Risk factors for abnormal postpartum glycemic states in women diagnosed with gestational diabetes by the International Association of Diabetes and Pregnancy Study Groups criteria

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Abstract

Aims/Introduction: To evaluate the rate of postpartum glycemic screening tests (PGST) in women with gestational diabetes mellitus (GDM), and to investigate risk factors for abnormal PGST results.

Materials and Methods: We retrospectively analyzed the obstetric data of 1,648 women with GDM who gave birth after 28 completed weeks of gestation between 1 July 2011 and 31 December 2019 at Taipei Chang Gung Memorial Hospital, Taiwan. GDM was diagnosed by the International Association of Diabetes and Pregnancy Study Groups criteria. PGST was carried out at 6–12 weeks postpartum with a 75-g, 2-h oral glucose tolerance test, and the results were classified into normal, prediabetes and diabetes mellitus. Multiple logistic regression was used to assess the associations between various risk factors and abnormal PGST results.

Results: In total, 493 (29.9%) women underwent PGST and 162 (32.9%) had abnormal results, including 135 (27.4%) with prediabetes and 27 (5.5%) with diabetes mellitus. Significant risk factors for postpartum diabetes mellitus included insulin therapy during pregnancy (adjusted odds ratio [OR] 10.79, 95% confidence interval [CI] 4.07–28.58), birthweight >4,000 g (adjusted OR 10.22, 95% CI 1.74–59.89) and preterm birth <37 weeks' gestation (adjusted OR 3.33, 95% CI 1.09–10.22); whereas prepregnancy body mass index >24.9 kg/m² (adjusted OR 1.99, 95% CI 1.24–3.21) was the major risk factor for postpartum prediabetes.

Conclusions: Less than one-third of women with GDM underwent PGST, and nearly one-third of these women had abnormal results. Future efforts should focus on reducing the barriers to PGST in women with GDM.

Introduction

Based on the diagnostic criteria that are applied1,2, gestational diabetes mellitus (GDM) complicates 3–13% of pregnancies and is a major risk factor for maternal gestational hypertensive diseases, as well as neonatal complications, including hypoglycemia, hyperbilirubinemia and respiratory distress syndrome3,4. Furthermore, women with GDM are more likely to develop type 2 diabetes mellitus and cardiovascular diseases in their later life than women without GDM5,6. The identification of women at risk for impaired postpartum glucose metabolism is crucial for the early initiation of effective interventional strategies, such as increased physical activity, healthy nutritional advice, weight reduction and maintenance of an ideal bodyweight, which can delay or prevent the progression from GDM to type 2 diabetes mellitus or other metabolic disorders in the immediate postpartum period or several years later5,7. Therefore, the American Diabetes Association and the American College of Obstetricians and Gynecologists recommend type 2
diabetes mellitus screening with a 75-g, 2-h oral glucose tolerance test (OGTT) at 4–12 weeks postpartum for all women with GDM. However, the rate of carrying out the postpartum glycemic screening test (PGST) shows a wide variation, which ranges from 33 to 73%, among different countries or studies. Compared with the USA and European countries, the rate of PGSTs for women with GDM is lower in Asian countries, despite the higher risk for type 2 diabetes mellitus after GDM among Asian women than among other ethnicities.

Several risk factors have been reported to be associated with the development of postpartum type 2 diabetes mellitus in women who had GDM. These include a high glycated hemoglobin level at GDM diagnosis, high glucose parameters on the 100-g, 3-h OGTT, history of GDM, and a high prepregnancy body mass index (BMI). Based on the result of a postpartum 75-g, 2-h OGTT, a woman can be categorized as normal, or diagnosed with prediabetes (including isolated impaired fasting glucose [IFG], isolated impaired glucose tolerance [IGT] and IFG plus IGT) or diabetes. It is unclear whether women with prediabetes have a similar risk factor profile as those who are diagnosed with diabetes. Furthermore, most previous studies examined the risk factors for postpartum type 2 diabetes mellitus in women with GDM that was diagnosed with the 100-g, 3-h OGTT (see reviews in Tovar et al., Nouhjah et al. and Benhalima et al.). Just a few studies were carried out among women with GDM that was diagnosed with a 75-g, 2-h OGTT based on the criteria defined by the International Association of Diabetes and Pregnancy Study Groups (IADPSG); most of these studies had small sample sizes and were conducted on non-Asian populations. Thus, it remains unclear whether Asian women with GDM that was diagnosed on the basis of the IADPSG criteria have a similarly increased risk and risk profile for abnormal postpartum glucose metabolism than those with a GDM diagnosis that was based on other screening strategies and diagnostic criteria.

Therefore, the present study was carried out to examine the risks and risk profile for abnormal postpartum glucose metabolism in women who were diagnosed with GDM based on the IADPSG criteria. The primary objective of this research was to ascertain the rate of PGST, and the secondary objective was to investigate the risk factors for prediabetes and diabetes at 6–12 weeks postpartum in a population of Taiwanese women with GDM.

**METHODS**

**Data collection**

Study data were extracted from the computerized obstetrics database of Taipei Chang Gung Memorial Hospital, Taiwan. Information on maternal demographic characteristics, and medical and obstetric histories, as well as the course of the index pregnancy and perinatal outcomes were recorded. The details of the database organization have been previously reported. We retrospectively examined the data of all women who gave birth after 28 completed weeks of gestation between 1 July 2011 and 31 December 2019. The institutional review board of Chang Gung Memorial Hospital approved the study (approval no. 201800894B0). The approving body waived the need for informed consent, given the retrospective nature of the study and the use of anonymized participant information.

**Diagnosis of GDM**

During the study period, all pregnant women who were treated at this hospital underwent universal screening for GDM with a one-step approach, as recommended by the IADPSG. The IADPSG recommends testing to be routinely carried out between 24 and 28 weeks of gestation or at the first prenatal visit in high-risk women. Based on the results of a 75-g, 2-h OGTT, a woman was diagnosed with GDM when one or more of her plasma glucose concentrations were equivalent to or exceeded the following levels: fasting, 92 mg/dL; 1 h, 180 mg/dL; or 2 h, 153 mg/dL. After a GDM diagnosis, women were referred to dieticians for advice on dietary and lifestyle modifications, and underwent regular monitoring of blood glucose levels. Insulin therapy was indicated if medical nutritional therapy failed to consistently maintain a fasting glucose level <95 mg/dL and a 2-h postprandial level <120 mg/dL.

**Postpartum glycemic screening test**

After delivery, women with GDM are offered a PGST with a standard 75-g, 2-h OGTT that is usually undertaken at 6–12 weeks postpartum. Based on the levels of fasting and 2-h plasma glucose concentrations, a woman was classified into one of the following diagnoses: (i) diabetes: fasting glucose $\geq 126$ mg/dL or 2-h glucose $\geq 200$ mg/dL; (ii) isolated IFG: fasting glucose $\geq 100$ and <126 mg/dL, and 2-h glucose <140 mg/dL; (iii) isolated IGT: fasting glucose <100 mg/dL, and 2-h glucose $\geq 140$ mg/dL and <200 mg/dL; (iv) IFG plus IGT: fasting glucose $\geq 100$ mg/dL and <126 mg/dL, and 2-h glucose $\geq 140$ mg/dL and <200 mg/dL; and (v) normal, fasting glucose <100 mg/dL and 2-h glucose <140 mg/dL. For this study, women with isolated IFG, isolated IGT and IFG plus IGT were grouped together as prediabetes.

**Data analysis**

The present study consisted of two parts. In the first part of the study, we investigated the rate of GDM women who underwent the PGST. We further evaluated maternal characteristics and pregnancy outcomes between GDM women with and without PGST by frequency (percentage), and compared the distribution differences using the $\chi^2$-test or Fisher’s exact test. Multiple logistic regression analysis was then carried out to determine factors associated with undergoing PGST in women with GDM, after adjusting for potential confounders from maternal characteristics and pregnancy outcomes that were statistically significant in the univariate analysis. The maternal characteristics for analysis included age at delivery (stratified as <20, 20–34 and >34 years); prepregnancy BMI (stratified as...
<18.5, 18.5–24.9 and >24.9 kg/m²); mode of delivery (spontaneous or operative vaginal delivery, or cesarean delivery [CS]); primiparity; history of induced or spontaneous abortions, preterm birth and fetal death; conception assisted by reproductive technology; cigarette smoking during pregnancy; multiple gestation; genetic amniocentesis; uterine fibroids; group B streptococcal colonization of the rectogenital tract; maternal diseases, such as chronic hypertension, pre-eclampsia, and hypo- and hyperthyroidism; and first- or second-degree family history of diabetes, GDM history in a previous pregnancy and insulin therapy for GDM during pregnancy. The pregnancy outcomes for analysis included fetal sex (male or female); preterm birth before 34 or 37 weeks of gestation, birthweight <1,500, <2,500 or >4,000 g; small-for-gestational age infants, defined as birthweight <10th percentile of mean weight corrected for sex and gestational age;³⁰,³¹; large-for-gestational age infants, defined as birth weight >90th percentile of mean weight corrected for fetal sex and gestational age ³⁰,³¹; low 1- and 5-min Apgar scores (<7); neonatal intensive care unit admission; fetal death; neonatal death; congenital anomalies (chromosomal or structural); premature rupture of membranes; meconium-stained amniotic fluid; oligohydramnios; polyhydramnios; acute chorioamnionitis; placental abruption; placenta previa; placenta accreta; postpartum hemorrhage, defined as a blood loss >500 mL for vaginal delivery, 1,000 mL for CS or excessive bleeding that results in signs of hypovolemia, such as hypotension or tachycardia; and severe perineal injury, defined as third- or fourth-degree perineal laceration.

The objective of the second part of the study was to investigate risk factors for abnormal PGST results, including prediabetes and diabetes. We compared the distribution differences in the aforementioned maternal characteristics and pregnancy outcomes between GDM women with normal and abnormal PGST results. Only variables with statistical differences in the univariate analysis among these three groups of women were selected for further multiple logistic regression analysis. We then generated two models for multiple logistic regression to determine independent risk factors for abnormal PGST results; model 1 adjusted for the confounding effects of maternal characteristics, whereas model 2 adjusted for the confounding effects of both maternal characteristics and pregnancy outcomes.

Statistical analysis
All statistical analyses were carried out in SPSS version 20.0 (IBM Corp., Armonk, NY, USA). Continuous variables are presented as the mean ± standard deviation, and categorical variables as the number and frequency (%). Comparisons between GDM women with and without PGST were carried out with the Student’s t-test, χ²-test or Fisher’s exact test, as appropriate. Intergroup comparisons among women with normal PGST results and those with prediabetes and diabetes were undertaken with logistic regression or the Kruskal–Wallis test followed by Dunnett's post-hoc test. A P-value <0.05 was considered statistically significant. In multiple logistic regression, adjusted odds ratios (OR) and associated 95% confidence intervals (CI) were calculated to identify factors associated with the attendance of PGST, and to assess the associations between various risk factors and abnormal PGST results.

RESULTS
Differences in the rates of various maternal characteristics and pregnancy outcomes between women with GDM with and without PGST
During the study period, a total of 1,648 women with 1,696 infants (including 48 sets of twins) were diagnosed with GDM on the basis of the IADPSG criteria, and 493 (29.9%) women had a PGST at 6–12 weeks postpartum. Compared with women with GDM who did not undergo the PGST, the rates of operative vaginal delivery, family history of diabetes, insulin therapy during pregnancy and severe perineal injury were higher in women with GDM who underwent a PGST (Tables 1,2). In contrast, the rates of CS, male fetus, preterm birth <37 weeks and placenta previa were lower in women with GDM who underwent a PGST than that in women with GDM who did not undergo the PGST.

Factors associated with undergoing the PGST in women with GDM
Multiple logistic regression with adjustment for the confounding effects of maternal characteristics and pregnancy outcomes showed that women with GDM with operative vaginal delivery (adjusted OR 1.87, 95% CI 1.11–3.15), insulin therapy during pregnancy (adjusted OR 1.63, 95% CI 1.10–2.40) and family history of diabetes (adjusted OR 1.30, 95% CI 1.05–1.61) were more likely to undergo the PGST (Table 3).

Differences in the rates of various maternal characteristics and pregnancy outcomes between women with GDM with normal and abnormal PGST results
Among the 493 women who underwent the PGST, 162 (32.9%) women were found to have abnormal PGST results, including 135 (27.4%) women diagnosed with prediabetes and 27 (5.5%) women with diabetes. Among the women with pre-diabetes, 51 were classified as isolated IFG, 70 as isolated IGT and 14 as IFG plus IGT. The maternal characteristics of these 493 women are shown in Tables 4 and Table S1. Compared with women who had normal PGST results, the rates of prepregnancy BMI >24.9 kg/m², CS, history of fetal death and insulin therapy during pregnancy were higher in women with prediabetes. Furthermore, women diagnosed with diabetes were more likely to have a prepregnancy BMI >24.9 kg/m², CS and insulin therapy during pregnancy than women with a normal postpartum glycemic status. Therefore, prepregnancy BMI >24.9 kg/m², CS, history of fetal death and insulin therapy during pregnancy were selected as potential risk factors for abnormal PGST results for multiple logistic regression analysis in model 1.
The pregnancy outcomes of the 493 women who underwent the PGST are shown in Tables 5 and S2. Univariate analysis showed that there were significant differences in the rates of preterm birth (<37 weeks of gestation), birthweight (<1,500 or >4,000 g), large-for-gestational age infants, and low 1-min Apgar score between newborns from women with normal PGST results and those from women with prediabetes or diabetes. Therefore, these variables, in association with prepregnancy BMI >24.9 kg/m², CS, history of fetal death and insulin therapy during pregnancy, were included as potential risk factors for abnormal PGST results in the multiple logistic regression analysis in model 2. Although univariate analysis showed significant differences in the rates of low 5-min Apgar score and fetal death among these three groups of women, these two variables were not selected for model 2 because the numbers of individuals were small and no women with normal PGST results had fetal death or newborns with a low 5-min Apgar score.

### Risk factors for postpartum prediabetes and diabetes

In model 1, we applied multiple logistic regression to adjust for the confounding effects of maternal characteristics, and found that prepregnancy BMI >24.9 kg/m² remained as the major risk factor (adjusted OR 1.99, 95% CI 1.24–3.21) for postpartum prediabetes when the confounding effects of pregnancy outcomes were simultaneously adjusted in model 2 (Table 6).

The results of multiple logistic regression on the risk factors for postpartum diabetes are shown in Table 7. Insulin therapy during pregnancy was found to be the major risk factor for postpartum diabetes in model 1. After adjusting the confounding effects of maternal characteristics and pregnancy outcomes, significant risk factors for postpartum diabetes included insulin therapy during pregnancy (adjusted OR 10.79, 95% CI 4.07–28.58), birthweight >4,000 g (adjusted OR 10.22, 95% CI 1.74–59.89) and preterm birth <37 weeks of gestation (adjusted OR 3.33, 95% CI 1.09–10.22).

### DISCUSSION

In the present retrospective study, we found that less than one-third of women with GDM received a PGST at 6–12 weeks postpartum. Women with GDM with operative vaginal delivery, insulin therapy during pregnancy and a family history of diabetes were more likely to undergo the PGST. Furthermore, among women who underwent the PGST, 32.9% had abnormal results, including 27.4% with prediabetes and 5.5% with
We further demonstrated different risk profiles between women with postpartum prediabetes and those with diabetes. Similar to the results of a recent multicenter report from Korea, the proportion of women with GDM who underwent a PGST in the present study was lower than those in most previous reports. The difference in the rate of PGST can be explained by differences in the research design across different studies. Active invitation of women in randomized clinical trials and prospective studies is more likely to have a positive effect on the PGST rate. Furthermore, a lower PGST rate in the present study might be attributed to reasons related to both physicians and patients. With regard to the physician-related factors, it is possible that some of the physicians in this hospital did not take PGST into account as part of their routine practice for the postpartum management for women with GDM during pregnancy, because they were unaware of or unfamiliar with this recommendation, forgot to order the test owing to heavy outpatient clinical load, or consciously ignored it, as they considered GDM to be a benign condition because most women with GDM have a favorable pregnancy outcome. With regard to the patient-related factors, the inconvenience of PGST and time utilization are the most commonly cited reasons for women with a history of GDM for not undergoing the PGST. A sn e a r l yo n e-third of the women with GDM were noted to have abnormal PGST results, it is important to remind or educate obstetricians of the necessity to carry out this screening test to identify women with GDM at risk for metabolic disorders later in life. Furthermore, the use of a variety of proactive patient contact programs, such as phone calls, education programs or postal reminders, has been shown to increase the PGST rate.

Table 2 | Pregnancy outcomes of the women who did and who did not undergo the postpartum glycemic screening test

| Variable                                           | Not screened (n = 1,189) | Screened (n = 507) | P     |
|---------------------------------------------------|-------------------------|--------------------|-------|
| Gestational age (weeks)                           | 37.7 ± 2.4              | 37.9 ± 2.4         | 0.072 |
| Birthweight (g)                                   | 3,049 ± 595             | 3,082 ± 589        | 0.286 |
| Male fetus                                        | 647 (5.4%)              | 249 (4.9%)         | 0.049 |
| Preterm birth <34 weeks                           | 53 (4.5%)               | 18 (3.6%)          | 0.430 |
| Preterm birth <37 weeks                           | 227 (19.1%)             | 69 (13.6%)         | 0.006 |
| Birthweight <1,500 g                              | 24 (2.0%)               | 10 (2.0%)          | 1.000 |
| Birthweight <2,500 g                              | 165 (13.9%)             | 54 (10.7%)         | 0.082 |
| Birthweight >4,000 g                              | 35 (2.9%)               | 19 (3.7%)          | 0.450 |
| Small-for-gestational age infants                  | 99 (8.4%)               | 32 (6.3%)          | 0.165 |
| Large-for-gestational age infants                  | 175 (14.8%)             | 65 (12.9%)         | 0.323 |
| 1-min Apgar score <7                               | 21 (1.8%)               | 14 (2.8%)          | 0.194 |
| 5-min Apgar score <7                               | 10 (0.8%)               | 5 (1.0%)           | 0.780 |
| Neonatal intensive care unit admission            | 72 (6.1%)               | 30 (5.9%)          | 1.000 |
| Fetal death                                       | 6 (0.5%)                | 5 (1.0%)           | 0.321 |
| Neonatal death                                    | 1 (0.1%)                | 0                  | 1.000 |
| Congenital anomaly                                | 11 (0.9%)               | 10 (2.0%)          | 0.092 |
| Premature rupture of membranes                    | 35 (2.9%)               | 13 (2.6%)          | 0.751 |
| Meconium-stained fluid                            | 104 (8.7%)              | 39 (7.7%)          | 0.505 |
| Oligohydramnios                                   | 12 (1.0%)               | 5 (1.0%)           | 1.000 |
| Polyhydramnios                                    | 9 (0.8%)                | 2 (0.4%)           | 0.522 |
| Acute chorioamnionitis                            | 5 (0.4%)                | 5 (1.0%)           | 0.176 |
| Placental abruption                               | 18 (1.5%)               | 5 (1.0%)           | 0.495 |
| Placenta previa                                   | 34 (2.9%)               | 5 (1.0%)           | 0.020 |
| Placenta accreta                                  | 6 (0.5%)                | 2 (0.4%)           | 1.000 |
| Postpartum hemorrhage                             | 20 (1.7%)               | 7 (1.4%)           | 0.833 |
| Severe perineal injury                            | 68 (5.7%)               | 46 (9.1%)          | 0.015 |

Data are presented as a number (%) or the mean ± standard deviation. P-values are based on the χ²-test, Fisher’s exact test or Student’s t-test.

Table 3 | Factors associated with undergoing the postpartum glycemic screening test in women with gestational diabetes mellitus

| Variable                                           | Adjusted OR (95% CI) | P       |
|---------------------------------------------------|----------------------|---------|
| Operative vaginal delivery                        | 1.87 (1.11–3.15)     | 0.018   |
| Insulin therapy during pregnancy                  | 1.63 (1.10–2.40)     | 0.015   |
| Family history of diabetes mellitus               | 1.30 (1.05–1.61)     | 0.018   |
| Male fetus                                        | 0.78 (0.63–0.97)     | 0.027   |
| Preterm birth <37 weeks                           | 0.65 (0.47–0.90)     | 0.009   |
| Cesarean delivery                                 | 0.84 (0.67–1.06)     | 0.141   |
| Placenta previa                                   | 0.46 (0.18–1.20)     | 0.112   |
| Severe perineal injury                            | 1.27 (0.83–1.93)     | 0.273   |

CI, confidence interval; OR, odds ratio.

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Table 4 | Maternal characteristics of the women with normal and abnormal postpartum glycemic screening results

| Maternal characteristics of the women with normal and abnormal postpartum glycemic screening results | Normal (n = 331) | Prediabetes (n = 135) | Diabetes (n = 27) | P |
|--------------------------------------------------------------------------------------------------|-----------------|----------------------|-----------------|---|
| Age (years)                                                                                       |                 |                      |                 |   |
| 20–34                                                                                             | 128 (38.7%)     | 51 (37.8%)           | 10 (37.0%)      | 0.974 |
| >34                                                                                                | 203 (61.3%)     | 84 (62.2%)           | 17 (63.0%)      | 0.974 |
| Prepregnancy body mass index (kg/m²)                                                             |                 |                      |                 |   |
| <18.5                                                                                             | 35 (10.6%)      | 11 (8.1%)            | 0               | 0.047 |
| 18.5–24.9                                                                                         | 241 (72.9%)     | 83 (61.5%)           | 16 (59.3%)      | 0.032 |
| >24.9                                                                                             | 55 (16.6%)      | 41 (30.4%)**         | 11 (40.7%)**    | <0.001 |
| Weight gain during pregnancy (kg)                                                                | 11.2 ± 4.4      | 10.2 ± 4.4***        | 10.1 ± 5.8      | 0.064 |
| Primiparity                                                                                       | 188 (56.8%)     | 77 (57.0%)           | 12 (44.4%)      | 0.452 |
| Cesarean delivery                                                                                 | 128 (38.7%)     | 66 (48.9%)*          | 17 (63.0%)*     | 0.012 |
| Operative vaginal delivery                                                                        | 24 (7.3%)       | 7 (5.2%)             | 1 (3.7%)        | 0.573 |
| History of induced or spontaneous abortions                                                       | 117 (35.3%)     | 35 (25.9%)           | 8 (29.6%)       | 0.130 |
| History of fetal death                                                                           | 2 (0.6%)        | 5 (3.7%)*            | 1 (3.7%)        | 0.048 |
| History of preterm birth                                                                         | 1 (0.3%)        | 2 (1.5%)             | 0              | 0.337 |
| Conception through reproductive technology                                                        | 17 (5.1%)       | 9 (6.7%)             | 2 (7.4%)        | 0.756 |
| Cigarette smoking during pregnancy                                                               | 1 (0.3%)        | 0 (0.0%)             | 0              | 0.671 |
| Multiple gestation                                                                               | 11 (3.3%)       | 3 (2.2%)             | 0              | 0.364 |
| Genetic amniocentesis                                                                            | 150 (45.3%)     | 67 (49.6%)           | 15 (55.6%)      | 0.187 |
| Uterine fibroids                                                                                  | 13 (3.9%)       | 8 (5.9%)             | 0              | 0.195 |
| Group B streptococcal colonization                                                               | 53 (16%)        | 29 (21.5%)           | 3 (11.1%)       | 0.252 |
| Chronic hypertension                                                                             | 1 (0.3%)        | 3 (2.2%)             | 1 (3.7%)        | 0.085 |
| Pre-eclamps                                                                                      | 8 (2.4%)        | 5 (3.7%)             | 2 (7.4%)        | 0.384 |
| Hyperthyroidism                                                                                  | 6 (1.8%)        | 1 (0.7%)             | 1 (3.7%)        | 0.488 |
| Hypothyroidism                                                                                   | 0              | 1 (0.7%)             | 0              | 0.273 |
| Family history of diabetes mellitus                                                              | 165 (50.0%)     | 66 (48.9%)           | 16 (59.3%)      | 0.610 |
| History of gestational diabetes                                                                  | 16 (48%)        | 11 (8.1%)            | 1 (3.7%)        | 0.362 |
| Insulin therapy during pregnancy                                                                 | 17 (5.2%)       | 17 (12.7%)**         | 14 (51.9%)**    | <0.001 |

Data are presented as a number (%) or the mean ± standard deviation. Prediabetes includes isolated impaired fasting glucose, isolated impaired glucose intolerance and impaired fasting glucose combined with impaired glucose intolerance. P-values are based on the logistic regression or Kruskal–Wallis test. *p < 0.05; **p < 0.01; ***p < 0.001, compared with women with normal postpartum glycemic screening results.

It has been shown that the incidence of GDM increases with the adoption of a one-step approach and the IADPSG criteria than with other screening strategies and diagnostic criteria. However, the effect of implementing the IADPSG criteria on the rate of abnormal glucose metabolism immediately in the postpartum period or several years after delivery remains unclear. In a recent meta-analysis of eight studies, published between 2003 and 2015, among Asian women with a history of GDM based on non-IADPSG criteria, the rates of diabetes and prediabetes diagnosed at 4–12 weeks postpartum were in the range of 8.2–20.6% (mean 13.9%) and 15.5–41.8% (mean 28.3%), respectively. These results are higher than those in the present study. It is possible that our adoption of the IADPSG criteria identifies more women with mild disease than those with other GDM criteria. These women with mild GDM return to a euglycemic state either after delivery of the placenta or as a result of lifestyle modification, thereby reducing the rate of postpartum diabetes and prediabetes.

Furthermore, the risk factor profile for abnormal PGST results could be affected by the diagnostic criteria used for GDM. Previous studies using non-IADPSG criteria reported that risk factors that are significantly associated with postpartum prediabetes and/or diabetes include a family history of diabetes, gestational age at diagnosis of GDM, insulin use during pregnancy and prepregnancy BMI. With the use of the IADPSG criteria for GDM, we found that women with GDM with a prepregnancy BMI >24.9 kg/m² are more likely to have prediabetes, whereas women with GDM receiving insulin therapy during pregnancy, a fetal birthweight >4,000 g or preterm birth <37 weeks of gestation are more likely to be diagnosed with diabetes at 6–12 weeks postpartum. Further studies are required to clarify the effect of implementing the IADPSG criteria for GDM on the rate and risk profile of abnormal glucose metabolism in the immediate postpartum period or several years after delivery.

Isolated IFG, isolated IGT and IGT plus IFG are generally considered as intermediate states in glucose metabolism disorders that exist between normal glucose tolerance and overt diabetes. The present study shows the different risk factor profiles among women with GDM with different abnormal PGST results, suggesting that different metabolic abnormalities characterize these conditions. Insulin resistance and impaired β-
cell function are the primary defects that are observed in type 2 diabetes mellitus patients. Both isolated IFG and isolated IGT are insulin-resistant states, with a difference in the location of the insulin resistance. Individuals with isolated IFG predominantly have hepatic insulin resistance and normal muscle insulin sensitivity, whereas those with isolated IGT have normal-to-slightly reduced hepatic insulin sensitivity and moderate-to-severe muscle insulin resistance. Previous studies showed that the pattern of impaired insulin secretion differs between the aforementioned two groups. Participants with isolated IFG manifest a decrease in basal insulin secretion and first-phase insulin release, whereas those with isolated IGT have severe impairment in both, first- and second-phase insulin responses to intravenous and oral glucose. Furthermore,

| Variable                                           | Model 1                      | Model 2                      |
|----------------------------------------------------|------------------------------|------------------------------|
|                                                    | Adjusted OR (95% CI)         | Adjusted OR (95% CI)         |
| Prepregnancy body mass index >24.9 kg/m²            | 1.87 (1.17–2.98)             | 1.99 (1.24–3.21)             |
| History of fetal death                             | 3.37 (0.72–15.69)            | 3.73 (0.68–20.49)            |
| Cesarean delivery                                  | 1.27 (0.84–1.91)             | 1.32 (0.86–2.02)             |
| Insulin therapy during pregnancy                   | 1.18 (0.61–2.28)             | 1.25 (0.63–2.50)             |
| Birthweight >4,000 g                               | –                            | 0.13 (0.02–1.07)             |
| Preterm birth <37 weeks                            | –                            | 0.60 (0.30–1.20)             |
| Birthweight <1,500 g                               | –                            | 5.26 (0.75–36.86)            |
| Large-for-gestational age infants                   | –                            | 0.87 (0.43–1.79)             |
| 1-min Apgar score < 7                              | –                            | 1.69 (0.40–7.20)             |

CI, confidence interval; OR, odds ratio.
individuals with IFG plus IGT manifest severe liver and muscle insulin resistance, as well as markedly impaired insulin secretion. Understanding of the risk factors and pathophysiological abnormalities that characterize isolated IFG, isolated IGT and IFG plus IGT provides insights on interventions to slow or halt the progression to type 2 diabetes mellitus. 

The present study was rigorous with regard to the use of patient interviews, the extraction of data from medical records and the application of multivariable logistic regression analysis that was adjusted for potential confounders. Therefore, the association between various maternal and pregnancy outcome variables and abnormal PGST results was objectively investigated. However, the present study had several limitations that merit attention. A major limitation was the possibility of selection bias because of the retrospective and observational design. Indeed, there were differences in the rate of certain maternal characteristics and pregnancy outcomes between women who chose to or not to undergo the PGST. These include operative vaginal delivery, insulin therapy during pregnancy, family history of diabetes and delivery of a male fetus or before 37 weeks of gestation. Future prospective studies might help clarify whether differences of these variables have a major impact on the findings of the present study. Next, some important factors that might have an effect on the development of postpartum glucose intolerance were not examined, because this information was unavailable from our obstetric database. These factors include the frequency and intensity of breastfeeding, and changes of bodyweight, physical activity and nutritional condition during the postpartum period. Furthermore, we did not measure the levels of glucose and insulin for homeostatic model assessments to assess β-cell function and insulin resistance in women with different abnormal postpartum glycemic metabolism disorders. Finally, the present study was carried out at a single tertiary care hospital in Taiwan, thereby limiting the generalizability of the conclusions.

In summary, the rate of PGST is suboptimal in the Taiwanese female post-pregnancy population. Future work should focus on reducing the barriers to screening for both healthcare providers and women with GDM. More research is required to elucidate the effects of implementing the IADPSG criteria for GDM on the rate and risk profile of abnormal glucose metabolism during postpartum or metabolic and cardiovascular diseases later in life.

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DISCLOSURE
The authors declare no conflict of interest.

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SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table S1 | Maternal characteristics of the women with normal and different categories of abnormal postpartum glycemic screening results.

Table S2 | Pregnancy outcome of the women with normal and different categories of abnormal postpartum glycemic screening results.