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Research: Pregnancy

Association of pre-pregnancy BMI and postpartum weight retention with postpartum HbA1c among women with Type 1 diabetes

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Abstract

Aim To examine the association of pre-pregnancy BMI and postpartum weight retention with postpartum HbA1c levels in women with Type 1 diabetes.

Methods We longitudinally evaluated 136 women with Type 1 diabetes who received prenatal, pregnancy, and postpartum care through Joslin Diabetes Center’s Diabetes and Pregnancy Program between 2004 and 2009. Weight, BMI and HbA1c concentrations were assessed before the index pregnancy and repeatedly monitored after delivery until 12 months postpartum. We used linear mixed models to assess the association of postpartum HbA1c with pre-pregnancy BMI and postpartum weight retention.

Results The mean HbA1c concentration increased from 49 mmol/mol (6.6%) at 6 weeks postpartum to 58 mmol/mol (7.5%) by 10 months postpartum, a level similar to the mean pre-pregnancy HbA1c concentration. Postpartum weight retention showed a linearly decreasing trend of 0.06 kg/week (P < 0.0001), with ~0.1 kg average postpartum weight retention by 1 year postpartum. Compared with women with a pre-pregnancy BMI ≥ 25 kg/m², women with a lower pre-pregnancy BMI maintained a 3.4 mmol/mol (0.31%) lower HbA1c concentration, after adjusting for several sociodemographic, reproductive and diabetes-related factors (P = 0.03). There was a suggestion of a time-varying positive association between HbA1c and postpartum weight retention, with the most significant difference of 3.7 mmol/mol (0.34%; P = 0.05) at 30 weeks postpartum among women with postpartum weight retention ≥ 5 kg vs those with postpartum weight retention < 5 kg.

Conclusions Pre-pregnancy BMI and postpartum weight retention were positively associated with HbA1c during the first postpartum year in women with Type 1 diabetes. Interventions to modify the behaviours associated with these body weight factors before pregnancy and after delivery may help women with Type 1 diabetes maintain good glycaemic control after pregnancy.


Introduction

Among pregnant women with Type 1 diabetes, HbA1c concentration, an indicator of glycaemic control over the preceding 2–3 months, is closely monitored to optimize pregnancy outcomes. Although pregnant women are motivated by careful preconception counselling to improve their blood glucose control, the current standard postpartum care in the USA concludes early at 6 weeks post-pregnancy [1]. Given that women often achieve good glycaemic control during pregnancy, capitalizing on this motivation to improve glucose levels could reduce a woman’s longer-term risk of diabetes complications, but postpartum glycaemic control and associated factors are not well understood.

One major factor that could affect postpartum glycaemic control is excessive postpartum weight retention, defined as the difference between pre-pregnancy and postpartum weight at a specified time period. Up to 20% of healthy women retain ≥ 5 kg body weight by 6–18 months after delivery [2]. Excessive postpartum weight retention is associated with
increased inflammation and insulin resistance [3], and contributes to increases in the prevalence of overweight/obesity [4]. In women with Type 1 diabetes, the addition of overweight/obesity could further exacerbate their already increased risk of cardiovascular disease and other diabetes-related complications [5–8]. Little is known, however, about postpartum weight retention and its association with glycaemic control in women with Type 1 diabetes. Another factor that could affect postpartum HbA1c is pre-pregnancy BMI, which reflects certain health behaviours before pregnancy, such as energy intake and physical activity levels [9]. Pre-pregnancy BMI is known to be associated with postpartum weight retention, with overweight/obese women being more likely to retain greater amounts of weight [10].

Although two previous studies have evaluated postpartum HbA1c in women with Type 1 diabetes [11,12], evaluation of the associations between pre-pregnancy BMI, postpartum weight retention and postpartum HbA1c has been largely undocumented, with no study to our knowledge in women in the USA. If these modifiable factors are found to be associated with postpartum changes in HbA1c, targeted interventions before pregnancy and during the postpartum period may help women maintain good postpartum glycaemic control, with implications for long-term health.

In the present study, we longitudinally explored the trajectories of HbA1c levels and postpartum weight retention from 6 weeks until 1 year postpartum in women with Type 1 diabetes. We further investigated whether pre-pregnancy BMI or postpartum weight retention were associated with post-pregnancy HbA1c, adjusted for several socio-economic and clinical factors available from medical record data.

Subjects and methods

Study population

The study population included women with pre-existing Type 1 diabetes. Type 1 diabetes was diagnosed based on history of the disease and clinical characteristics including signs of insulinopenia and young age at diagnosis [13]. All the women in the present study received prenatal and endocrinology care from the Diabetes and Pregnancy Program at the Joslin Diabetes Center (JDC) and Beth Israel Deaconess Medical Center (BIDMC), Boston, MA. The JDC/BIDMC Diabetes and Pregnancy Program combines care from high-risk maternal-fetal medicine specialists with care from endocrinologists, diabetes nurse educators, nutritionists and exercise physiologists to manage and ensure healthy pregnancies through targeted glycaemic control. This programme includes preconception counselling, routine prenatal appointments and postnatal visits based on American Diabetes Association guidelines. Approximately 55% of the women received preconception counselling from the Diabetes and Pregnancy Program before becoming pregnant.

During pregnancy, women received diabetes education on specific topics, including glucose pattern identification and management, use of basal/bolus approaches, carbohydrate counting, temporary basal use for physical activity and review of sick day rules with regards to pregnancy. Pregnant women with Type 1 diabetes were seen from the early first trimester (~6 weeks gestation) through to 6 weeks postpartum and then returned to the non-pregnant Diabetes Program at JDC for routine endocrinology care.

Between 2004 and 2009, the programme managed a total of 338 pregnancies with Type 1 diabetes. For the present study, women were eligible if they had Type 1 diabetes, were participants in the JDC/BIDMC Diabetes and Pregnancy Program, had data on HbA1c and weight before and after pregnancy and were aged ≥ 18 years. Women were excluded if the pregnancy did not result in a single live birth or if they had a second pregnancy within 12 months of the index delivery. In addition, we excluded women who were not patients in the JDC Diabetes Programs before or after their pregnancy. Based on these eligibility criteria, 149 women (44%) were identified. To exclude potential inter-correlations in gestational weight gain and postpartum weight retention between consecutive pregnancies [14,15], the primary analysis focused on the first pregnancy during the study period. This study was approved by the JDC Committee for Human Subjects.

Medical record abstraction

We collected information from patients’ electronic medical records on sociodemographic factors, medical conditions and diabetes treatment, as well as on reproductive and anthropometric factors. The date of each visit was also collected to estimate time since delivery.

Pre-pregnancy and postpartum HbA1c concentration

The HbA1c measures < 1 year before pregnancy were used to indicate pre-pregnancy levels. If multiple measures were available, we used the one taken nearest to the start of the pregnancy but before the woman received preconception care.
counselling. At 6 weeks postpartum, HbA1c was measured in all women through the JDC/BIDMC Diabetes and Pregnancy Program using Tosoh 2.2 Plus (coefficient of variation = 1.66%), Roche Hitachi Tina-Quant (coefficient of variation = 2.2–3.0%), and Roche Integra Tina-Quant A1c Generation 2 (coefficient of variation < 1.7%) devices. HbA1c measurements from 6 weeks postpartum occurred during standard non-pregnant adult endocrinology care at JDC and were taken using a Tosoh G7 analyser (coefficient of variation = 1.14%) and the Roche Integra Tina-Quant A1c Generation 2 (coefficient of variation < 1.7%). All methods were compatible with International Federation of Clinical Chemistry Standards [16–18]. In the present study, the timing of postpartum measurements was evaluated as the number of weeks relative to delivery and these measurements were taken from 6 to 52 weeks postpartum.

Pre-pregnancy BMI

Women were weighed to the nearest pound in their light street clothes with shoes off. Pre-pregnancy weight was defined as body weight measured at the first trimester prenatal visit [19]. Height information was collected by stadiometer at the initial visit and recorded in inches. Pre-pregnancy BMI was calculated as weight (kg) divided by height (m²).

Postpartum weight retention

Postpartum weight was measured concurrently with HbA1c during clinic visits. Postpartum weight retention was defined as the difference between postpartum weight and pre-pregnancy weight and was time-dependent. We evaluated postpartum weight retention both continuously and as substantial postpartum weight retention (retaining ≥ 5 kg) vs not (< 5 kg) [20].

Statistical analysis

We calculated means/standard deviations or medians/ranges for continuous variables and frequencies/percentages for categorical variables. We used linear mixed models to explore the trajectories of HbA1c concentrations and postpartum weight retention in women with Type 1 diabetes as a function of postpartum weeks, respectively. The postpartum week was modelled using both a linear model and a quadratic model to allow assessment of possible non-linear trends. A random intercept and slope for postpartum weeks were included in the models. Based on the likelihood ratio test comparing the linear and the quadratic model, a quadratic model was selected for HbA1c (likelihood ratio test P < 0.001) and a linear model was selected for postpartum weight retention (likelihood ratio test P = 0.294). Predicted HbA1c levels or postpartum weight retention were calculated against varying postpartum weeks, respectively.

To examine whether changes in HbA1c over 1 year postpartum differed by pre-pregnancy BMI, we further included a fixed effect for pre-pregnancy BMI (< 25 or ≥ 25 kg/m²) and an interaction term between pre-pregnancy BMI and postpartum week into the selected quadratic HbA1c model, adjusted for maternal age, race/ethnicity, gestational age centred at 37 weeks, duration of diabetes, diabetes complications (i.e. retinopathy, nephropathy, neuropathy and other), parity and insulin pump use. Maternal age and duration of diabetes were also individually evaluated in the model with other covariates to examine the impact of their potential correlations. To examine the association of postpartum weight retention with HbA1c, the analysis was repeated with pre-pregnancy BMI replaced by the indicator for postpartum weight retention (< 5 or ≥ 5 kg). Since further adjustment of pre-pregnancy BMI in the model for postpartum weight retention yielded similar results, we included the same set of covariates in the final models for pre-pregnancy BMI and postpartum weight retention. A likelihood ratio test was used to assess whether the postpartum HbA1c trajectory differed by pre-pregnancy BMI or substantial postpartum weight retention status comparing the models with and without the linear and quadratic interaction terms.

In the exploratory analysis, a P value < 0.20 was used to investigate possible statistical interactions with time. If the P value was < 0.20, the cross-product terms would be retained in the final model, otherwise they would be dropped from the model. Multivariate-adjusted least squares mean HbA1c levels were calculated at varying postpartum weeks by pre-pregnancy BMI or substantial postpartum weight retention categories, respectively. All variables in the mixed model were computed with restricted maximum likelihood estimation, whereas the likelihood ratio test was conducted using the maximum likelihood method. All analyses were conducted in SAS 9.3 (Cary, NC, USA).

Results

Of 149 eligible women, 139 had multiple (up to five) records on HbA1c concentration and weight from 6 weeks until 1 year postpartum. Three women were excluded because they had extremely high HbA1c levels (> 108 mmol/mol (12%)] on at least one occasion, leaving 136 women for the analysis. The mean (sd) maternal age was 31.8 (5.5) years and the mean (sd) duration of diabetes was 17.0 (8.3) years (Table 1). The median (range) pre-pregnancy BMI was 25.4 (18.8–39.6) kg/m² with 53.3% of the women being overweight or obese. The median (range) pre-pregnancy HbA1c before receiving preconception counselling in the Diabetes and Pregnancy Program was 55.2 (39.9–97.8) mmol/mol [7.2% (5.8–11.1)%], with 61.1% of the women reaching or
exceeding the American Diabetes Association HbA1c recommendation of < 53 mmol/mol (7.0%).

**Crude trajectories of postpartum HbA1c and weight retention**

In the quadratic model for postpartum trajectories of HbA1c, both linear (0.67; *P* < 0.0001) and quadratic (−0.008; *P* < 0.0001) terms for week were highly significant, suggesting that HbA1c levels were elevated during the postpartum period, but levelled off over time (Fig. 1a). The HbA1c level increased from a predicted average of 49 mmol/mol (6.6%) at 6 weeks postpartum to a peak of 58 mmol/mol (7.5%) at ~40 weeks postpartum, a level similar to the pre-pregnancy HbA1c average. By contrast, the trajectories of postpartum weight retention showed a linear trend of continuous weight loss by 0.06 kg per week (−0.06 kg per week; *P* < 0.0001; Fig. 1b). This corresponded to a decline in postpartum weight retention from 2.25 kg at 6 weeks postpartum to 0.98 kg at 26 weeks postpartum. The model-predicted trend of HbA1c and postpartum weight retention fit well with the actual observations, e.g. the average HbA1c concentration was 49, 55, 58 and 60 mmol/mol (6.6, 7.2, 7.5 and 7.6%) and the average postpartum weight retention was 2.4, 1.2, 0.5 and 0.2 kg for postpartum weeks 6–13, 13–26, 26–39, 39–52, respectively.

**Adjusted associations of postpartum HbA1c with pre-pregnancy BMI**

We found a significant positive association between pre-pregnancy BMI and postpartum HbA1c levels adjusted for several sociodemographic, reproductive and diabetes-related factors (*P* = 0.03), and this association did not appear to vary with time (*P* for interaction = 0.905; Table 2); thus, parallel trends for HbA1c changes were observed over time, with overweight or obese women before pregnancy having a
HbA1c concentration 3.4 mmol/mol (95% CI 0.3 to 6.5) or 0.31% (95% CI 0.03 to 0.59) higher (Fig. 2a). Notably, women with a higher pre-pregnancy BMI also attained significantly higher pre-pregnancy HbA1c levels before initiation of preconception counselling (61 mmol/mol (7.7%) vs 55 mmol/mol (7.2%; 0.02).  

**Adjusted associations of postpartum HbA1c with postpartum weight retention**

Compared with the association of postpartum HbA1c levels with pre-pregnancy BMI, the positive association with postpartum weight retention was weaker, and probably differed by time (P value for interaction = 0.150; Table 2). Women who retained substantial weight (≥5 kg) generally had a higher HbA1c level than those who did not during 1 year postpartum, and the largest difference was 3.7 mmol/mol (0.34%; P = 0.05) at ~30 weeks postpartum (Fig. 2b).

**Other predictors of postpartum HbA1c**

In addition to pre-pregnancy BMI, the multivariate-adjusted model also showed that longer gestational age (P = 0.04), insulin pump use (P < 0.01) and lower parity (P for trend = 0.02) were significantly associated with lower postpartum HbA1c levels (Table 2). Similar associations between postpartum HbA1c levels and covariates were also found in the multivariate model for postpartum weight retention.

**Discussion**

In the present longitudinal postpartum follow-up of women with Type 1 diabetes, we observed an increase in HbA1c level that was similar to pre-pregnancy levels by ~10 months postpartum. A continuous loss of body weight was also noted among these women during the same time period. Despite the increasing trend for HbA1c, postpartum HbA1c
levels were significantly lower for women with pre-pregnancy BMI < 25 kg/m² vs ≥ 25 kg/m². Women without substantial postpartum weight retention (i.e. < 5 kg) also had somewhat lower postpartum HbA₁c levels relative to those with substantial postpartum weight retention.

Few studies have examined the postpartum trajectory of HbA₁c levels in women with Type 1 diabetes. Consistent with the only two previous studies [11,12], a similar rebound in blood glucose control to pre-pregnancy conditions was observed in women with Type 1 diabetes, despite substantial diabetes education interventions during pregnancy and HbA₁c concentration being at target levels in the very early postpartum period (~6 weeks post-delivery). Women may lose their strong motivation for good blood glucose control when facing complex physical and emotional changes post-pregnancy [1]; these subsequently higher HbA₁c levels long-term could lead to increased risk of diabetes-related complications in the future [21].

In a previous meta-analysis examining the natural history of postpartum weight retention in the general population, the average postpartum weight retention measured in BMI was 2.42 kg/m² at 6 weeks, 1.14 kg/m² at 6 months and 0.46 kg/m² at 12 months, roughly equivalent to 6.20, 2.92 and 1.18 kg, assuming an average height of 1.60 m [22]. The only study that focused on post-pregnancy weight changes in women with Type 1 diabetes also reported an average weight retention of 2.5 kg > 12 months after delivery [11]. The steady decrease in postpartum weight retention was similar to that observed in this study, but postpartum weight retention was lower among the women in the present study. This may be explained by differences in the present US and the Polish study populations (e.g. higher pre-pregnancy BMI and higher education levels in the present study population). In addition, there appeared to be higher inter-individual variability in postpartum weight retention among our women with Type 1 diabetes, with some showing substantial postpartum weight loss (> 5 kg) compared with pre-pregnancy weight. Reasons for this extreme weight loss are unclear and require further study.

Pre-pregnancy BMI could be considered an approximate surrogate for lifestyle factors (e.g. nutrition quality and physical activity) and obesity-related health effects (e.g. insulin resistance) that may have existed before pregnancy. The significant positive association between pre-pregnancy BMI and postpartum HbA₁c levels suggests that these behavioural and physiological factors may be maintained after pregnancy. This is important to note, given that women in the present study population underwent extensive diabetes education during pregnancy. The fact that these women did not adapt these newly learned skills to their post-pregnancy lifestyle may highlight the need for improved postpartum care to reinforce techniques learned during pregnancy to ensure carryover beyond pregnancy. It also suggests the need for care providers to be aware of barriers to self-management of blood glucose levels during this transition period.

Interestingly, the simultaneous change of postpartum weight retention with increasing postpartum HbA₁c did not confer a stronger association than that seen between pre-pregnancy BMI and postpartum HbA₁c. It is possible that the association was attenuated when we analysed HbA₁c with postpartum weight retention measured on the same day. Also, the association may be potentially confounded by some
factors that could not be adjusted for based on limited medical record data, such as breastfeeding and postpartum depression. Additionally, as noted above, most women in the present study, regardless of their pre-pregnancy weight, tended to be able to return to their pre-pregnancy weight by the end of the 12-month post-pregnancy follow-up. The lesser magnitude of between-person difference in postpartum weight retention may have prevented us from detecting a more significant effect. Nevertheless, what remained different between individuals may have been the rate of weight loss, which helps explain why the association with postpartum weight retention differed by time and little association was observed at the end of the follow-up.

The present study has several limitations. First, the findings may not apply to an ethnically diverse and educationally disadvantaged population. Second, several potential confounders are not available from medical records, such as total caloric intake, breastfeeding and certain psychosocial factors. Also, we could not exclude the potential influence by factors such as iron deficiency anaemia, which may affect HbA1c levels [23]. Third, we did not have data to prove that the lowering of HbA1c during pregnancy was only attributable to behavioural changes adopted from education. It has also been shown that pregnant women without diabetes tend to have lower HbA1c concentrations than their non-pregnant counterparts [24]. However, Type 1 diabetes requires maintenance of good diabetes control during pregnancy, which includes ongoing focus and commitment to diabetes self-management, as insulin requirements may double over the course of the pregnancy in the setting of changing degrees of insulin resistance [25]. As such, in the present population of pregnant women with Type 1 diabetes, it is unlikely that lower levels of HbA1c are solely due to normal physiological decreases in HbA1c concentrations typically found in women without Type 1 diabetes. Finally, the possibility of chance findings cannot be excluded because of the relatively small sample size.

Despite these limitations, the study has several strengths. To our knowledge, it is one of the few longitudinal studies that have examined postpartum changes in HbA1c concentrations and body weight in US women with Type 1 diabetes, and the first to evaluate the potential impact of body weight factors on postpartum HbA1c levels. The serial measurements of HbA1c and body weight with precise records of collection date allow us to model the patterns of change more finely from a longitudinal perspective. Along with HbA1c levels, both pre-pregnancy and postpartum weights are more reliable because they are clinically measured rather than self-reported values. Also, pre-pregnancy HbA1c levels were obtained before the women received preconception counseling, which provided a referent condition independent of any prenatal or pre-pregnancy interventions. Additionally, we were able to take into account several potential confounders (e.g. insulin pump use, parity and gestational age of index pregnancy).

In summary, among women with Type 1 diabetes, HbA1c trajectories increased to pre-pregnancy levels over the first postpartum year, while body weight on average continued to decrease to pre-pregnancy levels. There is evidence that postpartum HbA1c levels are positively associated with pre-pregnancy BMI and postpartum weight retention in this population. These findings underscore the importance of improved postpartum care that may be needed for women with Type 1 diabetes to manage their blood glucose levels effectively after pregnancy. Future work should identify specific barriers and other modifiable factors that contribute to postpartum HbA1c elevations to develop targeted interventions to improve postpartum glycaemic control.

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Competing interests
None declared.

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