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Healthful dietary patterns and long-term weight change among women with a history of gestational diabetes mellitus

Deirdre K. Tobias

Division of Preventive Medicine, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA

Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, MA

Cuilin Zhang

Epidemiology Branch, Division of Intramural Population Health Research, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institutes of Health, Rockville, MD

Jorge Chavarro

Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, MA

Channing Division of Network Medicine, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA

Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA

Sjurdur Olsen

Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, MA

Centre for Fetal Programming, Department of Epidemiology Research, Statens Serum Institut, Copenhagen, Denmark

Wei Bao

Epidemiology Branch, Division of Intramural Population Health Research, Eunice Kennedy Shriver National Institute of Child Health and Human Development, National Institutes of Health, Rockville, MD

Department of Epidemiology, College of Public Health, University of Iowa, Iowa City, IA

Anne Ahrendt Bjerregaard

Centre for Fetal Programming, Department of Epidemiology Research, Statens Serum Institut, Copenhagen, Denmark

Teresa T. Fung

Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, MA

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Corresponding Author: Deirdre K. Tobias; 900 Commonwealth Avenue Boston, MA 02215; Telephone: 617-525-9857; dtobias@partners.org.

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Simmons College, Boston, MA

JoAnn E. Manson

Division of Preventive Medicine, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA

Frank B. Hu

Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, MA

Channing Division of Network Medicine, Department of Medicine, Brigham and Women's Hospital and Harvard Medical School, Boston, MA

Department of Epidemiology, Harvard T.H. Chan School of Public Health, Boston, MA

Abstract

Background/Objective—Diet represents a key strategy for the prevention of obesity and type 2 diabetes among women with a history of gestational diabetes mellitus (GDM), although effective dietary patterns to prevent weight gain in the long-term are largely unknown. We sought to evaluate whether improvement in overall diet quality is associated with less long-term weight gain among high risk women with prior GDM.

Subjects/Methods—Women with a history of GDM (N=3 397) were followed from 1991 to 2011, or until diagnosis of type 2 diabetes or other chronic disease. Usual diet was assessed via food frequency questionnaire every 4 years from which we calculated the Alternative Healthy Eating Index (aHEI-2010), Alternate Mediterranean Diet (AMED), and Dietary Approaches to Stop Hypertension (DASH) dietary pattern scores. Weight, lifestyle, and health-related outcomes were self-reported every 2 years. We estimated the change in dietary score with change in body weight using linear regression models adjusting for age, baseline body-mass index, baseline and simultaneous change in physical activity and smoking status, and other risk factors.

Results—Women were followed up to 20 years, gaining an average 1.9 kg (SD=7.0) per 4-year period. Women in the highest quintile (Q5) of diet change (most improvement in quality) gained significantly less weight per 4-year period than the lowest quintile (Q1; decrease in quality), independent of other risk factors (4-year weight change, aHEI-2010: Q5=1.30 kg vs. Q1=3.27 kg; AMED: Q5=0.94 kg vs. Q1=2.56 kg, DASH: Q5=0.64 kg vs. Q1=2.75 kg). Significant effect modification by BMI (p-interactions <0.001) indicated a greater magnitude of weight change among women with a higher baseline BMI for all three patterns.

Conclusions—Increased diet quality was associated with less weight gain, independent of other lifestyle factors. Postpartum recommendations on diet quality may provide one strategy to prevent long-term weight gain in this high risk group.

Keywords

dietary patterns; weight gain; obesity; prevention; gestational diabetes

INTRODUCTION

Gestational diabetes mellitus (GDM) is the onset or identification of impaired glucose tolerance in pregnancy, with prevalence estimates among US women ranging from 1% to 14% of pregnancies.⁽¹⁾ Women with a history of GDM are at an exceptionally high risk of developing obesity-related chronic diseases later in life, such as type 2 diabetes and hypertension, compared to parous women without prior GDM.^(2, 3) Body weight and weight gain have been identified as major risk factors for the progression from GDM to the development of these chronic diseases postpartum.^(4–6)

The identification of readily adoptable lifestyle factors associated with long-term weight maintenance is essential to develop effective clinical recommendations for women with recent GDM to prevent long-term weight gain. Evidenced-based data in this regards among the high risk women, however, are sparse. Many guideline recommendations for overall health and maintaining a healthy body weight have recently shifted to adopting the perspective of healthy eating patterns, rather than focusing solely on individual nutrients.^(7, 8) The role of healthful dietary patterns in the prevention of long-term weight gain has not been prospectively evaluated among women with a history of GDM. Therefore, we sought to assess the relationship between change in adherence to three healthful dietary patterns, the 2010 Alternative Healthy Eating Index (aHEI-2010), the Alternate Mediterranean Diet (AMED), and the Dietary Approaches to Stop Hypertension (DASH), and long-term change in weight, to determine whether improved diet quality may provide one strategy for the prevention of weight gain among a high risk group of women with a history of GDM, prior to development of type 2 diabetes.

SUBJECTS AND METHODS

Study Population

The study population is composed of women with a history of GDM in the Nurses' Health Study II (NHS II), as part of the ongoing Diabetes & Women's Health Study⁽⁹⁾, which aims to identify determinants of progression from GDM to type 2 diabetes. The NHS II is a longitudinal prospective cohort which began in 1989 with the enrollment of 116 430 female nurses, aged 24–44 at baseline. Questionnaires are distributed every two years to update information on a variety of lifestyle and health-related characteristics, with follow-up for each cycle greater than 90%. This study has been approved by the institutional review board of the Partners Health Care System (Boston, MA, USA), with participants' consent implied by the return of the questionnaires.

Participants were included in this analysis if they reported at least one GDM pregnancy on the baseline questionnaire or incident GDM during follow-up through 2001. Self-report of a physician's diagnosis of GDM has been validated against medical records in a subgroup of NHS II participants, with 94% of cases confirmed.⁽¹⁰⁾ We excluded women reporting a multiple birth pregnancy, cancer, a cardiovascular disease event (stroke or myocardial infarction), or type 2 diabetes prior to GDM. Additionally, those missing information on body weight, having an invalid food frequency questionnaire (>70 items left blank, or total energy intake <500 or >3 500 kcal/day), or pregnant while completing the biennial

questionnaire did not contribute to the adjacent 4-year intervals, since valid estimates of diet and/or weight change could not be computed. Women with subsequent pregnancies remained in the cohort, regardless of whether they had recurrent GDM. Women were censored during follow-up if they reported a multiple birth pregnancy, cancer, cardiovascular disease, type 2 diabetes, or death. Follow-up after type 2 diabetes and other chronic diseases was excluded avoid confounding by clinical advice, diabetes-related therapies, and other interventions leading to weight loss. Follow-up continued through return of the 2011 questionnaire.

Assessment of Adherence to Dietary Patterns

Participants complete a validated semi-quantitative food frequency questionnaire (FFQ) in 1991 and every 4 years thereafter.⁽¹¹⁾ The FFQ captures usual intake of several food items over the past year and has been extensively validated. We computed adherence scores for three common healthful dietary patterns; the 2010 Alternative Healthy Eating Index (aHEI-2010), the Alternate Mediterranean Diet (AMED), and the Dietary Approaches to Stop Hypertension (DASH). Participants' adherence score for each pattern is computed as the sum of points across the patterns' dietary components, with a higher score indicating greater adherence, ranging from 2.5–87.5 points for aHEI-2010, 0–8 for AMED, and 8–39 for DASH. Details for the patterns' scoring methods have been published in detail elsewhere.^(12, 13)

Outcome and Covariate Assessment

Body weight was reported on each biennial questionnaire. A previous validation study observed that self-reported weight was highly correlated with technician-measured weight among a subset of Boston-area cohort participants ($r=0.97$).⁽¹⁴⁾

Additional lifestyle, reproductive, and health-related characteristics were captured at baseline and updated every 2 years, including pregnancies, menopausal status, and smoking status. Validated total physical activity was ascertained at baseline and approximately every 4 years by report of how frequently participants engaged in common recreational activities, which was converted into total metabolic equivalent tasks (MET-hours) per week.⁽¹⁵⁾

Statistical Methods

Change in pattern adherence scores and change in weight were computed as the difference for each 4-year period, from 1991 through 2011. The first 4-year period began with the first FFQ after the report of a GDM pregnancy. Covariate information was also calculated for each 4-year change, where appropriate. Missing covariate data was carried forward for the continuous variables and a missing indicator category was used for categorical variables, when necessary (<5% of data).

The relationship between change in dietary pattern adherence and change in body weight over repeated 4-year periods was evaluated with generalized estimating equations, specifying an unstructured working correlation structure to account for within-person repeated outcome measures. We analyzed change in dietary pattern adherence scores as a continuous measure for a 1 standard deviation (SD) increase and in quintiles, with the third

quintile serving as the reference group. The p-values for linear trends across quintiles were estimated by modeling the median value of each category as a continuous variable. Multivariable models adjusted for age, the dietary pattern adherence score at the beginning of the 4-year period, baseline body-mass index (BMI) in kg/m², baseline and change in total physical activity (MET-hours per week), change in cigarette smoking status (stayed a never smoker, stayed a former smoker, new smoker, re-started smoking, quitter, stayed a current smoker), baseline (1, 2, 3, 4) and change in parity (number of pregnancies lasting 6 months), menopausal status at end of the interval (premenopausal, postmenopausal, unsure), race/ethnicity (white, black, Asian, other), family history of diabetes (yes/no), and 4-year time period (1991–1995, 1995–1999, 1999–2003, 2003–2007, 2007–2011). Models for the DASH diet additionally adjusted for baseline and change in alcohol (grams per day), since it is not a component of the pattern. Total energy intake was considered a potential causal intermediate between change in diet and change in weight and was not included in the main multivariable model; however, we included baseline and 4-year change in a sensitivity analysis.

We conducted a stratified analysis by BMI (<25.0 kg/m²=normal weight, 25.0–29.9=overweight, 30.0=obese) to assess whether results differed according to starting body weight. Additionally, we examined the joint association between simultaneous 4-year changes in diet (tertiles) and total physical activity (decrease of >1.0 MET-hours/week, no change [–1.0 to 1.0], increase of >1.0) on change in body weight.

In additional sensitivity analyses we excluded outliers for change in pattern scores at the 0.5 and 99.5 percentiles. Additionally, we restricted to never smokers to reduce the potential for residual confounding by change in smoking status, a predictor of weight change. All analyses were run on SAS Version 9.3, with alpha<0.05 as the level of significance.

RESULTS

There were 3 397 women eligible for inclusion in our analysis of the 4 631 parous women who reported a history of GDM in at least 1 pregnancy (Supplemental Figure). Baseline characteristics are presented in Table 1. At baseline, women were on average 38.6 (SD=5.2) years of age, with a BMI of 26.6 kg/m² (SD=6.2). Thirty-three percent had a family history of diabetes and the majority (92%) was Caucasian. Women were followed for a maximum of 20 years, with an average weight gain per 4-year period of 1.9 kg (SD=7.0 kg).

Table 2 gives the main results for the relationship between change in diet quality and change in weight. Increased adherence to each dietary pattern score was significantly associated with less weight gain within the same 4-year period, independent of baseline BMI, baseline and change in physical activity, smoking status, and several other factors; per 1 SD increase, aHEI-2010: –1.24 kg (95% CI=–1.42, –1.06), AMED: –0.55 kg (95% CI=–0.71, –0.39), DASH: –0.84 kg (95% CI=–1.02, –0.67). Analyses by quintiles of dietary pattern change gave similar findings (Figure 1), with women in the fifth quintile (most improvement) gaining significantly less weight than women with stable or decreased adherence scores (all p-trends<0.001 for all dietary patterns).

There was significant effect modification by baseline BMI category (all p -interactions < 0.001). At all BMI levels, an increased adherence to any dietary pattern was associated with less weight gain; however, the magnitude of weight change was greater with higher BMI levels, as shown in Figure 2. We did not observe statistically significant interactions between change in dietary pattern scores and change in physical activity with weight change (p for interactions: aHEI-2010=0.30, AMED=0.86, DASH=0.92; Supplemental Table 1), indicating that regardless of level of change in physical activity, improvement in diet quality was associated with less weight gain. An increase in total energy intake (kilocalories/day) was associated with a simultaneous weight gain in the multivariable models. Including baseline and simultaneous 4-year change in total energy intake in the multivariable model moderately strengthened the relationships between AMED and DASH patterns weight change (-0.77 kg, 95% CI= $-0.94, -0.60$; -1.12 kg, 95% CI= $-1.31, -0.93$, per 1 SD, respectively), and minimally impacted aHEI-2010 (-1.19 kg, 95% CI= $-1.37, -1.01$ per 1 SD). Conclusions were unchanged with the exclusion of outliers at the extreme ends of diet change, and when restricted to never smokers, supporting the robustness of these results.

DISCUSSION

Change in diet quality was significantly and independently associated with long-term weight change among women with a history of GDM. Average 4-year weight gain in our study population was approximately 1.9 kg. Compared with women who decreased their diet quality in a 4-year period, those with improved diet quality gained approximately 2–3 kg less, independent of simultaneous changes in physical activity, smoking status, parity, and other potential risk factors for weight gain.

This is the first study to assess the long-term relationship between changes in diet quality and weight among women with a history of GDM in the observational setting. Previous randomized trials have evaluated the impact of lifestyle interventions among women with a history of GDM, for the prevention of post-partum progression to type 2 diabetes and/or weight loss; however, most include multi-component interventions (e.g., diet plus physical activity, breastfeeding, behavioral), and few report follow-up beyond 6–12 months post-partum.^(16–20) A weight loss trial among women with prior GDM evaluated the effects of a diet-only intervention versus a non-intervention control group, reporting no differences in BMI after a median 51 months of follow-up.⁽²¹⁾ One possible explanation for a lack of benefit may be that the authors cite that improvement in diet quality over follow-up was similar between the two groups. Numerous dietary intervention weight loss RCTs have been conducted in the general population or other high risk subgroups, and overall healthy dietary patterns such as the Mediterranean diet have been effective for modest weight loss, compared with no intervention or low-fat diet.^(22–24) The effectiveness of interventions for prevention of gradual long-term weight gain may differ from those intended for substantial weight loss in the short-term; thus, randomized trials among women with a history of GDM, specifically for long-term weight gain prevention, are warranted.

A shift in energy balance is a plausible mechanism by which change in diet quality is associated with change in weight. Improved diet quality, measured in our study as an

increase in adherence scores to three dietary patterns, can be achieved through a reduction in foods and nutrients associated with weight gain, an increase in foods and nutrients associated with weight loss, or some combination of the two. For example, eliminating sugar-sweetened beverages, known contributors of weight-gain^(25–27), would be expected to lead to less long-term weight gain. Alternatively, increasing foods high in fiber and other satiating constituents, such as fruits, vegetables, nuts, and whole grains, has been associated with less long-term weight gain among US adults, likely through a decrease in the intake of other foods; thus lowering overall energy intake even in the absence of intentional caloric restriction.^(26, 28–31) Other potential intermediates of diet quality independent of its effect on caloric intake with weight change are possible, including inflammation, changes to gut microbiota, or other unknown mechanisms.

There are advantages to evaluating dietary patterns to address the relationship between diet quality and weight change. The aHEI-2010, AMED, and DASH dietary patterns emphasize some similar components, encouraging healthful foods such as fruits, vegetables, nuts and legumes, and lean sources of meat, while red meat and sugar sweetened beverages are discouraged. Nutrients and foods may have an undetectable or subtle impact on total energy intake and subsequent weight change when analyzed individually;⁽²⁶⁾ however, analyzing overall eating habits provides a comprehensive assessment of numerous dietary components, and accounts for any known or unknown complex interactions between them. Furthermore, healthful dietary patterns are adaptable to clinical advice and public health recommendations, and may be more easily incorporated into a healthy lifestyle pattern over the long-term. Other strengths of this study include the repeated measures of diet and weight over 20 years of follow-up, allowing us to analyze long-term patterns of change. We did not observe a relationship between baseline dietary pattern scores with subsequent 4-year weight change (data not shown), indicating that current dietary habits may be most relevant to gradual changes in weight.⁽²⁶⁾

Limitations to this analysis include the reliance on self-reported body weight to compute weight change; however a previous validation showed high correlation of 0.97 between self-reported and technician-measured weight among a subset of Boston-area cohort participants.⁽¹⁴⁾ Error in self-reported diet, if random, would lead to an underestimate of the associations. Second, our analysis carefully controlled for simultaneous change in other lifestyle factors, such as physical activity and smoking status; however, residual confounding from the self-report of these variables or confounding by other unmeasured factors may remain. Third, our participants were US nurses and the majority were Caucasian, which may limit the generalizability of our findings; nonetheless, the relative homogeneity of our population's socio-economic and educational background decreases the impact of confounding by these factors. A recent analysis conducted among women participating the US National Health and Nutrition Examination Survey observed a mean aHEI-2010 score of 39.9 from 1999–2000 based on the 24-hour diet recall method⁽³²⁾, which is not drastically lower than the mean score among our NHS II population with prior GDM from the 1999 FFQ (47.0).

Conclusions

Our study suggests improved diet quality may lead to less long-term weight gain among women with a history of GDM prior to progression to type 2 diabetes, particularly those who are overweight or obese. The identification of healthful dietary patterns for the prevention of weight gain is essential for the population as a whole; however, given their demonstrated propensity for metabolic dysfunction, women with prior GDM represent a subgroup at high risk of obesity-related conditions. These findings suggest that all three healthful dietary patterns may prevent postpartum and long-term weight gain, providing clinicians and patients with a variety of options to improve dietary quality, including higher intakes of fruits and vegetables, lean meats, whole grains, nuts, legumes, and low intakes of red and processed meats, sugar-sweetened beverages, and refined carbohydrates. Randomized trials of dietary interventions may further validate these findings. Postpartum clinical visits for women with GDM often include recommendations to reduce their risk of progression to type 2 diabetes and to prevent weight gain. Findings from the present study suggest that improved diet quality, independent of other lifestyle factors, may mitigate the majority of midlife weight gain in this high risk population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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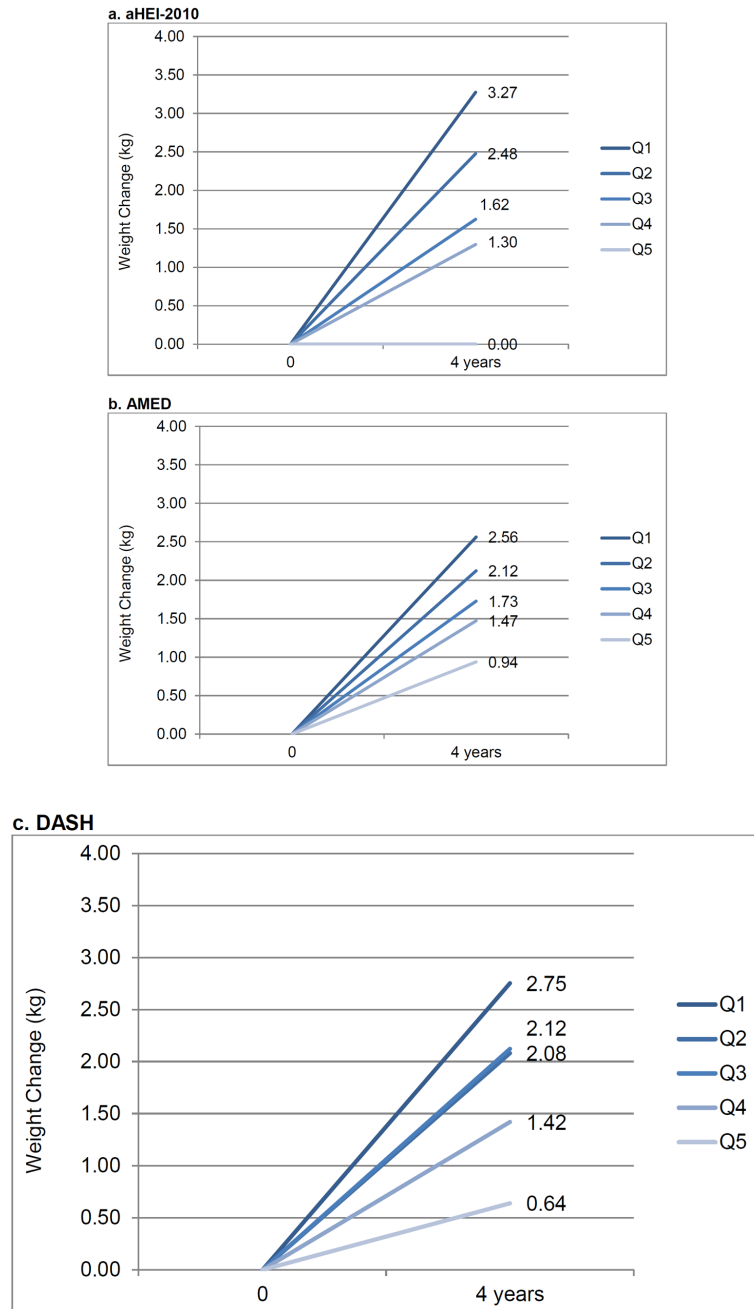


Figure 1.

Figure 1 illustrates the multivariable-adjusted average 4-year weight change (kg) for each quintile of 4-year change in dietary pattern adherence scores among 3 397 US women with a history of GDM; panel A) aHEI-2010, B) AMED, and C) DASH dietary patterns. The median values of quintiles of 4-year change in dietary pattern scores are the following, aHEI-2010: -9.0, -2.0, 3.0, 8.0, 16.0 points, AMED: -2.0, -1.0, 0.0, 1.0, 2.0 points, and DASH: -5.0, -2.0, 0.0, 2.0, 5.0 points. Multivariable models are adjusted for age, baseline dietary pattern score, baseline body-mass index, baseline and change in physical activity (MET-hours/week), baseline and change in parity, change in smoking status, family history

of diabetes, menopausal status, and time period; alcohol (grams/day) for DASH only.
aHEI-2010=2010 Alternate Health Eating Index, AMED=Alternative Mediterranean Diet,
DASH=Dietary Approaches to Stop Hypertension.

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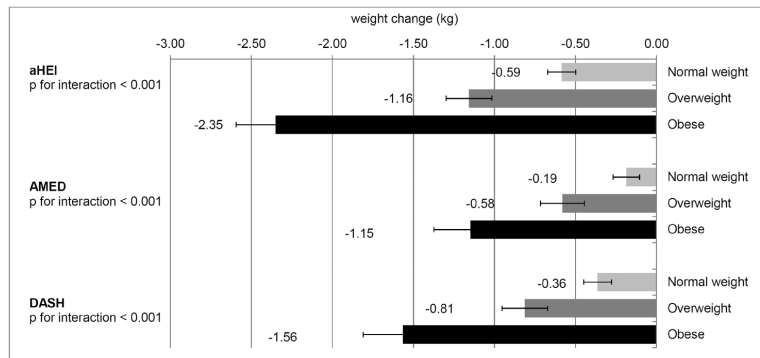


Figure 2.

Figure 2 presents the multivariable-adjusted mean 4-year weight change (kg) per 1 SD 4-year increase in dietary pattern adherence scores among 3 397 US women with a history of GDM, according to body-mass index at the beginning of the 4-year period (normal weight=BMI<25.0, overweight=BMI 25.0–29.9, obese=BMI 30.0). 1 SD in change for aHEI-2010=9.85, AMED=1.79, DASH=4.20. Multivariable models are adjusted for age, baseline dietary pattern score, baseline body-mass index, baseline and change in physical activity (MET-hours/week), baseline and change in parity, change in smoking status, family history of diabetes, menopausal status, and time period; alcohol (grams/day) for DASH only; aHEI-2010=2010 Alternate Health Eating Index, AMED=Alternative Mediterranean Diet, DASH=Dietary Approaches to Stop Hypertension.

Table 1

Baseline characteristics and average 4-year changes among 3,397 US women with a history of GDM

	Baseline Mean (SD)	Average 4-Year Change Mean (SD) ^a
Age (years)	38.6 (5.2)	--
Body weight (kg)	71.5 (17.6)	1.9 (7.0)
BMI (kg/m ²)	26.6 (6.2)	0.7 (2.6)
BMI category (%)		
Normal (<25.0)	49.1	--
Overweight (25.0–29.9)	27.5	--
Obese (≥30.0)	23.3	--
BMI category change (%)		
Decrease BMI category	--	5.8
No category change	--	78.6
Increase BMI category	--	15.6
aHEI-2010	47.4 (11.2)	3.3 (9.8)
AMED	4.1 (1.9)	0.0 (1.8)
DASH	23.6 (5.0)	−0.2 (4.2)
Total energy intake (kcal/d)	1901 (571)	−31 (518)
Alcohol (grams/day)	2.5 (5.0)	0.6 (5.1)
Physical activity (MET-hrs/wk)	17.3 (23.7)	0.5 (25.7)
Physical activity change (%)		
Decrease (>−1 MET-hrs/wk)	--	40.4
No change (−1 to 1 MET-hrs/wk)	--	17.7
Increase (>1 MET-hrs/wk)	--	42.0
Smoking status (%)		
Never	66.4	--
Past	23.1	--
Current	10.3	--
Smoking status change (%)		
Began (never to current)	--	0.2
Resumed (former to current)	--	1.1
Quit (current to former)	--	2.2
Parity (pregnancies ≥6m)	2.3 (1.0)	0.1 (0.2)
Breastfeeding, total months	16.4 (15.7)	--
Age at first birth	27.4 (4.9)	--
Oral contraceptive use (%)		
Never	12.8	--
Past	80.5	--
Current	6.7	--
Family history of diabetes (%)	33.4	--
Caucasian race/ethnicity	92.4	--

SD=standard deviation, BMI=body-mass index, MET=metabolic equivalent tasks, aHEI-2010=2010 Alternate Health Eating Index, AMED=Alternative Mediterranean Diet, DASH=Dietary Approaches to Stop Hypertension

^a average across all five 4-year time periods from 1991 to 2011

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Table 2

Relationships between 4-year increase in dietary pattern adherence scores (per 1 SD) and weight change, among 3,397 US women with a history of GDM

	Weight Change per 1 SD ^b Increase in Diet Pattern Score			
	Age-Adjusted Weight Change – kg (95% CI)	p-value	Multivariable-Adjusted Weight Change ^a – kg (95% CI)	p-value
aHEI-2010	-1.17 (-1.34, -0.99)	<0.001	-1.24 (-1.42, -1.06)	<0.001
AMED	-0.41 (-0.56, -0.26)	<0.001	-0.55 (-0.71, -0.39)	<0.001
DASH	-0.71 (-0.89, -0.54)	<0.001	-0.84 (-1.02, -0.67)	<0.001

SD=standard deviation, CI=confidence interval, aHEI-2010=2010 Alternate Health Eating Index, AMED=Alternative Mediterranean Diet, DASH=Dietary Approaches to Stop Hypertension

^aMultivariable models adjusted for age, baseline dietary pattern score, baseline body-mass index, baseline and change in physical activity (MET-hrs/week), change in smoking status, baseline parity, change in parity, menopausal status, race/ethnicity, family history of diabetes, and time period; baseline and change in alcohol (grams/day) for DASH only

^b1 standard deviation in change for aHEI-2010=9.85, AMED=1.79, DASH=4.20 points