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Effect of postpartum glucose tolerance results on subsequent weight retention in women with recent gestational diabetes: A retrospective cohort study

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ABSTRACT

Aims: Glucose tolerance normalizes postpartum in most women with gestational diabetes (GDM), which may provide false reassurance and decrease weight-reducing behaviours. We evaluated whether awareness of normal postpartum glucose tolerance was associated with higher weight retention than being unaware of glucose tolerance.

Methods: This cohort study of women with GDM collected survey data during pregnancy and in the first and second postpartum year. We compared women who reported normal glucose tolerance ('aware, normal') in the first year to those reporting no testing or unsure of results ('unaware'). The primary outcome was self-reported weight in the second year compared between groups using multivariable linear regression.

Results: Among 319 women, 110 (34.5%) were 'aware, normal'; 183 (57.4%) were 'unaware'; and 26 (8.2%) were 'aware, abnormal'. After adjusting for baseline weight and covariates, women with normal results had a mean 3.66 kg higher weight (CI 1.08–6.24 kg, $p = 0.0056$) by the second year than those unaware of results.

Conclusions: Women with GDM with normal postpartum glucose tolerance had significantly higher weight by the second year than those unaware of their results. Normal glucose tolerance after pregnancy may be misinterpreted as resolution of diabetes risk and decrease risk-reducing behaviours.

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1. Introduction

Gestational diabetes mellitus (GDM) is not only associated with fetal complications [1], but is a predictor for future diabetes risk in women [2]. Women with GDM have a 7-fold higher chance of diabetes compared to women without GDM and 20% develop diabetes within a decade [2,3]. As lifestyle changes have been associated with prevention of diabetes in high-risk populations, health behaviour modification is recommended after a GDM delivery [4,5]. Most guidelines also advise testing for persistent glucose intolerance with a 75-gram Oral Glucose Tolerance Test (OGTT) within 6 months after delivery [4,5]. While 60–80% of women revert to normal glucose tolerance in the postpartum period [6–9], they nonetheless remain at risk of progression to diabetes and would benefit from risk-reducing strategies. However, without appropriate counseling, women with a normal postpartum glucose test may be falsely reassured that the problem has resolved and they are no longer at risk of diabetes.

Indeed, evidence indicates that less than one third of women with GDM identify themselves at high risk of diabetes [10–12]. This is important, as those with a high diabetes risk perception are more likely to make positive behaviour changes [10]. With the added responsibility of caring for a newborn, postpartum women often discard healthy lifestyle behaviours that were recommended during pregnancy [10,13,14]. More than two thirds of women with recent GDM do not return to pre-pregnancy weight after delivery [15], which has been associated with a higher risk of diabetes [16,17], obesity [18], and cardio metabolic complications [19]. Under such circumstances, it is imperative to consider the implications of inadequate risk communication for women whose blood glucose values return to the "normal" range after delivery. In addition to the barriers associated with new motherhood, normal test results may further impede motivation for risk-reducing behaviours and weight loss after delivery. There have been no studies to our knowledge that have evaluated this possibility.

In that context, our objective was to determine whether postpartum women with recent GDM who report normal postpartum glucose tolerance have higher subsequent weight retention after one year as compared to those who are unaware of their results. As a secondary objective, we compared women who reported normal versus abnormal glucose tolerance.

2. Subjects, materials and methods

2.1. Study population and data sources

This retrospective cohort study was part of a larger prospective cohort study of patients with GDM from 6 centres from Ontario, Canada. All women with GDM at these centres attend specialized diabetes clinics during which they receive nutritional and pharmacologic management to maintain glycemic control. They are also educated regarding maternal risk of diabetes after pregnancy, and the need for lifestyle modification to reduce that risk. The overall objective of that study was to evaluate barriers and facilitators for diabetes prevention and risk factors for diabetes in women with GDM [20]. That cohort study from 2009 to 2013 recruited women aged 18 years or older with physician-diagnosed GDM after 24 weeks gestation based on Canadian diagnostic criteria [4]. Exclusion criteria included inability to speak English, known pre-pregnancy type 1 or type 2 diabetes or any other medical or fetal complication. Participants were asked to complete self-administered questionnaires at three time points: once during pregnancy (in-pregnancy), at 3–11 months postpartum (early postpartum) and at 12–24 months postpartum (late postpartum). Women from the baseline cohort who self-reported a new diagnosis of diabetes or pregnancy were excluded from the postpartum surveys. Clinical data were also collected from medical charts [20]. The population for this study included all women who completed the survey at all 3 timepoints.

2.2. Exposure assessment

The primary exposure was self-reported awareness of postpartum blood glucose tolerance, which was defined based on responses to two questions in the early postpartum (3–11 months) questionnaire: (1) *"Have you had a diabetes test SINCE after delivering your baby?*" (yes/no) and (2) "*What were the results of your diabetes test?*" (normal/borderline/diabetes/not sure). We categorized awareness into three mutually exclusive categories: (1) *'aware, normal'* if they answered 'yes' to the first question and 'normal' to the second question; (2) *'unaware'* if they answered the first question as 'no', or as 'yes' with the second question as 'unsure'; and (3)*'aware, abnormal'* if they answered 'yes' to the first question and 'borderline' or 'diabetes' to the second question.

Women with ambiguous answers, such as reporting not having the test but still reporting knowledge of results or reporting having the test but not answering the second question, were excluded.

2.3. Outcome assessment

The primary outcome was self-reported weight (kilograms [kg]) at late postpartum (12–24 months). Women with nonsensical or missing weight data were excluded. We also evaluated body-mass index [BMI, based on weight in kilograms over self-reported height in meters squared (kg/m^2)] at late postpartum as a secondary outcome. Other secondary outcomes were self-reported diabetes risk perception, physical activity level and diet at early postpartum as previously defined [20].

2.4. Covariate assessment

We recorded baseline data from the in-pregnancy and early postpartum questionnaires, including weight, age, annual household income, immigration status, ethnicity, breastfeeding, physical activity and diet [20]. We also collected data from medical charts on family history of type 2 diabetes, previous GDM, and requirement of insulin during pregnancy.

2.5. Statistical analysis

We identified potential covariates based on theory and evidence from scientific literature. We examined the distributions for homogeneity, and covariates with minimal variation between the exposure groups were excluded. Among covariates demonstrating high collinearity, the more relevant ones were included in the models. Based on these steps we selected the covariates that were included in the final statistical models.

The primary analysis compared outcomes of the 'aware, normal' group to the 'unaware' group. Secondarily, we compared outcomes of the 'aware, normal' group to the 'aware, abnormal' group. Associations between exposures at early postpartum and continuous weight and BMI outcomes at late postpartum were analysed using multivariable linear regression models. We analysed associations with binary outcomes using multivariable logistic regression models.

There was a high loss-to-follow up from early postpartum (N = 700) to late postpartum (N = 356) in the original cohort. We created a multivariable logistic regression model using the entire cohort who had completed the early postpartum survey to estimate the probability of completing the late postpartum survey. The inverse of these predicted probabilities were used as weights in regression models for outcomes to perform an inverse probability weighted (IPW) analysis.

We used analysis of variance (ANOVA) to test significance of the regression models and individual covariates, with an alpha value of 0.05 for significance. We conducted model diagnostics including residual analysis and checking for multicollinearity (variance inflation factors) and heteroscedasticity (residual plots). Missing data were excluded from descriptive statistics and multivariate analyses. All analyses were carried out in R version 3.5.1. The final models were assessed for over-fitting and optimism using the bootstrap with 1000 iterations.

2.6. Sensitivity analysis

It is possible that women who reported completing the OGTT but being unsure of the results were informed of results during the follow-up period. To address this concern, we repeated the analyses limiting the 'unaware' category to women who did not complete the OGTT. Finally, to address the possibility that higher-weight women were both more likely to do the postpartum OGTT and to retain weight (selection bias), we conducted another sensitivity analysis restricting the sample to women who had done the OGTT comparing the 'aware, normal' women to 'unaware' women who did the test but were unsure of results.

2.7. Ethics

Ethics approval was obtained from the Institutional Review Board of Women's College Hospital and from all participating recruitment sites.

3. Results

3.1. Baseline data

From the initial cohort of 1353 women, 700 (51.7%) women completed the first 2 surveys and 356 (26.3%) women completed the all 3 surveys. We included a final sample of N = 319 in our study after applying exclusions (Fig. 1). Among these, 110 (34.5%) were categorized as 'aware, normal'; 26 (8.15%) as 'aware, abnormal'; and 183 (57.4%) as 'unaware'. Among the 183 'unaware' participants, 150 participants reported not doing the test and 33 participants reported doing the test but being unsure of results. Baseline data were similar between the 2 'unaware' groups, except for mean baseline weight, which was higher in women who did not do the test (72.8 ± standard deviation, SD 21.5 kg) versus 68.2 ± 13.9 kg). Table 1 provides baseline data stratified by awareness status. The mean ± SD age was 34.6 ± 4.31 years, almost half of the study population (47.4%) were non-Caucasian and 45.8% were born outside of Canada. Baseline variables were comparable between the 'aware, normal' and 'unaware' groups. The 'aware, abnormal' group had higher baseline weight, and were more likely to have required insulin during pregnancy and be of non-Caucasian ethnicity than the other two groups. The 'aware, normal' group completed the early postpartum questionnaire at a modestly later time than the 'unaware' group (5.10 ± 2.16 versus 4.25 ± 1.82 months postpartum). There were no differences in the average time of completion of the late postpartum questionnaire between groups (15.4 [SD = 2.75] versus 15.8 [SD = 2.79]).

3.2. 'Aware, normal' versus 'unaware'

The weight and BMI outcome results for the primary analysis are presented in Table 2. The mean weight of the 'aware, normal' group at late postpartum was 74.8 kg (SD = 22.1) compared to 68.6 kg (SD = 16.7) in the 'unaware' group at late postpartum. The 'aware, normal' group gained a mean 0.414 kg (SD = 8.67) compared to a mean 3.13 kg (SD = 12.7) weight loss in the 'unaware' group between early and late postpartum. The average postpartum follow up time was comparable between the two groups (10.3 [SD = 3.17] versus 11.5 months [SD = 3.43]). After adjustment for baseline weight and selected covariates and inverse probability weight for completing the late postpartum questionnaire, the 'aware, normal' group had a mean 3.66 kg higher weight (95% confidence interval, CI 1.08–6.24, p = 0.0056) at late postpartum compared to the 'unaware' group.

The 'aware, normal' group also had a higher mean BMI (28.0 kg/m^2 [SD = 7.57]) than the 'unaware' group (25.8 kg/m^2 [SD = 5.83]) at late postpartum. This constituted a mean 0.114 kg/m^2 (SD = 3.15) gain in BMI for the 'aware, normal' group compared to a mean 1.18 kg/m^2 (SD = 4.78) loss in BMI in the 'unaware' group. Multivariate regression model estimated that the "aware normal" group had a significantly higher mean 1.34 kg/m^2 BMI (N = 228, 95% CI 0.385–2.30,

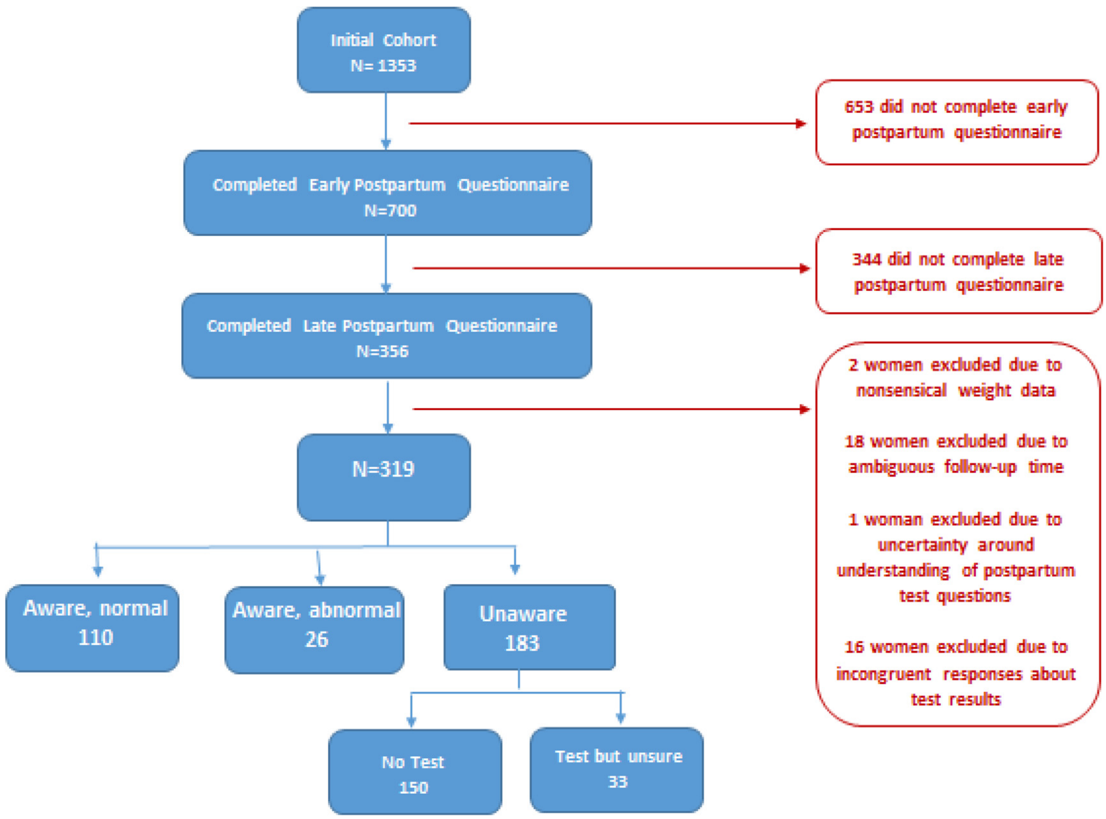

Fig. 1 – Consort diagram of cohort selection criteria.

p = 0.0062) compared to the "unaware" group. The bootstrap validation suggested only a small degree of optimism. In both cases, the R^2 of the fitted models were inflated by about 0.06. The corrected R^2 for the weight model was 0.72, down from 0.78 while the corrected R^2 for the BMI model was 0.69, down from 0.75.

There were no significant differences between the 'aware, normal' and 'unaware' groups in likelihood of high diabetes risk perception (N = 254, OR 1.67, 95% CI 0.852–3.28, p = 0.135); adequate fruit and vegetable intake (N = 256, OR 0.590, 95% CI 0.329–1.06, p = 0.076); or engagement in moderate or vigorous activity (N = 256, OR 0.865, 95% CI 0.501–1.49, p = 0.601).

3.3. *'Aware, normal' versus 'aware, abnormal'*

Table 3 shows the weight and BMI outcome results comparing the 'aware, normal' group (N = 110) to the 'aware, abnormal' group [N = 26], who had a mean weight of 72.5 kg (SD = 23.8) and BMI of 26.4 kg/m^2 (SD = 7.86) at late postpartum. The average follow up time in the "aware, abnormal" group was similar to the "aware, normal" group, (10.2 months [SD = 2.23]). Those who reported abnormal results lost an average of 2.66 kg (SD = 8.06) in weight and 0.914 kg/m^2 (SD = 2.65) in BMI during the follow-up period. After adjustment for baseline weight and covariates, those who reported normal results had a non-significant 2.37 kg higher mean weight (N = 108, 95% CI −0.636 to 5.38, p = 0.121) and a 0.821 kg/m^2 higher mean BMI (N = 108, 95% CI −0.263 to 1.91, p = 0.136) at late postpartum than those who reported abnormal results.

3.4. *Sensitivity analysis*

Results were similar when we repeated the analyses after excluding women who reported completing the OGTT but being unsure of their results (N = 33), limiting the 'unaware' group to women who did not do the postpartum OGTT (N = 150). Compared to this group, after adjustment for covariates the 'aware, normal' group had a significant mean 3.90 kg higher weight (N = 199, 95% CI 1.03–6.76, p = 0.0080) and 1.43 kg/m^2 higher BMI (N = 199, 95% CI 0.359–2.49, p = 0.009) at late postpartum. When we restricted the "unaware" group to only women who did the test and were unsure of their test results (N = 33), after adjustment for covariates the 'aware, normal' group had a non-significant mean 1.53 kg higher weight (N = 116, 95% CI −0.520 to 3.58, p = 0.142) and 0.570 kg/m^2 higher BMI (N = 116, 95% CI −0.206 to 1.35, p = 0.148) at late postpartum.

4. Discussion

This cohort study of women with GDM found that awareness of postpartum glucose tolerance status had a significant impact on subsequent weight changes. After adjustment for baseline weight and other factors, women who reported normal postpartum glucose tolerance had a mean 4 kg higher weight by the second postpartum year than women who did

Table 1 – Baseline variables of cohort, by exposure status (awareness of postpartum OGTT results).

Baseline variables	Total cohort (N = 319)	Awareness of postpartum OGTT results: Aware, normal (N = 110)	Aware, abnormal (N = 26)	Unaware (N = 183)
Age (years), mean (SD)	34.6 (4.31)	34.0 (4.33)	34.6 (4.24)	35.9 (4.29)
Parity > 1, N(%)	158 (50.3%)	48 (43.6%)	12 (50%)	98 (54.4%)
Non-Caucasian. N(%)	148 (47.4%)	53 (48.6%)	14 (56.0%)	81 (45.5%)
Born outside of Canada, N(%)	146 (45.8%)	49 (44.5%)	15 (57.7%)	82 (44.8%)
Income > $60,000, N(%)	245 (77.8%)	82 (75.9%)	20 (76.9%)	143 (79.0%)
University/college education, N(%)	300 (94.3%)	106 (96.4%)	24 (92.3%)	170 (93.4%)
Family history T2DM, N(%)	133 (41.7%)	50 (45.5%)	11 (42.3%)	72 (39.3%)
History of GDM, N(%)	45 (14.1%)	17 (15.5%)	3 (11.5%)	25 (13.7%)
Insulin use in pregnancy, N(%)	126 (41.7%)	44 (42.3%)	14 (58.3%)	68 (39.1%)
Weight (kg), mean (SD)				
Pre-pregnancy	71.1 (20.1)	73.6 (22.2)	75.3 (26.0)	69.0 (17.5)
Early postpartum	73.1 (20.9)	74.4 (21.2)	76.3 (23.8)	71.9 (20.4)
Body Mass Index (Kg/m^2), mean (SD)	27.4 (7.30)	27.9 (7.47)	27.4 (7.63)	27.1 (7.17)
Breastfeeding, N(%)	214 (67.1%)	74 (67.3%)	17 (65.4%)	123 (67.2%)
Months since delivery, mean (SD)				
Early postpartum questionnaire	4.60 (2.00)	5.10 (2.16)	4.92 (2.06)	4.25 (1.82)
Late postpartum questionnaire	15.6 (2.75)	15.4 (2.75)	15.1 (2.52)	15.8 (2.79)

OGTT = oral glucose tolerance test; SD = standard deviation; N = number; T2DM = type 2 diabetes; GDM = gestational diabetes mellitus.
Note: all totals will not add up to 100 because of missing responses.

Table 2 – Results for late postpartum weight and BMI between women who reported normal OGTT results and women who reported being unaware of OGTT results, multivariable linear regression.

	Aware, normal (N = 110)	Unaware (N = 183)	Mean (95% CI) difference, adjusted[a]	P-value
Weight (kg) late postpartum, mean (SD)	74.8 (22.1)	68.6 (16.7)	3.66 (1.08–6.24)	0.0056
Weight change (kg) early to late postpartum, mean (SD)	0.414 (8.67)	−3.13 (12.7)	–	
BMI (kg/m^2) late postpartum, mean (SD)	28.0 (7.57)	25.8 (5.84)	1.34 (0.385–2.30)	0.0062
BMI change (kg/m^2) from early to late postpartum, mean (SD)	0.114 (3.15)	−1.18 (4.78)	–	

OGTT = oral glucose tolerance test; CI = confidence interval; SD = standard deviation; BMI = body-mass index, NS = not significant.
[a] Linear regression adjusted for weight/BMI at early postpartum, age, ethnicity, income, immigration status, family history of T2DM, history of GDM, Insulin use, breastfeeding, physical activity, fruit and vegetable intake, follow-up time, and propensity weight for completing late postpartum survey.

Table 3 – Results for late postpartum weight and BMI between women who reported normal OGTT results and women who reported abnormal OGTT results, multivariable linear regression.

	Aware, normal (N = 110)	Aware, abnormal (N = 26)	Mean (95% CI) difference, adjusted[a]	P-value*
Weight (kg) late postpartum, mean (SD)	74.8 (22.1)	72.5 (23.8)	2.37 (−0.636 to 5.38)	NS (0.121)
Weight change (kg) early to late postpartum, mean (SD)	0.414 (8.67)	−2.06 (8.06)	–	
BMI (kg/m^2) late postpartum, mean (SD)	28.0 (7.57)	26.4 (7.86)	0.821 (−0.263 to 1.91)	NS (0.14)
BMI change (kg/m^2) from early to late postpartum, mean (SD)	0.114 (3.15)	−0.914 (2.65)	–	

OGTT = oral glucose tolerance test; CI = confidence interval; SD = standard deviation; BMI = body-mass index, NS = not significant.
[a] Linear regression adjusted for weight/BMI at early postpartum, age, ethnicity, income, immigration status, family history of T2DM, history of GDM, Insulin use, breastfeeding, physical activity, fruit and vegetable intake, follow-up time, and propensity weight for completing late postpartum survey.

not know their results. Their weight was also 2 kg higher than those who reported abnormal glucose tolerance, although this was not statistically significant due to small numbers in the latter group. Women with GDM with resolution of glucose intolerance after delivery may be less likely to engage in risk-reducing behaviours, placing them at greater risk of postpartum weight retention and subsequent diabetes [16].

To our knowledge, this is the first study investigating how awareness of postpartum glucose results might affect subsequent diabetes risk factors in women with recent GDM. As this is a population with a high incidence of early diabetes [2], efforts to improve modifiable risk factors are essential. GDM is associated with a 7-fold higher risk of diabetes [2], and 20% develop diabetes within the first decade [2,3]. Postpartum weight retention, a common modifiable risk factor in women with GDM [15], is an important contributor to this progression [16,17,19]. One study that followed women with GDM for an average 7.5 years after delivery, found that each 4.5 kg (10 lbs) increase in weight was associated with a two-fold higher risk of diabetes [16]. These findings underscore the importance of promoting weight-reducing interventions in women with GDM despite normal glucose results after delivery.

To address their higher risk of diabetes, behaviour counseling is recommended for all women with GDM with a focus on weight loss interventions [4,5]. However lifestyle advice given during pregnancy is often abandoned after delivery when they are no longer being actively managed for GDM [13]. Women with previous GDM are less likely to engage in healthy behaviours after pregnancy [10,13,21–23], and more than two thirds do not return to their pre-pregnancy weight [15]. Few postpartum behaviour programs exist for women with GDM, despite their proven ability to reduce diabetes in high-risk populations [24–26] and promote weight loss in women with recent GDM [27]. Postpartum interventions have been hampered by low patient engagement and high drop-out rates, which has been attributed to the competing demands of new motherhood [27]. Our study suggests that focusing on short-term glucose tolerance test results, especially if they are normal, may further distract from efforts to implement risk-reducing interventions in postpartum women with GDM.

The finding of greater weight retention in women with normal OGTT results is of particular concern, as glucose tolerance normalizes in 60–80% of women with recent GDM [6–9]. Yet evidence indicates that they continue to have significant beta-cell impairment [28] and remain at elevated risk for diabetes [2,3]. While we could not determine reasons for our findings, we hypothesize that resolution of glucose intolerance after delivery falsely reassures women that diabetes is no longer a concern thereby decreasing motivation for risk-reducing behaviours. It has been shown that most women with a history of GDM have a low perception of diabetes risk [10–12], and higher and more accurate risk perception is associated with greater lifestyle modification [10]. While our study did not find statistical differences in diabetes risk perception, diet, or physical activity between groups, these self-reported measures may have been more susceptible to positive recall bias and overestimation than weight.

Less than half of women return for postpartum diabetes testing [29,30], and, for those that do, this is often the only opportunity for behaviour counselling. By focusing on the results of the OGTT, we may be missing a “teachable moment” during which women can be counselled regarding their risk of diabetes and of the need for ongoing healthy lifestyle behaviours. For women with normal results, other modifiable risk factors should be identified and targeted. Although further research is needed to identify effective diabetes prevention strategies after GDM, postpartum weight loss should be prioritized to lower their risk of diabetes [16,17,19].

The strengths of this study include a rich, longitudinal data source on a diverse ethnic mix of women. Although all measures used in the analyses are self-reported, we were able to extract information from multiple concurrent data sources. We were able to follow women from pregnancy until the second postpartum year, which allowed us to evaluate the impact of glucose tolerance results on weight retention in a prospective fashion. However, our study also had several limitations. The observational design of the study and the use of self-reported data might have led to unmeasured confounding. Our study sample might have been biased because we chose only those women who had completed both the early and late postpartum questionnaires, and there was a high rate of loss to follow-up between these time periods. Questionnaires were administered via electronic mail, and response rates may have been lower in the second year postpartum due to return to work, greater time since their GDM pregnancy, or no longer being eligible to participate due to another pregnancy. To address this issue we adjusted for likelihood of completing the late postpartum questionnaire using inverse probability weighting to make our study sample more representative of the women who were lost to follow-up. A selection bias may have also influenced our results, as women needed to perform the OGTT in order to be aware of their results. However, baseline weight and other variables were similar between those who did and did not complete the OGTT. Finally, our patient population may differ from others and further studies in other clinical settings are needed to confirm the findings.

In conclusion, this study identified a potential unintended consequence of postpartum glucose testing in women with GDM. Awareness of normal postpartum glucose tolerance was associated with a significantly higher weight by the second postpartum year than being unaware of results. Future studies are needed to explore reasons for this finding. In the meantime, our findings serve to remind providers of the importance of accurate diabetes risk communication after a GDM delivery.

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Conflict of interest

The authors declare no conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.diabres.2019.04.016.

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