Published in final edited form as:

J Hum Nutr Diet. 2016 April ; 29(2): 209–216. doi:10.1111/jhn.12296.

Portion Controlled Meals Provide Increases in Diet Quality During Weight Loss and Maintenance

Lauren T. Ptomey^a, Erik A. Willis^a, Jeannine R. Goetz^b, Jaehoon Lee^c, Amanda N. Szabo-Reed^a, Debra K. Sullivan^b, and Joseph E. Donnelly^a

Erik A. Willis: ewillis@ku.edu; Jeannine R. Goetz: jgoetz@kumc.edu; Jaehoon Lee: jaehoon.lee@ttu.edu; Amanda N. Szabo-Reed: aszabo@ku.edu; Debra K. Sullivan: dsullivan@kumc.edu; Joseph E. Donnelly: jdonnelly@ku.edu

^aCardiovascular Research Institute, Division of Internal Medicine, The University of Kansas Medical Center, 3901 Rainbow Boulevard, Kansas City, KS, 66160 USA

^bDepartment of Dietetics and Nutrition, The University of Kansas Medical Center, 3901 Rainbow Boulevard, Kansas City, KS, 66160 USA

^cInstitute for Measurement, Methodology, Analysis, and Policy, Texas Tech University, 2500 Broadway Street; Lubbock, TX 79409 USA

Abstract

Background—Behavioral weight loss interventions utilizing portion controlled meals (PCMs) produce significant decreases in weight. However, the impact on diet quality during weight maintenance is unknown. To assess the influence of a weight management intervention employing PCMs and increased physical activity on diet quality during weight loss and weight maintenance.

Methods—197 overweight and obese adults (67% women; BMI = 34.0 ± 4.6 kg/m²; age = 46.1 ± 8.9 yrs.) completed an 18-month trial. The weight loss phase, 0–6 months, consisted of energy restriction achieved using PCMs plus fruits and vegetables and increased physical activity. During weight maintenance, 6–18 months, participants consumed a diet designed to maintain weight loss. Body weight and dietary intake were assessed at baseline, 6, 12, and 18 months. Healthy Eating Index-2010 (HEI) was calculated using data obtained from 3-day food records.

Results—Body weight was $14.3 \pm 6.6\%$, and $8.7 \pm 8.0\%$ below baseline at 6 and 18 months, respectively. The HEI-2010 score following weight loss, (66.6 ± 9.4) was significantly higher than baseline (46.4 ± 8.9) and remained significantly higher than baseline at 18 months (57.7 ± 10.6 ; both $p < 0.001$).

Conclusion—A weight management intervention using PCMs resulted in both clinically significant weight loss and increased diet quality scores, demonstrating that the use of PCMs during weight loss allows for meaningful changes in diet quality during weight maintenance.

Corresponding author: Lauren Ptomey, PhD, RD, LD, Postdoctoral Fellow, Cardiovascular Research Institute, Division of Internal Medicine, University of Kansas Medical Center, 3901 Rainbow Blvd, Mail Stop #1007, ATTN: Energy Balance Lab, Kansas City, KS 66160, Phone: 913-945-8182, Fax: 913-945-8280, LPtomey@kumc.edu.

Authorship: LP, DS, JD designed the study, JG, DS, and JD collected the data, LP, ASR, JL analyzed the data, JL did the statistical analysis, LP, EW, JG drafted the paper, all authors reviewed its content and approved the final version.

Conflict of Interest: All authors report no conflicts of interest.

Keywords

Portion Controlled Meals; Diet Quality; Weight Loss; Weight Maintenance; Diet

INTRODUCTION

The prevalence of overweight and obesity [body mass index (BMI) ≥ 25.0] among US adults is ~68%, with 34% considered obese (BMI ≥ 30)¹. Overweight and obesity contribute to heart disease, hypertension, diabetes, and some cancers as well as psychosocial and economic issues². Evidence suggests that as little as 5–10% weight loss of initial body weight can improve obesity-related health complications^{1,3,4}. As a result, reduced-energy diets have become a major component of many weight loss programs^{5,6}.

Many individuals make repeated attempts to lose and maintain weight using a variety of diets and are unsuccessful. Portion controlled meals (PCMs) are often used in structured weight loss and maintenance programs. PCMs are any pre-portioned, packaged, low-calorie, high-nutritional content food intended to substitute for a “regular” meal prepared from raw ingredients. PCMs have consistently shown significantly greater weight loss and maintenance when compared to a conventional diet, as well as improvements in metabolic risk factors^{7–10}. Several studies suggest replacing as little as one meal per day with a PCM is associated with superior weight loss maintenance compared to programs utilizing conventional diet programs, such as calorie counting^{7,8,10–12}.

Despite strong evidence for the use of PCMs in weight loss and maintenance, there is a common public concern that those individuals who lose weight using PCMs do not develop an understanding of what constitutes “healthy eating” and do not develop the strategies and skills to maintain a healthy diet during weight maintenance. Thus, it is suggested that when PCMs are discontinued individuals will lack the ability to make proper healthy eating decisions. Previous studies suggest that consuming PCMs may improve diet quality during the period they are consumed^{11,13}, but the long-term impact on diet quality of individuals following a weight loss intervention utilizing PCMs is unknown. Data from the (blinded for review) Equivalent Weight Loss for Phone & Clinic Weight Management Program (DK76063; acronym-Phone vs Clinic) afforded an opportunity to examine the effect of PCMs on diet quality during a weight loss and maintenance intervention that included PCMs, physical activity, and behavior education.

METHODS

A comprehensive description for Phone vs Clinic of the initial participant population, rationale, design, and methods has been previously published¹⁴ as well as the primary outcome¹⁵. Briefly, Phone vs Clinic randomized overweight and obese individuals (BMI 25–44.9 kg·m²), living in the United States and aged 18–65 years, to a standardized weight management program delivered using either traditional face-to-face clinics or group conference calls (phone). The primary aim was to determine if weight loss at six months was equivalent for participants randomized to face-to-face clinic or group conference calls. This study was conducted according to the guidelines laid down in the Declaration of Helsinki,

and all procedures involving human subjects were approved by the [name of the ethics committee removed for blinding]. Written informed consent was obtained from all subjects.

INTERVENTION

Educational sessions—Educational sessions for both groups were conducted weekly during the weight loss phase (month 0 to 6) and then gradually reduced during weight maintenance (months 7–18). Meetings were held twice per month during months 7–9, monthly during months 10–12, and every other month for the remainder of the 18 months. Both groups received the same education sessions. Weekly groups of 11–20 participants were led by health educators with backgrounds in nutrition, psychology, or exercise physiology and at least 1 year of experience in weight management. Meetings followed a standard protocol: review and discussion of self-reported data including minutes of physical activity, daily steps via step counter, and dietary compliance; a behaviorally-based lesson on a topic related to nutrition, physical activity and lifestyle modification; and group discussion, problem solving, and assignment of activities to assist participants in developing behavioral strategies associated with successful weight management.

Diet: weight loss (months 0–6)—Energy intake was reduced to ~5021 to 6278 kJ (1200 to 1500 kcal) per day using a combination of commercially available PCMs (Health Management Resources, Boston, MA) that were provided, for the first 6 months, free of cost as part of the study. Participants were instructed to consume a minimum daily total of 3 shakes [~418.4 kJ (100 kcal) each], 2 entrees [between 586 and 1130 kJ (140 and 270 kcal each)], and at least five 1-cup servings of fruits or vegetables. The entrées were ready-made meals that were shelf-stable and just needed to be heated up in a microwave for 1 minute. There were 12 entrée choices, which included beef stroganoff, mushroom risotto, cheese ravioli, turkey chili, and vegetable beef stew. All participants reported the number of shakes, entrées, fruits, and vegetables consumed each day to their health educator biweekly.

Diet: weight maintenance (7–18 months)—Participants were instructed to consume a weight maintenance diet with an energy level designed to maintain weight loss using the equation of Mifflin et al ¹⁶. Participants were given a meal plan based on their energy needs and the United States Department of Agriculture's 2005 "My Pyramid" (www.mypyramid.gov) recommended servings of food groups. During weight maintenance, participants were encouraged but not required to continue consuming a minimum of 14 PCMs and 35 servings of fruits and vegetables per week.

Exercise—Participants were asked to complete 300 minutes per week of moderate to vigorous exercise during the 18-month trial. Exercise progressed from 45 minutes per week at intervention onset to the target of 300 minutes per week at the end of month 3 and remained at target for the final 12 months of the study.

ASSESSMENTS

All assessments were completed by trained research assistants at baseline, 6, 12, and 18 months.

Body weight, height, and BMI—Body weight was recorded using a digital scale accurate to ± 0.1 kg (Befour Inc Model #PS6600, Saukville, WI). All participants were weighed wearing a standard hospital gown, after attempting to empty their bowels, between the hours of 6:00am and 10:00am, and prior to breakfast. Height was measured using a stadiometer (Model PE-WM-60-84, Perspective Enterprises, Portage MI), and body mass index (kg/m^2) was calculated.

Diet intake—Three-day food records were obtained to assess energy and macronutrient content of the diet. Participants were instructed to record all food and beverage consumption on 2 weekdays and 1 weekend day. Records were reviewed with the participants by a registered dietitian who used portion guides to help obtain accurate portion sizes. The portion guides used in the interviews were 3-dimensional models consisting of a variety of items intended to provide a reference and improve recall accuracy (i.e., glasses, mugs, bowls, circles, thickness sticks, chip bags, drink bottles, a 12-inch ruler, measuring cups and spoons, a grid, wedges, geometric shapes, and diagrams of chicken pieces)¹⁷. Records were removed from analysis if they did not represent a valid day (participant was very ill) or if the record could not be considered reliable (participant forgot 1 or more meals). The records were entered into the Nutrient Data System for Research (NDS-R; University of Minnesota, Minneapolis, MN; version 2011) for nutrient analysis.

Diet quality—The Healthy Eating Index-2010 (HEI-2010) was used to calculate diet quality from data obtained from the 3-day diet records at baseline, 6, 12, and 18 months. The HEI-2010 is a measure of diet quality developed by the United States Department of Agriculture that assesses conformance to the 2010 Dietary Guidelines for Americans¹⁸. The HEI-2010 assesses the intake of total fruits, whole fruits, total vegetables, dark green vegetables and beans, refined grains, whole grains, milk, meats and beans, seafood and plant protein, fatty acid ratio, sodium, and empty calories. The HEI-2010 provides a point value based on how well a person meets the dietary guidelines expressed as a percent per 4184 kJ (1000 kcals)¹⁹. The HEI-2010 was calculated using NDS-R output and a custom SAS code. Point values for each component were summed to give the final HEI score. Higher component scores are indicative of better diet quality. The total maximum score for HEI-2010 is 100. Total fruits, whole fruits, total vegetables, greens and beans, total proteins, and seafood and plant protein all have a maximum score of 5 points. Whole grains, dairy, fatty acids, refined grains, and sodium have a maximum score of 10 points. Empty calories have a maximum score of 20 points. Higher component scores are generally indicative of higher consumption of those foods; however, the scoring for refined grains, sodium, and empty calories is inverted with higher scores being given to indicate lower consumption of those foods.

Physical activity—Physical activity was assessed by a portable accelerometer (Actigraph GT1M, Actigraph, LLC, Pensacola, FL). The GT1M is a small, lightweight, uni-axial, piezoelectric accelerometer, which measures and records vertical accelerations from approximately 0.05g to 2.0g with a frequency response from 0.25 to 2.50 Hz reflected as activity counts per minute ($\text{cts} \cdot \text{min}^{-1}$). Accelerometers were worn on an elastic belt over the non-dominant hip for 7 consecutive days. The data collection interval was set at one minute

with a minimum of 10 hours constituting a valid monitored day. Three valid days were required to be included in the accelerometer analysis. Non-wear time was identified as 60 consecutive minutes with 0 cts.min⁻¹, with allowance for 1–2 minutes of accelerometer counts between 0 and 100. Data were downloaded using ActiGraph software and processed using a custom SAS program developed by our group. Sedentary time was defined as the time spent with accelerometer readings <100 cts.min⁻¹, light (100–2019 cts.min⁻¹), moderate (>3 METs, 2020–5999 cts.min⁻¹) and vigorous PA (>6 METs, >5999 cts.min⁻¹)²⁰.

Statistical analysis—Sample demographic characteristics were summarized by descriptive statistics and bivariate tests, such as independent-samples t-test, Chi-square, or Fisher's exact test. All assessment variables were compared between males and females using independent-samples or Satterthwaite t-test at baseline, 6, 12, and 18 months. The correlations among changes in diet quality, weight, and physical activity were examined at each time point. Statistical significance was determined at 0.05 alpha level, and all analyses were performed using SAS Software, version 9.3 (SAS Institute Inc., Cary, NC).

RESULTS

Participants

Three hundred ninety-five individuals were randomized to one of the two study groups (phone or clinic). This analysis includes 197 participants who completed the 18-month study and provided valid and reliable 3-day food records for calculation of HEI-2010 at all four of the time points. Baseline participant characteristics are presented in Table 1. There were no significant differences in baseline characteristics between the 197 participants included in this analysis and the 395 participants randomized at baseline.

PCM consumption and attendance

Participants consumed an average of 12.1 ± 1.4 entrees and 18.1 ± 2.5 shakes per week during the weight loss phase, which is less than the 14 entrees and 21 shakes they were instructed to consume during weight loss. However, they consumed more than the 35 fruits and vegetables as instructed (mean 40.7 ± 8.6). During weight maintenance, although not required, participants continued to consume an average of ~9 PCMs per week and 36.5 ± 10.5 fruits and vegetables per week during months 7–12 and 34.4 ± 9.8 per week during months 13–18. Full PCM consumption data is shown in Table 2. Attendance at behavioral sessions averaged 88% during weight loss and 76% during weight maintenance.

Diet quality

Total HEI-2010 scores significantly improved by 20.3 ± 11.9 ($p < 0.001$) during weight loss (baseline = 46.6 ± 8.9 ; month 6 = 66.6 ± 9.4) and remained above baseline during weight maintenance (12 months = 58.0 ± 10.1 ; 18 months = 57.7 ± 10.6 ; both $p < 0.001$). Men had significantly lower baseline HEI-2010 scores than women did at baseline ($p < 0.001$), month 6 ($p = 0.001$), and month 12 ($p = 0.017$), but men also had a significantly greater change in HEI-2010 scores across time from baseline to month 18 ($p = 0.013$). Total HEI-2010 scores for the complete sample, men, and women are shown in Table 3. An increase in HEI-2010

total score was significantly associated with a greater percent weight loss at months 6, 12, and 18 (all $p < 0.001$). HEI components that significantly improved across the study were servings of whole fruits, total vegetables, refined grains, fatty acid intake, and empty calories. HEI-2010 component scores across the 18-month study are found in table 4.

Weight changes

A detailed description of weight change in this trial has been published¹⁵. Weight loss in 197 participants included in this analysis was $-14.3 \pm 6.6\%$ and $-8.7 \pm 8.0\%$ at 6 and 18 months, respectively (both $p < 0.001$). Weight change was similar in men and women. In men, weight loss was $-15.4 \pm 6.3\%$ at 6 months and $-9.1 \pm 7.7\%$ at 18 months; in women, weight loss was $-13.8 \pm 6.7\%$ at 6 months and $-8.5 \pm 8.2\%$ at 18 months (all $p < 0.001$).

Physical activity

During weight loss, moderate to vigorous physical activity (MVPA) minutes increased from 16.9 ± 14.5 to 35.9 ± 22.4 minutes per day. MVPA decreased slightly to 28.2 ± 20.1 minutes at month 12 and 20.4 ± 22.2 minutes at month 18. Men had significantly greater minutes of MVPA than women at baseline, month 6, and month 18. Multivariate correlation analysis was performed between changes in HEI total scores, percent weight loss, sedentary activity ($\text{min} \cdot \text{d}^{-1}$), light activity ($\text{min} \cdot \text{d}^{-1}$), and MVPA ($\text{min} \cdot \text{d}^{-1}$). In the overall sample, a greater increase in percent weight loss was significantly associated with MVPA ($p < 0.01$) at 0–6, 0–12, and 0–18 months with a correlation of $r^2 = -0.32$. There was no significant correlation between MVPA and diet quality.

DISCUSSION

The specific aim of this analysis was to determine the impact of PCMs, combined with behavior education and exercise, on diet quality during weight loss and weight maintenance. The effect of a diet on diet quality is important as poor diet quality has been found to be associated with inflammation, insulin resistance, and some cancers^{21–23}. Improvements in diet quality may reduce the risk of these conditions separate from benefits seen with weight loss. However, the use of PCMs in overweight and obese individuals for weight loss raises concern that these products might not foster healthy food choices during weight maintenance. The results found that HEI-2010 scores at baseline were below the average HEI-2010 score of 53.5 reported for US adults²⁴ and that diet quality increased significantly following a 6-month weight loss program where PCM consumption was required.

These results are in general agreement with those from the available literature^{8,13,25,26}. For example, Ashley et. al.¹³ compared macronutrient and micronutrient levels in foods chosen by 96 women, ages 25–30 years, that were randomized into either a traditional diet group or PCM group, reported that those who were in the PCM group decreased intake of saturated fat, cholesterol, and sodium, with increased total fruits and vegetables. Additionally, those who used PCMs had significantly lower risk for inadequate intake of vitamins and minerals compared to traditional diet group. Noakes et. al.²⁵ and Miller et. al.²⁶ both found no difference in intake in any macronutrients or in micronutrients, including magnesium, calcium, iron, and zinc, in those consuming PCMs. Additionally Noakes et al.²⁵ found that

food choice and meal pattern resulted in similar energy distributions of protein and carbohydrate intakes and relatively low fat intake in those using PCMs compared to traditional diet. In addition, Ditschuneit et al.²⁷ reported a significant ($p<0.05$) decrease in total fat intake in both men and women using PCMs.

We are unaware of reports in the literature examining the impact of a PCM weight loss diet on diet quality during weight maintenance. Thus, we expanded on these findings and looked at the changes in diet quality after PCMs were no longer required to determine the effect of PCMs for weight loss on diet quality during 12 months of weight maintenance. Interestingly, diet quality remained significantly higher than baseline during weight maintenance even as the consumption of PCMs decreased to ~5 entrees and ~4 shakes per wk. HEI-2010 score during weight maintenance was 57.9, which is higher than the average for US adults²⁴. HEI-2010 components that improved significantly across the study were servings of whole fruits, total vegetables, refined grains, fatty acid intake, and empty calories. Results demonstrated that individuals increased their fruit and vegetables servings and decreased their intake of saturated fat, refined grains, and foods with added fat and sugar.

PCMs are often critiqued for being high in sodium. However, we found sodium scores did not change significantly from baseline. These results are in agreement with those of Ashley et al.¹³ who found sodium intake being reduced and were close to recommended values in those consuming PCMs. The observation that sodium intake is reduced or unchanged suggests that PCMs may not add significantly more sodium to an individual's diet.

It can be argued that the increased diet quality was driven by the increased consumption of fruits and vegetables during weight loss and their continued increased consumption during weight maintenance. However, there was an increase in other components of diet quality besides fruits and vegetables; most notably, there were a decreased intake of refined grains and empty calories and improved fatty acid ratio scores. Interestingly, physical activity and attendance at the educational sessions were not correlated with diet quality scores. These findings suggest that, while the behavior clinic helped individuals develop healthy lifestyle patterns, the PCMs may play a significant role in the increased diet quality over behavior clinic alone.

Strengths of the current study include the use of a randomized design trial with a weight management intervention over 18-months that delivered the same behavioral education to all participants, a large sample, the inclusion of both males and females, and a rigorous assessment of diet quality during both weight loss and weight maintenance. However, while the results are encouraging, this study should be considered in the context of certain limitations. First, Phone vs Clinic was not specifically designed or powered to detect between or within group differences in change of HEI-2010 scores in response to PCMs. Secondly, there is no comparison group to see if the same changes in HEI-2010 scores are obtained using traditional, reduced-energy meal plan diets. Finally, dietary intake was collected by self-reported diet records, which can be biased by social desirability or social approval²⁸ and have been shown to underestimate EI when compared with energy expenditure assessed by doubly labeled water²⁹⁻³³.

Previous research has shown that PCMs produce significant weight loss compared to a standard diet, provide a nutritionally adequate diet, and may increase fruit and vegetable consumption. Yet, there is doubt that individuals who lose weight by using PCMs develop an understanding of healthy eating during weight maintenance. Although we have no comparison of changes in diet quality using a traditional reduced energy meal plan diet, our results do not support the notion that weight loss using PCM diets are ineffective for either long-term maintenance of weight loss or result in poor long-term diet quality. Furthermore, PCMs during weight loss may actually help to improve the diet quality of individuals even during weight maintenance.

Acknowledgments

This study was supported by the National Institutes of Health grant R01- DK049181 and Health Management Resources, Boston MA

References

1. Flegal KM, Carroll MD, Ogden CL, Curtin LR. Prevalence and Trends in Obesity among Us Adults, 1999–2008. *JAMA*. Jan 20; 2010 303(3):235–241. [PubMed: 20071471]
2. Must A, Spadano J, Coakley EH, Field AE, Colditz G, Dietz WH. The Disease Burden Associated with Overweight and Obesity. *JAMA*. Oct 27; 1999 282(16):1523–1529. [PubMed: 10546691]
3. Pi-Sunyer X, Blackburn G, Brancati FL, et al. Reduction in Weight and Cardiovascular Disease Risk Factors in Individuals with Type 2 Diabetes: One-Year Results of the Look Ahead Trial. *Diabetes Care*. Jun; 2007 30(6):1374–1383. [PubMed: 17363746]
4. Villareal DT, Miller BV 3rd, Banks M, Fontana L, Sinacore DR, Klein S. Effect of Lifestyle Intervention on Metabolic Coronary Heart Disease Risk Factors in Obese Older Adults. *Am J Clin Nutr*. Dec; 2006 84(6):1317–1323. [PubMed: 17158411]
5. Seagle HM, Strain GW, Makris A, Reeves RS. Position of the American Dietetic Association: Weight Management. *Journal of the American Dietetic Association*. 2009; 109(2):330–346. [PubMed: 19244669]
6. Wing R, Jeffery R, Burton L, Thorson C, Nissinoff KS, Baxter J. Food Provision Vs Structured Meal Plans in the Behavioral Treatment of Obesity. *International journal of obesity and related metabolic disorders: journal of the International Association for the Study of Obesity*. 1996; 20(1): 56–62.
7. Ashley JM, St Jeor ST, Perumean-Chaney S, Schrage J, Bovee V. Meal Replacements in Weight Intervention. *Obes Res*. Nov; 2001 9(Suppl 4):312s–320s. [PubMed: 11707559]
8. Ditschuneit HH, Flechtner-Mors M, Johnson TD, Adler G. Metabolic and Weight-Loss Effects of a Long-Term Dietary Intervention in Obese Patients. *Am J Clin Nutr*. Feb; 1999 69(2):198–204. [PubMed: 9989680]
9. Flechtner-Mors M, Ditschuneit HH, Johnson TD, Suchard MA, Adler G. Metabolic and Weight Loss Effects of Long-Term Dietary Intervention in Obese Patients: Four-Year Results. *Obes Res*. Aug; 2000 8(5):399–402. [PubMed: 10968732]
10. Quinn Rothacker D. Five-Year Self-Management of Weight Using Meal Replacements: Comparison with Matched Controls in Rural Wisconsin. *Nutrition*. May; 2000 16(5):344–348. [PubMed: 10793302]
11. Ashley JM, St Jeor ST, Schrage JP, et al. Weight Control in the Physician's Office. *Arch Intern Med*. Jul 9; 2001 161(13):1599–1604. [PubMed: 11434791]
12. Academy of Nutrition and Dietetics. How Effective (in Terms of Client Adherence and Weight Loss and Maintenance) Are Meal Replacements (Liquid Meals, Meal Bars, Frozen Prepackaged Meals)? 2011. http://www.adaevidencelibrary.com/evidence.cfm?evidence_summary_id=250141
13. Ashley JM, Herzog H, Clodfelter S, Bovee V, Schrage J, Pritsos C. Nutrient Adequacy During Weight Loss Interventions: A Randomized Study in Women Comparing the Dietary Intake in a

Meal Replacement Group with a Traditional Food Group. *Nutr J*. 2007; 6:12. [PubMed: 17592648]

14. Lambourne K, Washburn RA, Gibson C, et al. Weight Management by Phone Conference Call: A Comparison with a Traditional Face-to-Face Clinic. Rationale and Design for a Randomized Equivalence Trial. *Contemp Clin Trials*. Sep; 2012 33(5):1044– 1055. [PubMed: 22664647]
15. Donnelly JE, Goetz J, Gibson C, et al. Equivalent Weight Loss for Weight Management Programs Delivered by Phone and Clinic. *Obesity*. Feb 14.2013
16. Mifflin MD, St Jeor ST, Hill LA, Scott BJ, Daugherty SA, Koh YO. A New Predictive Equation for Resting Energy Expenditure in Healthy Individuals. *Am J Clin Nutr*. Feb; 1990 51(2):241–247. [PubMed: 2305711]
17. Wright JD, Borrud LG, McDowell MA, Wang CY, Radimer K, Johnson CL. Nutrition Assessment in the National Health and Nutrition Examination Survey 1999–2002. *J Am Diet Assoc*. May; 2007 107(5):822–829. [PubMed: 17467380]
18. Guenther PM, Kirkpatrick SI, Reedy J, et al. The Healthy Eating Index-2010 Is a Valid and Reliable Measure of Diet Quality According to the 2010 Dietary Guidelines for Americans. *J Nutr*. Jan 22.2014
19. Guenther PM, Casavale KO, Reedy J, et al. Update of the Healthy Eating Index: Hei-2010. *J Acad Nutr Diet*. Apr; 2013 113(4):569–580. [PubMed: 23415502]
20. Troiano RP, Berrigan D, Dodd KW, Mâsse LC, Tilert T, McDowell M. Physical Activity in the United States Measured by Accelerometer. *Med Sci Sports Exerc*. 2008; 40(1):181. [PubMed: 18091006]
21. Monfort-Pires M, Folchetti LD, Previdelli AN, Siqueira-Catania A, de Barros CR, Ferreira SR. Healthy Eating Index Is Associated with Certain Markers of Inflammation and Insulin Resistance but Not with Lipid Profile in Individuals at Cardiometabolic Risk. *Appl Physiol Nutr Metab*. Apr; 2014 39(4):497–502. [PubMed: 24669992]
22. Shah BS, Freeland-Graves JH, Cahill JM, Lu H, Graves GR. Diet Quality as Measured by the Healthy Eating Index and the Association with Lipid Profile in Low-Income Women in Early Postpartum. *Journal of the American Dietetic Association*. 2010; 110(2):274–279. [PubMed: 20102856]
23. Bosire C, Stampfer MJ, Subar AF, et al. Index-Based Dietary Patterns and the Risk of Prostate Cancer in the Nih-Aarp Diet and Health Study. *American journal of epidemiology*. 2013; 177(6): 504–513. [PubMed: 23408548]
24. U.S. Department of Agriculture Center for Nutrition Policy and Promotion. Diet Quality of Americans in 2001–02 and 2007–08 as Measured by the Health Eating Index-2010. 2013. <http://www.cnpp.usda.gov/Publications/NutritionInsights/Insight51.pdf>
25. Noakes M, Foster PR, Keogh JB, Clifton PM. Meal Replacements Are as Effective as Structured Weight-Loss Diets for Treating Obesity in Adults with Features of Metabolic Syndrome. *J Nutr*. Aug; 2004 134(8):1894–1899. [PubMed: 15284372]
26. Miller GD. Improved Nutrient Intake in Older Obese Adults Undergoing a Structured Diet and Exercise Intentional Weight Loss Program. *J Nutr Health Aging*. Jun; 2010 14(6):461–466. [PubMed: 20617289]
27. Ditschuneit HH, Frier HI, Flechtner-Mors M. Lipoprotein Responses to Weight Loss and Weight Maintenance in High-Risk Obese Subjects. *Eur J Clin Nutr*. Mar; 2002 56(3):264–270. [PubMed: 11960302]
28. Thompson FE, Subar AF, Loria CM, Reedy JL, Baranowski T. Need for Technological Innovation in Dietary Assessment. *Journal of the American Dietetic Association*. 2010; 110(1):48. [PubMed: 20102826]
29. Ambler C, Eliakim A, Brasel JA, Lee W-N, Burke G, Cooper DM. Fitness and the Effect of Exercise Training on the Dietary Intake of Healthy Adolescents. *Int J Obes*. 1998; 1998(22):354–362.
30. Trabulsi J, Schoeller DA. Evaluation of Dietary Assessment Instruments against Doubly Labeled Water, a Biomarker of Habitual Energy Intake. *Am J Physiol Endocrinol Metab*. Nov; 2001 281(5):E891–899. [PubMed: 11595643]

31. Scagliusi FB, Ferriolli E, Pfrimer K, et al. Underreporting of Energy Intake in Brazilian Women Varies According to Dietary Assessment: A Cross-Sectional Study Using Doubly Labeled Water. *J Am Diet Assoc.* Dec; 2008 108(12):2031–2040. [PubMed: 19027406]
32. Schatzkin A, Kipnis V, Carroll RJ, et al. A Comparison of a Food Frequency Questionnaire with a 24-Hour Recall for Use in an Epidemiological Cohort Study: Results from the Biomarker-Based Observing Protein and Energy Nutrition (Open) Study. *Int J Epidemiol.* Dec; 2003 32(6):1054–1062. [PubMed: 14681273]
33. Wong WW, Roberts SB, Racette SB, et al. The Doubly Labeled Water Method Produces Highly Reproducible Longitudinal Results in Nutrition Studies. *The Journal of nutrition.* 2014; 144(5): 777–783. [PubMed: 24523488]

Table 1

Baseline participant characteristics for the complete sample and by gender.

Variable	Complete Sample (<i>n</i> =197)	Men (<i>n</i> =65)	Women (<i>n</i> =132)
Age (yrs.)	46.1 (8.9)	45.1 (9.1)	46.6 (8.8)
Height (cm)	169.8 (9.1)	178.8(6.1)	165.3 (6.7)
Weight (kg)	98.6 (17.2)	111.0 (15.7)	92.5 (14.5)
BMI (kg · m ⁻²)	34.1 (4.5)	34.6 (4.1)	33.8 (4.6)
Minority (%)	16.8%	15.4%	17.4%

Note. BMI = body mass index. Values are mean (*SD*) unless otherwise stated. Height and weight were significantly different between men and women (both $p < 0.001$), but there were no significant differences in age, BMI, and ethnicity (minority).

Table 2

Self-Reported Consumption of Portion Controlled Meals, Physical Activity Minutes, and Attendance at Education Sessions during an 18 month Behavioral Weight Loss Program.

Variable	Complete Sample (n=197)	Men (n=65)	Women (n=132)	p for sex difference
Entrees (number/wk)				
Months 0–6	12.1 (1.4)	12.3 (1.3)	12.1 (1.5)	0.241
Months 7–12	5.3 (3.7)	4.6 (3.7)	5.6 (3.6)	0.058
Months 13–18	3.9 (3.8)	3.1 (3.9)	4.3 (3.8)	0.062
Shakes (number/wk)				
Months 0–6	18.1 (2.5)	18.3 (2.7)	18.1 (2.4)	0.584
Months 7–12	5.6 (4.4)	5.0 (4.1)	5.8 (4.6)	0.232
Months 13–18	2.9 (4.3)	1.9 (3.4)	3.5 (4.6)	0.011
Fruits/Vegetables (number/wk)				
Months 0–6	40.7 (8.6)	44.8 (10.2)	38.6 (6.9)	<0.001
Months 7–12	36.5 (10.5)	40.4 (11.5)	34.5 (9.3)	0.001
Months 13–18	34.3 (9.8)	37.7 (11.6)	32.5 (8.1)	0.003
Education sessions (%attended)				
Months 0–6	88 (9)%	88 (9)%	88 (9)%	0.922
Months 7–12	76 (22)%	75 (25) %	77 (20)%	0.566
Months 13–18	76 (31)%	74 (31)%	77 (32)%	0.611
Moderate-to-vigorous physical activity (min/day)				
Month 0	16.9 (14.5)	23.8 (18.6)	13.5 (10.7)	0.002
Month 6	35.9 (22.4)	44.9 (27.2)	31.5 (18.3)	0.014
Month 12	28.2 (20.1)	32.4 (21.9)	26.1 (19.1)	0.201
Month 18	30.5 (22.2)	37.8 (25.8)	26.6 (19.2)	0.037

Note. Values are mean (SD) unless otherwise stated.

Table 3

Diet quality as assessed by the Healthy Eating Index-2010 (HEI) across 18 months in the complete sample, men, and women

Variable	Complete Sample (n=197)	Men (n=65)	Women (n=132)	p for sex difference
Total HEI score				
Month 0	46.4 (8.9)	42.2 (9.0)	48.4 (8.1)	<0.001
Month 6	66.6 (9.4)	63.6 (9.5)	68.1 (9.0)	0.001
Month 12	58.0 (10.1)	55.5 (10.4)	59.2 (9.8)	0.017
Month 18	57.7 (10.6)	56.5 (9.9)	58.3 (10.8)	0.255
Total HEI score change				
Months 0–6	20.3 (11.9)	21.4 (12.5)	19.7 (11.6)	0.338
p for change	<0.001	<0.001	<0.001	
Months 6–12	–8.6 (10.3)	–8.1 (11.1)	–8.9 (10.0)	0.573
p for change	<0.001	<0.001	<0.001	
Months 12–18	–0.3 (10.8)	0.9 (10.2)	–0.9 (11.0)	0.263
p for change	0.679	0.474	0.338	
Months 0–18	11.3 (11.9)	14.3 (12.1)	9.8 (11.6)	0.013
p for change	<0.001	<0.001	<0.001	
Months 6–18	–9.0 (11.2)	–7.1 (11.5)	–9.9 (10.9)	0.108
p for change	<0.001	<0.001	<0.001	

Note. Values are mean (SD) unless otherwise stated.

Table 4

Healthy Eating Index-2010 (HEI) component scores across 18 months in the complete sample, men, and women

Variable	Complete Sample (n=197)	Men (n=65)	Women (n=132)
Total fruits *			
0 month	1.26 (1.33)	0.95 (1.21)	1.42 (1.37)
6 months	4.13 (1.29)	3.96 (1.41)	4.21 (1.23)
12 months	3.14 (1.59)	3.07 (1.58)	3.17 (1.60)
18 months	3.08 (1.64)	3.22 (1.65)	3.02 (1.64)
Whole fruits *			
0 month	1.59 (1.49)	1.12 (1.40)	1.83 (1.48)
6 months	4.46 (1.14)	4.32 (1.27)	4.53 (1.06)
12 months	3.76 (1.53)	3.70 (1.55)	3.79 (1.53)
18 months	3.64 (1.61)	3.71 (1.47)	3.60 (1.68)
Total vegetables *			
0 month	2.63 (1.17)	2.42 (1.20)	2.73 (1.14)
6 months	4.59 (0.79)	4.55 (0.75)	4.60 (0.81)
12 months	3.88 (1.19)	3.83 (1.33)	3.91 (1.11)
18 months	3.68 (1.14)	3.68 (1.07)	3.68 (1.17)
Dark green & Orange Vegetables *			
0 month	1.32 (1.22)	1.00 (1.10)	1.47 (1.25)
6 months	3.41 (1.52)	2.89 (1.71)	3.66 (1.36)
12 months	2.55 (1.65)	2.24 (1.77)	2.70 (1.57)
18 months	2.23 (1.57)	2.19 (1.68)	2.25 (1.52)
Refined grains **			
0 month	4.76 (2.60)	4.98 (2.67)	4.65 (2.56)
6 months	8.14 (2.07)	8.17 (2.19)	8.12 (2.02)
12 months	5.46 (2.88)	5.64 (2.67)	5.37 (2.98)
18 months	5.42 (2.92)	6.26 (2.69)	5.01 (2.94)
Whole grains **			
0 month	3.69 (2.82)	3.28 (2.63)	3.89 (2.89)
6 months	1.93 (2.33)	2.18 (2.40)	1.80 (2.29)
12 months	3.60 (2.91)	3.13 (2.86)	3.83 (2.93)
18 months	3.65 (3.07)	3.11 (2.70)	3.92 (3.21)
Milk **			
0 month	5.99 (2.75)	4.57 (2.79)	6.69 (2.45)
6 months	6.76 (3.24)	5.41 (3.20)	7.43 (3.05)
12 months	5.98 (2.97)	4.63 (2.81)	6.65 (2.83)
18 months	5.86 (3.00)	4.70 (3.33)	6.44 (2.64)
Total protein *			
0 month	4.07 (0.95)	4.23 (0.85)	4.00 (1.00)

Variable	Complete Sample (n=197)	Men (n=65)	Women (n=132)
<i>6 months</i>	4.41 (0.79)	4.48 (0.68)	4.37 (0.84)
<i>12 months</i>	4.09 (0.99)	4.02 (0.97)	4.12 (1.01)
<i>18 months</i>	4.12 (1.03)	4.07 (1.12)	4.14 (0.99)
Seafood and Plant Protein *			
<i>0 month</i>	3.51 (1.35)	2.79 (1.50)	3.86 (1.12)
<i>6 months</i>	3.75 (1.51)	3.11 (1.61)	4.06 (1.36)
<i>12 months</i>	3.47 (1.50)	2.77 (1.55)	3.81 (1.36)
<i>18 months</i>	3.48 (1.52)	2.84 (1.77)	3.80 (1.27)
Fatty acid ratio **			
<i>0 month</i>	4.86 (2.41)	4.70 (2.23)	4.94 (2.49)
<i>6 months</i>	5.54 (2.45)	5.47 (2.21)	5.58 (2.57)
<i>12 months</i>	5.56 (2.47)	5.81 (2.38)	5.44 (2.52)
<i>18 months</i>	5.71 (2.53)	5.23 (2.28)	5.95 (2.62)
Sodium **			
<i>0 month</i>	3.54 (2.48)	3.27 (2.72)	3.67 (2.36)
<i>6 months</i>	2.45 (2.24)	2.05 (2.14)	2.64 (2.27)
<i>12 months</i>	2.63 (2.40)	2.56 (2.38)	2.66 (2.42)
<i>18 months</i>	2.89 (2.39)	2.66 (2.35)	3.00 (2.41)
Empty Calories ***			
<i>0 month</i>	9.14 (4.25)	8.85 (4.21)	9.28 (4.27)
<i>6 months</i>	17.09 (3.48)	17.00 (3.34)	17.13 (3.56)
<i>12 months</i>	13.89 (4.49)	14.15 (4.19)	13.75 (4.64)
<i>18 months</i>	13.91 (4.68)	14.80 (4.22)	13.47 (4.84)

Note. Values are mean (*SD*) unless otherwise stated.

* Maximum point value is 5

** Maximum point value is 10

*** Maximum point value is 20