Changes in Weight and Health Behaviors After Pregnancies Complicated by Gestational Diabetes Mellitus: The CARDIA Study

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Objective: Prepregnancy to postpregnancy change in weight, body mass index (BMI), waist circumference, diet, and physical activity in women with and without gestational diabetes mellitus (GDM) were compared.

Design and Methods: Using the Coronary Artery Risk Development in Young Adults study, women with at least one pregnancy during 20 years of follow-up (n = 1,488 with 3,125 pregnancies) was identified. Linear regression with generalized estimating equations to compare prepregnancy to postpregnancy changes in health behaviors and anthropometric measurements between 137 GDM pregnancies and 1,637 non-GDM pregnancies, adjusted for parity, age at delivery, outcome measure at the prepregnancy exam, race, education, mode of delivery, and interval between delivery and postpregnancy examination were used.

Results: When compared with women without GDM in pregnancy, women with GDM had higher prepregnancy mean weight (158.3 vs. 149.6 lb, \(P = 0.011\)) and BMI (26.7 vs. 25.1 kg/m², \(P = 0.002\)), but nonsignificantly lower total daily caloric intake and similar levels of physical activity. Both GDM and non-GDM groups had higher average postpartum weight of 7-8 lbs and decreased physical activity on average 1.4 years after pregnancy.

Conclusions: Both groups similarly increased total caloric intake but reduced fast food frequency. Prepregnancy to postpregnancy changes in body weight, BMI, waist circumference, physical activity, and diet did not differ between women with and without GDM in pregnancy. Following pregnancy, women with and without GDM increased caloric intake, BMI, and weight and decreased physical activity, but reduced their frequency of eating fast food. Given these trends, postpartum lifestyle interventions, particularly for women with GDM, are needed to reduce obesity and diabetes risk.

Introduction

Gestational diabetes mellitus (GDM) complicates about 7% of pregnancies in the United States, depending on the population studied (1). Women with a history of GDM are at high risk for type 2 diabetes (2,3), with 3.7% diagnosed by 9 months after delivery and 19% by 9 years after delivery, within a large Canadian healthcare system (4). Because of this increased risk, experts and national organizations are calling for increased screening, monitoring, and promotion of lifestyle changes for diabetes prevention (5,6). In addition to triggering increased provider surveillance, a diagnosis of GDM could heighten women’s awareness of diabetes risk and motivate healthy behavioral change. However, support for making these lifestyle changes is crucial. Lifestyle interventions, such as the Diabetes Prevention Program, may reduce diabetes incidence in women with GDM histories (7).

Cross-sectional studies show that providers may not adequately inform patients of their diabetes risk (8,9), women may fail to perceive themselves at risk for diabetes (10), and overall, at-risk women are not engaging in healthier lifestyles (11,12). A recent prospective cohort followed...
238 Canadian women with and without GDM for 1-year postpartum (13). They reported no differences at 1 year in work- or sports-related physical activity between groups; however, women with GDM reported increased leisure-time physical activity at 1 year when compared with women without GDM (13). However, few studies have measured weight and health behaviors from before to after pregnancy in women with GDM to assess postpregnancy changes, although one previous study reported less than a 2 kg difference in mean weight gain from before to after pregnancies among women with and without GDM pregnancies (3).

The Coronary Artery Risk Development in Young Adults (CARDIA) study is a prospective cohort study of young men and women with more than 20 years of follow-up. Our objective was to compare changes in health behaviors (dietary intake and physical activity) and anthropometric measures (weight, body mass index [BMI], and waist circumference) from before to several years after pregnancy in women with and without GDM. We hypothesized that a diagnosis of GDM, despite its potential role as a "prognostic sign" for diabetes, would not be associated with improved postpregnancy anthropometric measures or health behaviors (e.g., less weight gain and improved diet). Understanding postpregnancy changes in women with GDM could inform interventions aimed at promoting healthy postpregnancy behavior changes.

**Research Design and Methods**

**The CARDIA study**

The CARDIA study is a multicenter, longitudinal, cohort study examining determinants of cardiovascular disease among Black and White young adults. In 1985-1986, baseline examinations were performed on 5,115 participants (50% of eligible persons) aged 18-30 years, of whom 54% were women, 52% were black, and 48% were white. They were recruited from four geographic areas in the United States: Birmingham, Alabama; Chicago, Illinois; Minneapolis, Minnesota; and Oakland, California. For this analysis, we used data from participants who were followed up for 20 years with seven clinical examinations: 1985-1986 (baseline), 1987-1988 (year 2), 1990-1991 (year 5), 1992-1993 (year 7), 1995-1996 (year 10), 2000-2001 (year 15), and 2005-2006 (year 20). At year 20, the retention rate was 71.8 and 87.5% for completion of the in-person examination and telephone interview, respectively (14). The study was approved by the institutional review boards of all participating institutions. Details of the study design, methodology, and cohort characteristics have been reported elsewhere (15,16).

**Sample selection**

For this analysis, we included females with at least one pregnancy during the 20 years of follow-up. We excluded pregnancies in duplicate, classified as abortions, tubal pregnancies, or miscarriages, or if information about the pregnancy was incomplete (e.g., missing delivery date or mode). For the main analysis using anthropometric and physical activity outcomes, we excluded pregnancies if the participant’s prepregnancy CARDIA examination occurred more than 5 years before the postpregnancy CARDIA examination to improve its validity as representative of postpregnancy change.

Because dietary intake was assessed more than 5 years apart (baseline and year 7), we included all pregnancies that had occurred between the baseline and year 7 examinations for the dietary outcomes.

**Data collection**

**Definition of GDM and pregnancy related variables.** At each CARDIA examination, women reported the number of interim pregnancies, including abortions, miscarriages, and live births or stillbirths with delivery dates, length of gestation, and whether they were currently pregnant. Using a method previously described by Gunderson et al. (3), we selected pregnancies with at least 20 weeks gestation that resulted in a live birth. At each CARDIA examination, women reported having been diagnosed with diabetes or diabetes that occurred only during pregnancy since the previous exam (3). We assigned GDM status for each interim pregnancy based on self-report and absence of overt diabetes before conception. Self-report of GDM was previously validated in a subsample of 165 CARDIA women by abstracting medical record data for their 200 births between baseline and year 10 (3). The sensitivity for self-reported GDM was 100% (20/20), and the specificity was 92% (134/145) (3).

**Outcomes: Anthropometric measures and health behaviors.** Measurements of body weight, height, and waist circumference were obtained at each examination according to a standardized protocol described previously (17,18). BMI was computed as weight in kilograms divided by squared height in meters.

The CARDIA Physical Activity History was used to calculate moderate (e.g., taking walks), strenuous (e.g., bicycling), and total physical activity scores at each examination based on the frequency and duration of 13 different types of activities (19). The total physical activity score was calculated using a scoring algorithm (20) and then expressed in terms of "exercise units," with higher scores indicating greater amounts of exercise. The questionnaire has been externally validated using treadmill test performance, as well as compared with other physical activity questionnaires (21,22). For reference, at baseline, 74% of CARDIA participants with a total physical activity score between 300 and 399 exercise units met exercise recommendations to perform "regular vigorous exercise" during the past 6 months (19). At the CARDIA baseline examination, Black women reported on average 260 exercise units and White women reported on average 324 exercise units (19).

Dietary intake was collected at baseline and year 7 using the validated interviewer administered CARDIA Diet History questionnaire, which assessed total daily caloric intake (kilocalories [kcal] per day), percentage of kilocalories from total fat, and daily fiber intake (grams) (23,24).

At baseline and examination years 5 and 10, participants were asked how often they eat in a fast food restaurant, which we reported as times per month (25).

Data were realigned from the CARDIA examination schedule to conform with pregnancy timing so that one or more CARDIA examinations may have occurred prior to a given pregnancy. The prepregnancy outcome measures were assessed at the CARDIA examination immediately prior to the reported interim pregnancy, and the postpregnancy outcome measures were assessed at the examination as soon after the interim pregnancy. We calculated mean prepregnancy and postpregnancy values for each of the outcomes: weight, BMI, waist circumference, total physical activity, and dietary measures. We determined the change in each value by subtracting the prepregnancy value from the postpregnancy examination value. This procedure was followed for each pregnancy within each woman.
Other covariates. Sociodemographic, medical and family history, and behavioral characteristics (cigarette smoking, education, marital status, and employment status) were assessed by self- and interviewer-administered questionnaires at the baseline CARDIA examination.

Statistical analysis
We conducted baseline and prepregnancy descriptive analyses to compare women with one or more GDM pregnancies (GDM history) with women who did not develop GDM in an interim pregnancy (no GDM history) during 20 years of follow-up using Student’s t-test for comparisons of means, Wilcoxon rank-sum test for comparisons of medians, and Chi square for categorical variables.

We classified each pregnancy as GDM or non-GDM. We used linear regression models with the generalized estimating equation (GEE) method to compare the prepregnancy to postpregnancy changes in each outcome in GDM versus non-GDM pregnancies. We adjusted for parity, age at the time of delivery, prepregnancy outcome measure, race, education, mode of delivery, and interval between the delivery and postpregnancy outcome measure. Because GEE accounted for correlations among multiple pregnancies by the same woman over time (26), we elected to adjust for overall parity, but not the number or order of GDM pregnancies in any given woman.

In addition, because health behaviors may differ by prepregnancy obesity and race, we conducted analyses stratified by prepregnancy BMI (<30 and ≥30 kg/m²) and race (White and Black).

We used STATA software version 11 (StataCorp LP, College Station, TX) (27) and a two-tailed α-level of 0.05 for all analyses.

Results
Baseline characteristics of women with and without a history of GDM
Figure 1 shows the selection of the sample of women with and without a history of GDM and the associated number of GDM and non-GDM pregnancies. We identified 1,488 women with 3,125 interim pregnancies during 20 years of the CARDIA study, with the 80% of pregnancies occurring in the first 10 years of the study. After exclusions, our final sample included 121 women with a history of GDM, who had 137 GDM and 72 non-GDM pregnancies. In total, 1,001 women without a history of GDM had 1,565 non-GDM pregnancies. The final sample included 121 women with a history of GDM, who had 137 GDM and 72 non-GDM pregnancies. The final pregnancy analysis included 137 GDM pregnancies (from 121 women) and 1,637 non-GDM pregnancies (from 59 women with GDM in a different pregnancy and 1,001 women without any GDM history).

The baseline and prepregnancy characteristics comparing women with and without a GDM history during the 20 years of the CARDIA study are given in Table 1. Women with a GDM history did not differ from those without a GDM history in terms of race, marital status, educational attainment, or smoking status. Women with a GDM history had more interim births during CARDIA follow-up (mean 1.7 vs. 1.6, \( P = 0.031 \)), but had no difference in parity prior to CARDIA enrollment. Women with a GDM history were older at their first interim delivery (29.1 vs. 27.8 years, \( P = 0.001 \)), more likely to have a family history of diabetes (22.3% vs. 13.1%, \( P = 0.006 \)), had higher mean weight (158.1 vs. 147.3 lbs, \( P = 0.011 \)) and BMI (26.8 vs. 24.7, \( P = 0.002 \)), and were more likely to report being on a weight loss diet in the past (60.3% vs. 47.3%, \( P = 0.007 \)). However, women with a GDM history had a nonsignificantly lower total daily caloric intake (1,879 vs. 2,117 kcal/day, \( P = 0.051 \)) measured at the baseline exam. Total, strenuous, or moderate physical activity scores from the baseline exam were not different between the two groups.

Comparison of pre-to-post pregnancy anthropometric changes in GDM and non-GDM pregnancies
The mean anthropometric measures prior to pregnancy and following pregnancy and the adjusted prepregnancy to postpregnancy changes between the GDM and non-GDM pregnancy groups are given in Table 2. When compared with the non-GDM pregnancy group, the GDM pregnancy group had higher prepregnancy and postpregnancy weights (prepregnancy mean of 158.3 vs. 149.6 lbs, and postpregnancy mean of 165.7 vs. 157.8 lbs). However, the prepregnancy to postpregnancy weight change was not significantly different between the GDM and non-GDM groups after adjustment for age, race, education, parity, cesarean delivery, and the delivery to postpregnancy examination interval. Similarly, both groups had a mean of 7-8 lbs of postpregnancy weight retention after an average of 1.4 years (range: 0.4-5 years) following pregnancy.

Similar to weight, the GDM pregnancy group had elevated prepregnancy and postpregnancy BMI and waist circumference when compared with the non-GDM group. However, the prepregnancy to postpregnancy changes in BMI and waist circumference were not
significantly different between the GDM and non-GDM groups, using the same covariate adjustments as the outcome of weight.

Figure 2 displays the weight, BMI, and waist circumference trajectories prepregnancy to postpregnancy in the GDM and non-GDM groups. Women in both groups increased weight, BMI, and waist circumference prepregnancy to postpregnancy, with similar prepregnancy to postpregnancy changes.

Comparison of pre-to-post pregnancy physical activity and diet changes in GDM and non-GDM pregnancies
The health behavior measures prior to pregnancy and following pregnancy and the adjusted prepregnancy to postpregnancy changes between the GDM and non-GDM pregnancy groups are given in Table 3. The GDM and non-GDM pregnancy groups did not significantly

| TABLE 1 Baseline characteristics of women with and without a history of GDM over 20 years of follow-up |
|------------------------------------------------------------------------------------------------|
| Characteristics | GDM history (N = 121) | No GDM history (N = 1,001) | P-value |
| Mean age at CARDIA baseline exam (years) (SD) | 24.8 (3.8) | 24.3 (3.6) | 0.142 |
| Mean age at first interim delivery (years) (SD) | 29.1 (4.1) | 27.8 (4.5) | 0.001 |
| Black (vs. white), n (%) | 54 (44.6) | 511 (51.1) | 0.182 |
| Married (vs. single), n (%) | 43 (35.8) | 349 (34.9) | 0.845 |
| < High school diploma (vs. > high school), n (%) | 34 (28.1) | 352 (35.2) | 0.122 |
| Ever smoked (vs. never smoked), n (%) | 54 (44.6) | 393 (39.3) | 0.255 |
| History of diabetes in mother or father, n (%) | 27 (22.3) | 131 (13.1) | 0.006 |
| Mean number of pregnancies during 20 years of CARDIA follow-up examinations (SD) | 1.7 (0.8) | 1.6 (0.7) | 0.031 |
| History of ≥1 pregnancy, prior to baseline exam, n (%) | 61 (50.4) | 494 (49.3) | 0.840 |
| Mean weight (lb) (SD) | 158.1 (44.1) | 147.3 (34.7) | 0.011 |
| Mean BMI (kg/m²) (SD) | 26.8 (6.7) | 24.7 (5.6) | 0.002 |
| Median total daily caloric intake (kcal) (IQR) | 1,879 (1,573–2,554) | 2,117 (1,608–2,888) | 0.051 |
| Median total physical activity score (IQR) | 236 (108–432) | 256 (129–431) | 0.480 |
| Median strenuous activity score (IQR) | 114 (29–266) | 133 (48–276) | 0.209 |
| Median moderate activity score (IQR) | 100 (36–186) | 96 (40–175) | 0.798 |
| Been on weight loss diet, n (%) | 73 (60.3) | 472 (47.3) | 0.007 |
| Mean number of times eating fast food per month (SD) | 8 (10) | 7 (7) | 0.136 |

Abbreviations: BMI, body mass index; GDM, gestational diabetes mellitus; IQR, interquartile range; SD, standard deviation.

| TABLE 2 Prepregnancy to postpregnancy changes in anthropometrics in GDM and non-GDM pregnancies |
|------------------------------------------------------------------------------------------------|
| GDM pregnancy n = 137 | Non-GDM pregnancy n = 1,637 | Difference | P-valuea |
| Weight (lb) | | | | |
| Prepregnancy, mean (SE) | 158.3 (3.8) | 149.6 (0.9) | 6.2 | <0.001 |
| Postpregnancy, mean (SE) | 165.7 (3.9) | 157.8 (1.0) | 5.3 | 0.007 |
| Adjusted changeb (95% CI) | 7.3 (6.9–7.7) | 8.2 (8.1–8.3) | −0.7 (−3.1 to 1.7) | 0.577 |
| BMI (kg/m²) | | | | |
| Prepregnancy, mean (SE) | 26.7 (0.6) | 25.1 (0.1) | 1.1 | <0.001 |
| Postpregnancy, mean (SE) | 28.0 (0.6) | 26.4 (0.2) | 1.0 | 0.006 |
| Adjusted changeb (95% CI) | 1.2 (1.2–1.3) | 1.4 (1.3–1.4) | −0.07 (−0.5 to 0.3) | 0.745 |
| Waist circumference (cm) | | | | |
| Prepregnancy, mean (SE) | 80.4 (1.2) | 76.2 (0.3) | 3.2 | <0.001 |
| Postpregnancy, mean (SE) | 84.5 (1.3) | 80.2 (0.3) | 2.7 | 0.001 |
| Adjusted changeb (95% CI) | 4.0 (3.7–4.3) | 4.0 (3.9–4.1) | 0.4 (−0.6 to 1.5) | 0.427 |

Abbreviations: CI, confidence interval; SE, standard error.

P-values were calculated using linear regression with generalized estimating equations.

Adjusted for age, race, education, parity, cesarean delivery, and interval between delivery and postpregnancy examination.
differ in their prepregnancy or postpregnancy total physical activity scores. Both groups similarly decreased their mean total physical activity scores of postpregnancy by 44.3 (95% CI = 20.0-68.5) points in the GDM group and 54.0 (95% CI = 46.8-61.3) points in the non-GDM group, after an average of 1.4 years (range: 0.4-5 years) following pregnancy. The difference between the prepregnancy to postpregnancy changes in physical activity in the GDM and non-GDM pregnancy groups was not statistically significant (Table 3).

Regarding dietary changes, both the GDM and non-GDM groups increased in total daily caloric intake, percent calories from fat, and daily fiber intake on average 3.1 years (range: 0.1-7 years) after pregnancy. Both the GDM and non-GDM groups slightly decreased their frequency of eating fast food on average 2.2 years after delivery (range: 0.04-5.5 years). The difference in the prepregnancy to postpregnancy dietary changes was not statistically different between the two groups (Table 3).

Additional analyses
We conducted additional separate analyses stratified by prepregnancy BMI and Black versus White race to determine if these factors modified the association between health behaviors and anthropometric changes following pregnancy among the GDM and non-GDM pregnancy groups. These analyses confirmed the results between the two groups across prepregnancy BMI and race (data not shown).

### Table 3: Prepregnancy to postpregnancy changes in physical activity score and dietary intake in GDM and non-GDM pregnancies

|                              | GDM pregnancy | Non-GDM pregnancy | Difference | P-value<sup>a</sup> |
|------------------------------|---------------|-------------------|------------|---------------------|
| **CARDIA total physical activity score** |               |                   |            |                     |
| Prepregnancy, mean (SE)      | 282.4 (19.4)  | 290.0 (5.7)       | -4.2       | 0.816               |
| Postpregnancy, mean (SE)     | 233.6 (21.2)  | 235.9 (5.2)       | 4.7        | 0.807               |
| Adjusted change<sup>b</sup> (95% CI) | -44.3 (-68.5 to -20.0) | -54.0 (-61.3 to -46.8) | 4.6 (-30.9 to -40.0) | 0.801 |
| **Daily caloric intake (kcal)** | n = 78<sup>b</sup> | n = 909<sup>b</sup> |            |                     |
| Prepregnancy, mean (SE)      | 2,174 (138)   | 2,350 (40)        | -177       | 0.226               |
| Postpregnancy, mean (SE)     | 2,418 (167)   | 2,509 (38)        | -91        | 0.668               |
| Adjusted change<sup>c</sup> (95% CI) | 245 (99–391) | 158 (118–199)     | 28 (349 to 406) | 0.883 |
| **Percent calories from fat (%)** | n = 78<sup>b</sup> | n = 909<sup>b</sup> |            |                     |
| Prepregnancy, mean (SE)      | 38.4 (0.7)    | 37.8 (0.2)        | 0.7        | 0.341               |
| Postpregnancy, mean (SE)     | 41.8 (2.3)    | 41.8 (0.7)        | 0.2        | 0.941               |
| Adjusted change<sup>c</sup> (95% CI) | 3.3 (1.9–4.7) | 3.9 (3.4–4.2)     | 1.0 (-4.0 to 6.0) | 0.700 |
| **Daily fiber intake (g)**   | n = 78<sup>b</sup> | n = 909<sup>b</sup> |            |                     |
| Prepregnancy, mean (SE)      | 4.8 (0.3)     | 5.0 (0.1)         | -0.1       | 0.696               |
| Postpregnancy, mean (SE)     | 20.3 (1.1)    | 20.6 (0.3)        | -0.3       | 0.807               |
| Adjusted change<sup>c</sup> (95% CI) | 15.6 (15.0–15.8) | 15.6 (15.5–15.7) | -0.3 (-2.6 to 2.1) | 0.828 |
| **Fast food frequency (times per month)** | n = 112<sup>d</sup> | n = 1,283<sup>d</sup> |            |                     |
| Prepregnancy, mean (SE)      | 7.9 (1.0)     | 5.5 (0.2)         | 2.0        | 0.014               |
| Postpregnancy, mean (SE)     | 5.8 (0.6)     | 4.9 (0.2)         | 0.6        | 0.277               |
| Adjusted change<sup>c</sup> (95% CI) | -2.0 (-3.6 to -0.5) | -0.6 (-0.9 to -0.3) | 0.3 (-0.7 to 1.4) | 0.545 |

Abbreviations: CI, confidence interval; SE, standard error.
<sup>a</sup>P-values were calculated using linear regression with generalized estimating equations.
<sup>b</sup>For the analysis with the dietary intake outcomes (daily caloric intake, percent calories from fat, and daily fiber intake), we included all pregnancies between baseline and examination year 7, enabling comparisons for 78 GDM and 909 non-GDM pregnancies.
<sup>c</sup>Adjusted for age, race, education, parity, cesarean delivery, and interval between delivery and postpregnancy examination.
<sup>d</sup>Fast food frequency was assessed at baseline and examination years 5 and 10 enabling comparisons for 112 GDM and 1,283 non-GDM pregnancies.
Conclusions

This study describes prepregnancy to postpregnancy anthropometric and health behavioral changes in a 20-year prospective cohort study of Black and White women of childbearing age. When compared with women without GDM, women with GDM had higher prepregnancy weight and BMI, but similar levels of physical activity. However, we found similar prepregnancy to postpregnancy changes for GDM and non-GDM pregnancies, including increased weight, BMI, and waist circumference, which are known risk factors for progression to type 2 diabetes (28). Following pregnancy, regardless of GDM status, women similarly decreased physical activity, increased caloric intake, and included fiber intake, but reduced fast food frequency.

To our knowledge, this is the first study to examine prepregnancy to postpregnancy weight and diet changes in women with and without GDM. Using the CARDIA study, Gunderson et al. (3) previously reported 15.9 kg and 14.3 kg of total weight gain from the baseline to 20-year examinations in women with and without GDM histories, respectively. We confirmed postpregnancy weight gain in both groups, without a statistically significant difference between them, although women with GDM generally started with a higher prepregnancy weight and BMI. Retnakaran et al. (13) assessed 1-year preconception to 1-year postpregnancy change in physical activity in 238 pregnant women recruited at the time of their GDM screening. Notably, women with GDM significantly increased leisure-time activity, but not work- or sport-related activities, when compared with women without GDM. In contrast, our study assessed moderate, strenuous, and total physical activity, which decreased similarly after pregnancy, in both GDM and non-GDM groups. Several key characteristics distinguish these study populations. In particular, the majority of CARDIA participants had their pregnancies in the first 10 years of the study (early 1990s) and received clinical care from throughout the United States, whereas women in the Canadian cohort were recruited more recently from a single site, which may have provided more uniform and updated recommendations about diabetes prevention following GDM, thereby improving behavior change at 1 year. In addition, participants in CARDIA were assessed at scheduled study examinations, with an average of 1.4 years between the pregnancy and the postpregnancy examination. Thus, we may not have captured short-lived postpregnancy lifestyle changes if they reverted back to prepregnancy behaviors prior to their next assessment.

Because of their multiple risk factors, including elevated BMI and sedentary behavior, effective interventions aimed at preventing diabetes in women with recent GDM are extremely important. The Diabetes Prevention Program showed in the placebo arm that a GDM pregnancy was associated with a higher incidence of progression to type 2 diabetes when compared with high-risk parous women without GDM (38.4% vs. 25.7%) (7). Even with their increased risk, women with prior GDM benefited greatly from both the intensive lifestyle and metformin arms, with diabetes risk reductions of 53% and 50%, respectively (7). Because we found that all women, regardless of GDM diagnosis, gained weight, reduced activity, and increased caloric intake following pregnancy, our results additionally highlighted the need to engage all women during pregnancy and postpartum to make significant lifestyle changes, similar to those in the Diabetes Prevention Program (29). Two recent pilot lifestyle interventions (30,31) have specifically targeted women with recent GDM; however, adapting previously successful interventions such as the Diabetes Prevention Program to the needs of young working mothers is especially challenging.

Several studies have identified barriers to postpartum behavior change among women with GDM, including lack of risk perception for developing diabetes (10), possibly due to minimal health education during pregnancy and beyond (9), anxiety and postpartum stress (32), as well as the perception that exercise does not reduce diabetes risk (12). Successful interventions will need to specifically target the needs and barriers to change in this population to enable sustainable behavior change and weight loss. In addition, depending on the state, between 27 and 64% of all births in the United States are covered by Medicaid (33) and many women then return to uninsured status following delivery. Lack of health insurance reduces access to primary care services and opportunity for monitoring and interventions to promote and sustain lifelong behavior change. Successful future interventions may need to promote healthy postpregnancy behavior change, as well as to reach out to uninsured and lesser insured high-risk populations to prevent diabetes.

The strengths of our study include use of the CARDIA study, a more than 20-year prospective cohort study design with high rates of follow-up of a biracial US population and the use of standardized preconception and postpregnancy repeated anthropometric, dietary, and physical activity measures. The longitudinal nature of data collection enhanced the validity of our preconception measures and enhanced the feasibility of multiple adjustments in analyses. Studies that are designed to recruit women with GDM during or after pregnancy and collect preconception information at that time may be limited by recall bias. In addition, our study benefitted from the GDM validation study by Gunderson et al. (3), which showed high sensitivity and specificity of self-reported GDM. We also examined associations separately for Black and White racial groups and by prepregnancy BMI and found consistent associations.

Our study has several limitations. First, CARDIA is an observational study that was designed to assess the development of cardiovascular disease and not a pregnancy cohort study. Thus, the time interval for obtaining postpregnancy measurements was variable. The amount of time that passed between the prepregnancy examination and pregnancy, as well between pregnancy and the postpregnancy examination, may have affected weight and health behaviors. We accounted for these intervals by excluding postpregnancy examinations that occurred more than 5 years after the prepregnancy examination for anthropometric and weight outcomes. We also adjusted all analyses for the interval between the delivery and postpregnancy examination. In addition, we found that neither the interval between the prepregnancy examination and pregnancy, nor the interval between delivery and the postpregnancy examination changed the results. However, we may have missed short-lived postpregnancy changes that were not sustained longer than 1 year. Second, although self-report of GDM was validated by chart review (3), it is possible that we missed diagnoses of GDM within the CARDIA cohort; however, this is unlikely given that GDM was self-reported during a period of universal screening for GDM and that GDM requires both treatment and heightened monitoring for patients. If substantial numbers of women with a history of GDM had been misclassified, we may have failed to detect a difference in changes weight and health behaviors between the two groups. However, about 11 percent of women in the cohort reported more than one GDM-complicated pregnancies.
(totaling about seven percent of all pregnancies during 20 years), which is not less than the expected prevalence of GDM (1). Third, we do not have clinical information on the severity of GDM, medications used for GDM treatment, or gestational weight gain and were unable to assess the impact of these variables on postpregnancy weight or health behaviors. Fourth, as with other observational studies, we are limited by the data collection instruments to assess diet and physical activity. These CARDIA instruments have been validated within the larger cohort (21,22,24); however, they have not been tested among the subgroup of women before and after pregnancy and may be less sensitive to differences within this group. Finally, we did not assess all aspects of dietary intake in this study. Interestingly, we noted an increase in fiber intake from 5 to 15 g in both groups. Likely women increased their postpregnancy fiber intake relative to their increased total daily caloric intake; however, further study into dietary quality could help to target specific postpregnancy dietary recommendations.

In conclusion, our study found that both women with and without GDM had increased postpregnancy weight, BMI, and adverse health behaviors. GDM was not associated with significant postpregnancy differences in weight, BMI, waist circumference, diet, or physical activity when compared with parous women without GDM. Increased postpartum weight and decreased physical activity are risk factors for the progression to type 2 diabetes. Our study indicates the need for effective pregnancy and postpartum interventions, especially among women with GDM, to promote sustained and successful behavior change to reduce obesity and diabetes risk.

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