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ORIGINAL ARTICLE

Predictors of type 2 diabetes among Taiwanese women with prior gestational diabetes mellitus

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Abstract

Aim: The aims of this study were to determine the blood glucose screening rate of Taiwanese post-partum women with gestational diabetes (GDM) and to identify the predictors of type 2 diabetes among Taiwanese women with GDM.

Methods: The medical records of 130 women with GDM, who were delivered at a hospital in southern Taiwan between 1997 and 2010, were retrospectively reviewed. The GDM diagnosis was performed according to the National Diabetes Data Group and Expert Committee Criteria. The 2010 American Diabetes Association diabetes diagnosis criteria were used to determine whether post-partum women subsequently developed type 2 diabetes.

Results: In total, 71 records (54.6%) included blood glucose testing after childbirth between the first month and the ninth year, and 29 records (22.3%) documented subsequent type 2 diabetes. In a multiple logistic regression analysis, the patients' pre-pregnancy body mass indices and insulin use during pregnancy were independently associated with subsequent type 2 diabetes.

Conclusion: In this study, documentation during pregnancy, which could have provided beneficial insights, was limited. Healthcare professionals should develop a program to improve the post-partum follow-up of women diagnosed with GDM.

Key words: gestational diabetes mellitus, nursing, Taiwan, type 2 diabetes.

INTRODUCTION

The prevalence of gestational diabetes mellitus (GDM) is increasing in the Asian population (Zhang *et al*., 2011). Prevalence in the Asian population is higher than that in the non-Hispanic white, African American, or Hispanic populations (Hedderson *et al*., 2012). A recent survey has shown that the GDM prevalence was 7.4% in Taiwan (Lin, Wen, Wu, & Huang, 2009). If maternal blood glucose is not well controlled during the prenatal period, fetal and newborn health can be affected by conditions such as macrosomia and hypoglycemia (Ohno, Sparks, Cheng, & Caughey, 2011). The children of mothers who were diagnosed with GDM are also more likely to be overweight or obese (Kim, England, Sharma, & Njoroge, 2011). GDM is associated with increased rates of pregnancy-induced hypertension, maternal injury during vaginal birth, and delivery by cesarean section (Beucher, Viaris de Lesegno, & Dreyfus, 2010; Gorgal *et al*., 2012). Although glucose metabolism returns to normal and insulin resistance dissipates in most women after childbirth, women with GDM are at a high risk of developing type 2 diabetes and cardiovascular disease when during middle age (Vrachnis *et al*., 2012).

A systematic review has indicated that women with GDM are at high risk of developing type 2 diabetes mellitus (Golden *et al*., 2009). A meta-analysis found that women with GDM were 7.43 times more likely to develop type 2 diabetes compared with women who had normoglycemic pregnancies (Bellamy, Casas, Hingorani, & Williams, 2009). An Australian survival analysis

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study has indicated that the cumulative probability of developing diabetes within 5 years is 8.1% in women with GDM (Lee, Hiscock, Wein, Walker, & Permazel, 2007). The American Diabetes Association recommends that women with GDM receive post-partum glucose screenings at 6–12 weeks post-partum and repeat the test at least once every 3 years until normal results are obtained (American Diabetes Association, 2008). Follow up after glucose testing is important because this testing can discourage women from maintaining unhealthy lifestyles and facilitate the early detection of pre-diabetes and treatment of diabetes (Feig, 2012). Diabetes prevention can also reduce the medical costs of type 2 diabetes and its complications (Herman, 2011).

Although post-partum glucose can be screened with a fasting plasma glucose test or an oral glucose tolerance test (OGTT), the fasting plasma glucose test is more acceptable for women (Bennett, Bolen, Wilson, Bass, & Nicholson, 2009). A systematic review article has identified 11 published studies that reported the rate of post-partum glucose screening among women with GDM ranged 34–73%; the studied countries including the USA, Australia, Turkey, Canada, and Poland (Tovar, Chasan-Taber, Eggleston, & Okene, 2011). Compliance with post-partum glucose screening and long-term follow up was low because women with GDM did not perceive that they were at risk of developing type 2 diabetes (England *et al.*, 2009).

Gestational diabetes mellitus and type 2 diabetes have several common risk factors, such as a high body mass index (BMI), glucose intolerance, and first-degree relatives with type 2 diabetes (Buchanan & Xiang, 2005). Women who use insulin during pregnancy and have high pre-pregnancy BMI are more likely to develop type 2 diabetes (Cheung & Helmink, 2006; Cho, Lim, Jang, Park, & Metzger, 2005; Lee *et al.*, 2007; Löbner *et al.*, 2006). Vambergue *et al.* (2008) found that a family history of diabetes is a significant predictor of subsequent type 2 diabetes among women with histories of GDM. A systematic review indicated that both fasting blood glucose and antepartum 2 h OGTT (75 g or 100 g) plasma glucose values were predictors of diabetes in women with histories of GDM (Golden *et al.*, 2009). Several studies have indicated that antepartum 1 h, 2 h, and 3 h plasma glucose levels were predictors of diabetes in women with histories of GDM (Lee *et al.*, 2007; Retnakaran *et al.*, 2009; Vambergue *et al.*, 2008).

The rate of women receiving post-partum screening varies by race and ethnicity, and Asian women receiving care from health maintenance organizations in the USA are more likely to receive post-partum screening (Tovar *et al.*, 2011). The reasons for the screening rate variation by ethnic group are unclear, but Dietz *et al.* (2008) found great variation in clinician orders by practice site. After performing a published work review, the present authors found only one study that explored the diabetes risk factors among Taiwanese women with GDM. This study investigated women with GDM who delivered at a medical center in Northern Taiwan and developed type 2 diabetes (Ho, Hsieh, Li, & Su, 2006). Thus, the objectives of the current study were to determine the blood glucose screening rate of post-partum women with GDM and to identify the predictors of type 2 diabetes among Taiwanese women with GDM.

METHODS

Setting and participants

A retrospective study design was used, and the data were collected in 2011 at a medical center in southern Taiwan. The annual birth rate at this medical center was approximately 500. Using the hospital tracking system and codes, the present authors identified 307 chart numbers from women discharged with the International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM) diagnosis code 648, indicating diabetes mellitus in the mother that was classified elsewhere between 1997 and 2010. The authors first excluded 91 chart numbers that were duplicates and then excluded 48 charts that could not be found. After reviewing the medical records, the authors excluded 38 charts belonging to women who had not actually delivered at this medical center, women who had histories of type 1 or type 2 diabetes, and women who did not have documented histories of GDM. A total of 130 eligible charts from women diagnosed with GDM were reviewed. The GDM diagnosis was based on a 1 hour plasma glucose level of 140 mg/dL or more (7.8 mmol/L) on the 50 g glucose challenge test, followed by at least two abnormal values on a 100 g OGTT. The abnormal values were based on the following American National Diabetes Data Group criteria: fasting glucose, 105 mg/dL or more (5.8 mmol/L); 1 h glucose, 190 mg/dL or more (10.5 mmol/L); 2 h glucose, 165 mg/dL or more (9.2 mmol/L); and 3 h glucose, 145 mg/dL or more (8.0 mmol/L).

Data collection

This study was approved by the institutional review board of Kaohsiung Medical University. A research assistant performed the data collection in November

2010 and March 2011. The data included the patient age at pregnancy, family history of diabetes, parity, pre-pregnancy BMI, results of 50 g and 100 g OGTT, insulin prescribed during pregnancy, total weight gain during pregnancy, delivery method, and newborn birthweight. A diagnosis of type 2 diabetes was based on the medical records after childbirth and was performed when any of the following criteria were met: glycated hemoglobin (HbA1c), 6.5% or more; fasting plasma glucose, 126 mg/dL or more (7.0 mmol/L); 2 h plasma glucose, 200 mg/dL or more (11.1 mmol/L) during an OGTT; or random plasma glucose, 200 mg/dL or more (11.1 mmol/L) in a patient with classic symptoms of hyperglycemia or a hyperglycemic crisis (American Diabetes Association, 2010).

Data analysis

All continuous variables are presented as the mean ± standard deviation. Means comparisons were performed using Student's *t*-test, whereas proportions were compared using the χ^2-test. Multivariate logistic regression was used to compute the odds ratios (OR) and 95% confidence intervals (95% CI). Stepwise selection was used to select the variables for inclusion in multivariate regression models. All tests of statistical significance were two sided, and statistical significance was defined at the $\alpha < 0.05$ level. Statistical analyses were performed using SPSS software version 17 (SPSS, Chicago, IL, USA). A statistical power analysis was performed using G*Power version 3.1.3 (http://www.gpower.hhu.de/) The present authors used a post-hoc analysis to compute the statistical power 1-β as a function of the significance level alpha, the sample size, and the population effect size (Faul, Erdfelder, Buchner, & Lang, 2009).

RESULTS

Among 130 Taiwanese women with GDM, 71 (54.6%) received blood glucose tests, including a 75 g OGTT, fasting blood glucose, or HbA1c test, after delivery. Thirty-four (47.9%) of these 71 women received blood glucose tests during their first 6 months post-partum, and 37 (52.1%) had their blood glucose tested between 6 months and 9 years post-partum. Twenty-nine (40.8%) of these 71 women had type 2 diabetes, whereas the remaining 42 did not have type 2 diabetes (59.2%). As shown in Table 1, the characteristics of the women who received post-partum blood glucose tests ($n = 71$, 54.6%) were not significantly different from the

Table 1 Characteristics of women with or without post-partum screening for diabetes ($n = 130$)

	Without screening ($n = 59$), mean ± SD/N (%)	With screening ($n = 71$), mean ± SD/N (%)	*P*
Age at pregnancy (years)	31.9 ± 5.0	31.7 ± 4.7	0.816
Family history of DM[†]			0.962
No	11 (28.2)	12 (25.5)	
Yes	28 (71.8)	35 (74.5)	
Parity			0.761
1	30 (50.8)	38 (53.5)	
2–5	29 (49.2)	33 (46.5)	
Pre-pregnancy BMI (kg/m^2)	23.6 ± 3.8	24.9 ± 4.1	0.101
Glucose challenge test (mg/dL)	191.0 ± 40.5	192.4 ± 50.1	0.884
Fasting glucose (mg/dL)	103.8 ± 34.230	108.26 ± 32.508	0.501
1 h glucose (mg/dL)	214.5 ± 35.7	221.8 ± 47.6	0.388
2 h glucose (mg/dL)	211.2 ± 42.8	219.5 ± 56.9	0.420
3 h glucose (mg/dL)	166.8 ± 49.4	173.6 ± 58.4	0.540
Insulin use during pregnancy			0.829
No	36 (61.0)	42 (59.2)	
Yes	23 (38.9)	29 (40.8)	
Total weight gain (kg)	12.3 ± 5.6	12.9 ± 7.2	0.635
Mode of delivery			0.559
Vaginal delivery	22 (37.3)	23 (32.4)	
Cesarean section	37 (62.7)	48 (67.6)	
Infant birthweight (g)	3,171.4 ± 617.6	3,271.6 ± 676	0.385

[†]Item with missing data. BMI, body mass index; DM, diabetes mellitus; SD, standard deviation.

Table 2 Characteristics of women with or without type 2 diabetes after childbirth ($n = 71$)

	Women without diabetes after childbirth ($n = 42$), mean ± SD/N (%)	Women with diabetes after childbirth ($n = 42$), mean ± SD/N (%)	*P*
Age at pregnancy (years)	31.7 ± 4.5	31.8 ± 4.9	0.938
Family history of DM†			0.052
No	10 (35.7)	2 (10.5)	
Yes	18 (64.3)	17 (89.5)	
Parity			0.222
1	25 (59.5)	13 (44.8)	
2–5	17 (40.5)	16 (55.2)	
Pre-pregnancy BMI (kg/m^2)	23.6 ± 3.7	26.4 ± 4.2	0.014
Glucose challenge test (mg/dL)	183.2 ± 37.7	214.1 ± 68.1	0.128
Fasting glucose (mg/dL)	95.76 ± 16.1	133.3 ± 42.0	0.001
1 h glucose (mg/dL)	206.3 ± 32.0	252.7 ± 58.7	0.004
2 h glucose (mg/dL)	197.6 ± 22.6	265.6 ± 77.8	0.002
3 h glucose (mg/dL)	155.6 ± 32.5	210.5 ± 80.3	0.011
Insulin use during pregnancy			<0.001
No	34 (81.0)	8 (27.6)	
Yes	8 (19.0)	21 (72.4)	
Total weight gain (kg)	12.1 ± 6.9	13.8 ± 7.5	0.395
Mode of delivery			0.023
Vaginal delivery	18 (42.9)	5 (17.2)	
Cesarean section	24 (57.1)	24 (82.8)	
Infant birthweight (g)	3,097.9 ± 668.5	3,532.3 ± 610.5	0.008

†Item with missing data. BMI, body mass index; DM, diabetes mellitus; SD, standard deviation.

women who did not receive post-partum blood glucose tests ($n = 59$, 45.4%).

Comparing the 29 women with diabetes and the 42 women without diabetes, the present authors found that the women with diabetes had higher pre-pregnancy BMI and higher blood glucose levels based on a 100 g OGTT. Furthermore, the proportion of women with an insulin prescription during pregnancy, the proportion of women experiencing childbirth by a cesarean section, and the newborn baby's birthweight were all higher among the women with diabetes than among the women without diabetes (Table 2). The statistical power of the difference between the two independent means (two groups) for pre-pregnancy BMI was 0.824. The statistical power of the difference between the two independent means (two groups) for the 100 g OGTT ranged 0.955–0.998. The statistical power of the difference between the two independent proportions for insulin prescription during pregnancy was 0.998. The statistical power of the difference between the two independent proportions for modes of delivery was 0.828. The statistical power of the difference between the two independent means for the newborn birthweight was 0.962.

The variables, including pre-pregnancy BMI, plasma glucose levels based on the 100 g OGTT, insulin prescription during pregnancy, newborn birthweight, and childbirth by cesarean section, were analyzed using multivariate logistic regression. The stepwise selection method (entry, $P \geq 0.05$; removal, $P \leq 0.05$) was used to select the independent variables. The final result showed that a high pre-pregnancy BMI (OR, 1.26; 95% CI, 1.01–1.11; $P = 0.017$) and insulin prescription during pregnancy (OR, 19.66; 95% CI, 4.00–96.70; $P \leq 0.001$) were important predictors of diabetes in women with GDM (Table 3).

Table 3 Multivariate logistic regression analyses for predicators of type 2 diabetes ($n = 71$)

	Multivariate	
	OR (95% CI)	*P*
Pre-pregnancy BMI (kg/m^2)	1.26 (1.04–1.52)	0.020
Insulin use during pregnancy		
Yes vs. No	19.66 (4.00–96.70)	<0.001

BMI, body mass index; CI, confidence interval; OR, odds ratio.

DISCUSSION

The present authors found that a low post-partum blood glucose screening rate among Taiwanese women with

GDM, a high pre-pregnancy BMI, and insulin prescription during pregnancy were important predictors of type 2 diabetes in women with GDM.

Compared with a systematic review that found rates of post-partum blood glucose screening from 34–73% (Tovar *et al*., 2011), the rates in the present authors' study were not high. The present study results aligned with a Taiwanese study that found a 54% rate (Lin, Wen, Wu, Hung, & Huang, 2005) of post-partum blood glucose screening.

The present authors found that the characteristics of participants between women, who received post-partum blood glucose screening and who did not, did not differ significantly. Thus, future studies should be performed to identify the facilitators for women to receive post-partum blood glucose screening. If healthcare professionals can identify the facilitators that encourage women with GDM to receive post-partum blood glucose screening, they could design an intervention protocol. A recent study indicated that improved communication between healthcare providers, obstetrics and gynecology care providers, and endocrinologists, and establishing a reminder system could increase post-partum glucose screening in women with GDM (Korpi-Hyövälti, Laaksonen, Schwab, Heinoen, & Niskanen, 2012). However, there was little evidence showing that a reminder system could increase the acceptance of testing for type 2 diabetes in women who had a history of GDM (Middleton & Crowther, 2014). Further studies are needed to explore why some post-partum women do not take the blood glucose screening later.

The present authors found that among women with GDM, pre-pregnancy BMI; fasting, 1 h, 2 h, and 3 h blood glucose levels determined by a 100 g OGTT; insulin prescription during pregnancy; cesarean section delivery; and newborn birthweight differed significantly between the women with diabetes and the women without diabetes. The finding of this study was similar to the results of other studies (Golden *et al*., 2009; Ho *et al*., 2006; Lin *et al*., 2005; Retnakaran *et al*., 2009). A previous Taiwanese study also found that the fasting blood glucose level, as determined by a 100 g OGTT, was a diabetes risk factor (Lin *et al*., 2005). Another Taiwanese study found that the 1 h blood glucose level, as determined by a 100 g OGTT, was a risk factor for subsequent diabetes among women with GDM (Tseng, 2008). There were other diagnostic criteria for GDM. Golden *et al*. (2009) found that the fasting and the 2 h plasma glucose levels on an OGTT of pregnant women with a diagnosis of GDM were also significant predictors of T2DM based on either a 3 h 100 g OGTT or a 2 h 75 g OGTT.

Based on the multivariate logistic regression analysis, insulin prescription during pregnancy is the main predictor of type 2 diabetes among Taiwanese women with GDM. This finding confirms the results of previous studies in other countries (Löbner *et al*., 2006). Lee *et al*. (2007) analyzed 3578 women with GDM in Australia, and their results also indicated that insulin prescription during pregnancy was the key predictor of type 2 diabetes in post-partum women.

The current study indicated that a higher pre-pregnancy BMI among women with GDM was an important predictor of diabetes. This finding was consistent with the results of previous studies (Ho *et al*., 2006; Lin *et al*., 2005; Löbner *et al*., 2006). Healthcare providers could use this information to warn these women and increase their perceived susceptibility and threat of type 2 diabetes based on the "health belief model" (Becker, 1974). Healthcare providers could then intervene via lifestyle modulation programs during pregnancy to increase the likelihood of behavioral changes in these women.

Most previous studies have found that women with GDM were more likely to undergo non-elective cesarean sections and to have newborns with high birthweights (Gorgal *et al*., 2012, HAPO Study Cooperative Research Group *et al*., 2008). However, few studies have explored the association between cesarean sections, newborn birthweights, and diabetes. This study showed that neither cesarean section nor newborn birthweight were risk factors for diabetes in Taiwanese women with GDM. More studies are needed to confirm the findings of the present study.

Several studies have indicated that a family history of diabetes is a risk factor for diabetes among women with GDM (Jang, 2011; Tseng, 2008). However, the results of the current study were not consistent with this finding, most likely because of the retrospective study design and review of medical records because the data regarding family history were not completed in the medical records.

Limitations of the study

For the aim to identify the predictors of type 2 diabetes among Taiwanese women with GDM, the present authors included only 42 women without diabetes after childbirth and 29 women with diabetes after childbirth. Moreover, the participants were identified based on medical charts from one hospital; therefore, the documentation during their pregnancies, which could have provided beneficial insights, was limited. This study was a retrospective study that examined the post-partum

blood glucose screening rate and predictors of post-partum type 2 diabetes. Future studies might be designed as prospective studies with a larger sample size and might explore the relationship between the post-partum lifestyles of women with prior GDM and the risk of post-partum type 2 diabetes.

CONCLUSION

In conclusion, only half of the women with GDM in the present authors' study received post-partum blood glucose screenings. Pre-pregnancy BMI and insulin use during pregnancy were the most important predictors of diabetes in Taiwanese women with GDM. GDM is not only a high-risk prenatal disease in women but also a warning sign with health implications for mothers and their children. Unfortunately, many women with GDM are unaware of the potential risk to their health and miss opportunities for early protection. Therefore, healthcare professionals should regularly assess women's pre-pregnancy BMI and insulin use during pregnancy. The professionals should then educate women to create and maintain healthy lifestyles and emphasize the importance of regular blood glucose monitoring.

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CONFLICTS OF INTEREST

The authors have no conflict of interests.

AUTHOR CONTRIBUTIONS

C.-H. H. and P.-C. L. contributed to the conception and design of this study; P.-C. L. performed the data collection and statistical analysis and drafted the manuscript; C.-H. H. critically reviewed the manuscript and supervised the whole study process; and R. D. H. and T. F. C. performed the data collection.

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