy L, Casas J-P, Hingorani AD, Williams D. Type 2 diabetes mellitus after gestational diabetes: a systematic review and meta-analysis. Lancet 2009;373:1773–9. https://doi.org/10.1016/S0140-6736(09)60731-5.

[9] Gouesland K, Cottenet J, Mariet A-S, Sagot P, Petit J-M, Quantin C. Early screening for type 2 diabetes following gestational diabetes mellitus in France: hardly any impact of the 2010 guidelines. Acta Diabetol 2017;54:645–51. https://doi.org/10.1007/s00592-017-0986-x.

[10] Giuliani C, Sciacca L, Di BN, Tumminia A, Milluzzo A, Faggiano A, et al. Gestational diabetes mellitus pregnancy by pregnancy: early, late and nonrecurrent GDM. Diabetes Res Clin Pract 2022;188:109911. https://doi.org/10.1016/j.diabres.2022.109911.

[11] Chiefari E, Arcidiacono B, Foti D, Brunetti A. Gestational diabetes mellitus: an updated overview. J Endocrinol Invest 2017;40:899–909. https://doi.org/10.1007/s40618-016-0607-5.

[12] You H, Hu J, Liu Y, Luo B, Lei A. Risk of type 2 diabetes mellitus after gestational diabetes mellitus: a systematic review & meta-analysis. Indian J Med Res 2021;154:62. https://doi.org/10.4103/ijmr.IJMR_852_18.

[13] Kim C, Newton KM, Knopp RH. Gestational diabetes and the incidence of type 2 diabetes. Diabetes Care 2002;25:1862–8. https://doi.org/10.2337/diacare.25.10.1862.

[14] Napoli A, Sciacca L, Pintaudi B, Tumminia A, Dalfrà MG, Festa C, et al. Screening of postpartum diabetes in women with gestational diabetes: high-risk subgroups and areas for improvements—the STRONG observational study. Acta Diabetol 2021;58:1187–97. https://doi.org/10.1007/s00592-021-01707-9.

[15] Lawrence JM, Black MH, Hsu J-W, Chen W, Sacks DA. Prevalence and timing of Postpartum glucose testing and sustained glucose dysregulation after gestational diabetes mellitus. Diabetes Care 2010;33:569–76. https://doi.org/10.2337/dc09-2095.

[16] Pintaudi B, Fresa R, Dalfrà M, Marcone T, Dodesini AR, Napoli A, et al. Level of implementation of guidelines on screening and diagnosis of gestational diabetes: a national survey. Diabetes Res Clin Pract 2016;113:48–52. https://doi.org/10.1016/j.diabres.2015.12.008.

[17] Scavini M, Formoso G, Festa C, Sculli MA, Succurro E, Sciacca L, et al. Follow-up of women with a history of gestational diabetes in Italy: are we missing an opportunity for primary prevention of type 2 diabetes and cardiovascular disease? Diabetes Metab Res Rev 2021:37. https://doi.org/10.1002/dmrr.3411.

[18] Nielsen JH, Olesen CR, Kristiansen TM, Bak CK, Overgaard C. Reasons for women's non-participation in follow-up screening after gestational diabetes. Women Birth 2015;28:e157–63. https://doi.org/10.1016/j.wombi.2015.04.006.

[19] Lithgow GE, Rossi J, Griffin SJ, Usher-Smith JA, Dennison RA. Barriers to postpartum diabetes screening: a qualitative synthesis of clinicians' views. Br J Gen Pract 2021;71:e473–82. https://doi.org/10.3399/BJGP.2020.0928.

[20] Nielsen JH, Melendez-Torres GJ, Rotevatn TA, Peven K, Fonager K, Overgaard C. How do reminder systems in follow-up screening for women with previous gestational diabetes work? - a realist review. BMC Health Serv Res 2021;21:535. https://doi.org/10.1186/s12913-021-06569-z.

[21] Thayer SM, Lo JO, Caughey AB. Gestational diabetes. Obstet Gynecol Clin North Am 2020;47:383–96. https://doi.org/10.1016/j.ogc.2020.04.002.

[22] International Association of Diabetes and Pregnancy Study Groups Recommendations on the Diagnosis and Classification of Hyperglycemia in Pregnancy. Diabetes Care 2010;33:676–82. 10.2337/dc09-1848.

[23] Ministero della Salute - Istituto Superiore di Sanità - CEVEAS. Linea guida gravidanza fisiologica. Sistema Nazionale per le Linee Guida dell'Istituto Superiore di Sanità 2011.

[24] Soffer MD, Factor SH, Rosenman A, Levy C, Stone J. Improving postpartum glucose monitoring in women with gestational diabetes. J Matern Fetal Neonatal Med 2017;30:3014–9. https://doi.org/10.1080/14767058.2016.1271411.

[25] Clark HD, Graham ID, Karovitch A, Keely EJ. Do postal reminders increase postpartum screening of diabetes mellitus in women with gestational diabetes mellitus? a randomized controlled trial. Am J Obstet Gynecol 2009;200:634.e1–7. https://doi.org/10.1016/j.ajog.2009.01.003.

[26] Milluzzo A, Manuella L, Sciacca L. Semaglutide: a game changer for metabolic diseases? Explor Med 2022:173–80. https://doi.org/10.37349/emed.2022.00083.

[27] Tumminia A, Milluzzo A, Cinti F, Parisi M, Tata F, Frasca F, et al. Abnormal 1-hour post-load glycemia during pregnancy impairs post-partum metabolic status: a single-center experience. J Endocrinol Invest 2018:41. https://doi.org/10.1007/s40618-017-0774-z.

[28] Khalifeh A, Khosla J, Cantor E, Quist-Nelson J, Saccone G, Tumas J, et al. A reminder system for postpartum diabetes screening after gestational diabetes: a randomized clinical trial. J Matern Fetal Neonatal Med 2022;35:7518–22. https://doi.org/10.1080/14767058.2021.1951212.

[29] Van Ryswyk EM, Middleton PF, Hague WM, Crowther CA. Postpartum SMS reminders to women who have experienced gestational diabetes to test for type 2 diabetes: the DIAMIND randomized trial. Diabet Med 2015;32:1368–76. https://doi.org/10.1111/dme.12769.

[30] Lega IC, McLaughlin H, Coroneos M, Handley-Derry F, Donovan N, Lipscombe LL. A physician reminder to improve postpartum diabetes screening in women with gestational diabetes mellitus. Diabetes Res Clin Pract 2012;95:352–7. https://doi.org/10.1016/j.diabres.2011.10.023.

[31] Ferrara A, Peng T, Kim C. Trends in Postpartum diabetes screening and subsequent diabetes and impaired fasting glucose among women with histories of gestational diabetes mellitus. Diabetes Care 2009;32:269–74. https://doi.org/10.2337/dc08-1184.

[32] Hunt KJ, Conway DL. Who returns for postpartum glucose screening following gestational diabetes mellitus? Am J Obstet Gynecol 2008;198:404.e1–6. https://doi.org/10.1016/j.ajog.2007.09.015.

[33] Cho GJ, An J-J, Choi S-J, Oh S, Kwon H-S, Hong S-C, et al. Postpartum glucose testing rates following gestational diabetes mellitus and factors affecting testing non-compliance from four Tertiary centers in Korea. J Korean Med Sci 2015;30:1841. https://doi.org/10.3346/jkms.2015.30.12.1841.

[34] Pastore I, Chiefari E, Vero R, Brunetti A. Postpartum glucose intolerance: an updated overview. Endocrine 2018;59:481–94. https://doi.org/10.1007/s12020-017-1388-0.

[35] Kitzmiller JL, Dang-Kilduff L, Taslimi MM. Gestational diabetes after delivery. Diabetes Care 2007;30:S225–35. https://doi.org/10.2337/dc07-s221.

[36] Capula C, Chiefari E, Vero A, Foti DP, Brunetti A, Vero R. Prevalence and predictors of postpartum glucose intolerance in italian women with gestational diabetes mellitus. Diabetes Res Clin Pract 2014;105:223–30. https://doi.org/10.1016/j.diabres.2014.05.008.

[37] Schaefer-Graf UM, Klavehn S, Hartmann R, Kleinwechter H, Demandt N, Sorger M, et al. How do we reduce the number of cases of missed Postpartum diabetes in women with recent gestational diabetes mellitus? Diabetes Care 2009;32:1960–4. https://doi.org/10.2337/dc09-0627.

[38] Liu Z, Zhang Q, Liu L, Liu W. Risk factors associated with early postpartum glucose intolerance in women with a history of gestational diabetes mellitus: a systematic review and meta-analysis. Endocrine 2023;82:498–512. https://doi.org/10.1007/s12020-023-03472-x.