Dietary energy density and successful weight loss maintenance

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A B S T R A C T

Research shows a positive relationship between dietary energy density (ED) and body mass index (BMI), but dietary ED of weight loss maintainers is unknown. This preliminary investigation was a secondary data analysis that compared self-reported dietary ED and food group servings consumed in overweight adults (OW: BMI = 27–45 kg/m^2), normal weight adults (NW: BMI = 19–24.9 kg/m^2), and weight loss maintainers (WLM: current BMI = 19–24.9 kg/m^2 [lost ≥ 10% of maximum body weight and maintained loss for ≥ 5 years]) participating in 2 studies, with data collected from July 2006 to March 2007. Three 24-h phone dietary recalls from 287 participants (OW = 97, NW = 85, WLM = 105) assessed self-reported dietary intake. ED (kcal/g) was calculated by three methods (food + all beverages except water [F + AB], food + caloric beverages [F + CB], and food only [FO]). Differences in self-reported consumption of dietary ED, food group servings, energy, grams of food/beverages, fat, and fiber were assessed using one-way MANCOVA, adjusting for age, sex, and weekly energy expenditure from self-reported physical activity. ED, calculated by all three methods, was significantly lower in WLM than in NW or OW (FO: WLM = 1.39 ± 0.45 kcal/g; NW = 1.60 ± 0.43 kcal/g; OW = 1.83 ± 0.42 kcal/g). Self-reported daily servings of vegetables and whole grains consumed were significantly higher in WLM compared to NW and OW (vegetables: WLM = 4.9 ± 3.1 servings/day; NW = 3.9 ± 2.0 servings/day; OW = 3.4 ± 1.7 servings/day; whole grains: WLM = 2.2 ± 1.8 servings/day; NW = 1.4 ± 1.2 servings/day; OW = 1.3 ± 1.3 servings/day). WLM self-reported consuming significantly less energy from fat and more fiber than the other two groups. Self-reported energy intake per day was significantly lower in WLM than OW, and WLM self-reported consuming significantly more grams of food/beverages per day than OW. These preliminary findings suggest that consuming a diet lower in ED, characterized by greater intake of vegetables and whole grains, may aid with weight loss maintenance and should be further tested in prospective randomized controlled trials.

1. Introduction

Given the current prevalence of overweight and obesity among adults in the United States and the projected increase of these conditions in the future (Wang, Beydoun, Liang, Caballero, & Kumanyika, 2008), development of effective weight loss and weight loss maintenance strategies is imperative. While modest weight loss is achievable in programs utilizing a combination of energy intake restriction, physical activity, and behavioral modification, prevention of weight regain following weight loss has been less successful (Jeffery et al., 2000; Wang et al., 2008). Thus, it is important to identify dietary practices that promote successful long-term weight loss maintenance.

One dietary strategy that may facilitate weight loss maintenance is consuming a diet low in energy density (ED). The ED of a given food, defined as the ratio of energy of the food to the weight of the food (kcal/g), is largely determined by water content, but is also affected by fat and fiber (Rolls, Drewnowski, & Ledikwe, 2005). Foods low in ED, such as fruits, vegetables, and whole grains, may allow individuals to eat a greater weight of food relative to total energy consumed, which may increase satiation and prevent energy overconsumption (Rolls, 2009). Basic eating research has shown that decreasing ED results in increased satiation and decreased energy intake (Rolls, Roe, & Meengs, 2006), and cross-sectional epidemiological studies have shown a positive association between ED and body mass index (BMI) (Ledikwe et al., 2006a; Mendoza, Drewnowski, & Christakis, 2007). Recent randomized trials (RTs) examining the effect of ED on weight loss (Ello-Martin, Roe, Ledikwe, Beach, & Rolls, 2007; Rolls, Roe, Beach, & Kris-Etherton, 2005) as well as secondary analyses investigating

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associations between ED and body weight in previous RTs (Flood et al., 2009; Ledikwe et al., 2007) have also demonstrated that when greater reductions in ED in the diet occur, weight loss is increased (Ello-Martin et al., 2007; Flood et al., 2009; Ledikwe et al., 2007; Rolls, Roe, et al., 2005), although not all RTs have found this effect (Saquib et al., 2008). Additionally, the 2005 Dietary Guidelines for Americans recommendations for weight loss include consuming low ED foods, such as fruits, vegetables, and whole grains, as an energy intake lowering strategy (Department of Health & Human Services, 2005).

While research regarding the relationship between ED and weight loss maintenance is limited, a population-based observational study examining practices of individuals successful at maintaining weight loss found that weight loss maintainers consumed more fruits and vegetables than those who experienced weight regain (Kruger, Blanck, & Gillespie, 2008), and participants in the National Weight Control Registry (NWCR) report high fruit and vegetable intake (Phelan, Wyatt, Hill, & Wing, 2006). Another study investigating weight loss maintenance following a weight loss RT that had used a dietary prescription encouraging consumption of foods low in ED during weight loss, found that individuals who maintained their weight loss consumed a diet lower in overall ED than those individuals who regained weight (Greene et al., 2006). However, a low ED diet was not effective for improving weight loss maintenance in a recent RT examining the effect of adding a reduced ED eating program to cognitive–behavioral treatment (Lowe et al., 2008). Altogether, these studies suggest that consuming a diet low in ED may help with weight loss maintenance; however no studies have examined dietary ED in long-term successful weight loss maintainers. Additionally, no investigations have compared dietary ED of normal weight long-term successful weight loss maintainers to normal weight individuals without a history of obesity to see if differences in dietary ED occur. If differences in ED occur in these groups, this would provide additional support of the role that dietary ED may play in successful weight loss maintenance.

Thus, to further examine the importance of the ED of the diet in successful weight loss maintenance, the purpose of this preliminary study was to examine dietary ED calculated by three methods (Ledikwe et al., 2005) (with the inclusion of all beverages except plain water, with only energy-containing beverages, and with food only), in overweight/obese individuals (OW), normal weight individuals who had never been overweight (NW), and normal weight long-term successful weight loss maintainers (WLM), who had lost ≥10% of their lifetime maximum weight and kept it off for ≥5 years. A secondary objective was to investigate differences in self-reported food group intake that could contribute to differences in dietary ED between the three groups. This investigation was a secondary data analysis that involved participants from two different studies, with dietary data collected identically during the same time period. This approach was used to provide initial information regarding the relationship between self-reported dietary ED and weight loss maintenance to inform future controlled studies. As we have previously reported that WLM use more fat restriction strategies than NW (Phelan, Lang, Jordan, & Wing, 2009), it was hypothesized that WLM would self-report the diet lowest in ED followed by NW and OW and would self-report consuming more servings from food groups comprised primarily of low ED foods, including fruits, vegetables, and whole grains. Additionally, it was anticipated that self-reported ED would be lowest when calculated to include all beverages except water.

2. Methods and procedures

2.1. Participants

The study participants were part of two National Institutes of Health (NIH) funded investigations. The first was an 18-month randomized controlled trial (RCT) examining the influence of a dietary variety prescription on weight loss and weight loss maintenance during a standard behavioral intervention and data from OW participants were obtained from this investigation. This trial was registered at ClinicalTrials.gov (NCT00328744). The second investigation was a cross-sectional study examining weight control behaviors of successful long-term weight loss maintainers and normal weight controls and data from WLM and NW were obtained from this study.

2.1.1. OW participants

The OW group (n = 97) was comprised of overweight/obese (BMI = 27–45 kg/m^2) individuals, aged 18 to 65 years, who could walk at least two blocks, and consumed a variety of different snack foods, who were entering an 18-month weight-loss lifestyle intervention RCT. This RCT was conducted in two sites, Knoxville, TN and Providence, RI. Participants were recruited through local newspaper advertisements. While there were 202 total participants in this trial, the 97 participants in this study were recruited at the Providence, RI site between July 2006 and March 2007 and completed all screening procedures and baseline measures and were to be randomized into the trial. Baseline data from the RCT were used in this investigation.

2.1.2. WLM and NW participants

The WLM (n = 105) and NW (n = 85) groups were from the cross-sectional study, which was examining weight control behaviors in these groups. The WLM were not part of the NWCR, but were recruited, along with the NW participants, for an investigation of eating and leisure-time behaviors in WLM and NW participants. Participants in both groups were aged 18 years or older. The WLM had to have been overweight/obese (BMI > 25 kg/m^2) at some point in their life, normal weight (BMI = 19–24.9 kg/m^2) at entry into the trial, lost ≥10% of their maximum body weight and maintained that for at ≥5 years, and be weight stable (±4.5 kg) for the previous 2 years. NW had to be of normal weight (BMI = 19–24.9 kg/m^2) at entry into the trial, never have been overweight or obese (BMI ≥ 25 kg/m2), and weight stable (±4.5 kg) for the previous 2 years. Recruitment was conducted by placing advertisements in national and local publications and articles about the study published in media that target a general audience. Participants were located in all different parts of the U.S., but predominantly in New England (>70%). While a total of 267 WLM participants and 213 NW participants were included in the trial, only those participants who were recruited and had measures collected at approximately the same time period in which measures were collected from the OW group (July 2006–March 2007) were included in this investigation.

While the participants came from two different studies it is important to note the similarities of the participants. Participants from both trials resided predominantly in the New England area, and participants were recruited and data were collected during the same time frame.

2.2. Design and procedures

For the OW participants, data were collected as part of the baseline assessment measurements of the study prior to treatment initiation and participants were not paid for baseline measures. Data collection for the NW and WLM participants occurred upon study enrollment and participants were paid $50 for completing the study assessments. Both studies were approved by the Institutional Review Board at the Miriam Hospital in Providence, Rhode Island.

2.3. Measures

2.3.1. Participant characteristics

A demographic questionnaire was completed by all OW, WLM, and NW participants to assess background and health status characteristics. Basic descriptive information, including sex, age, education level, race/ethnicity, and marital status, was obtained. Additionally, the WLM completed self-reported information about lifetime maximum weight and BMI, amount of weight loss from maximum weight, and duration of weight loss maintenance.

2.3.2. Body mass index

OW participant weight was measured by electronic scale and height using a stadiometer according to standard procedures (Lohman, Roche, & Martorell, 1988), with participants wearing light clothing and without shoes. As most, but not all NW and WLM were from the New England area, NW and WLM weight and height were assessed by self-report. While self-reported anthropometric data have limitations due to potential bias, previous studies have shown that self-reported anthropometric data in NW and WLM correlate highly with documented weight (McGuire, Wing, Klem, Lang, & Hill, 1999). BMI was calculated as weight in kilograms divided by height in meters squared (kg/m^2).

2.3.3. Physical activity

Self-reported physical activity was assessed for OW, NW, and WLM using the Paffenbarger Activity Questionnaire (PAQ) (Paffenbarger et al., 1993). This questionnaire yields estimates of the total energy expended in physical activity per week based on flights of stairs climbed per day, city blocks walked per day, and hours of structured activity acquired within a typical week. The PAQ has been shown to be significantly correlated with an objective measure of physical activity (Rauh, Hovell, Hosfstetter, Sallis, & Gleghorn, 1992).

2.3.4. Dietary intake

Self-reported dietary intake was assessed for OW, NW, and WLM using identical procedures and collected during the same time period. Trained interviewers from the Cincinnati Center for Nutritional Research and Analysis at Children's Hospital Research Foundation of Cincinnati conducted three, 24-hour dietary recalls for all three groups. The recalls were conducted on random, non-consecutive days of the week (two weekdays and one weekend day) by blinded assessors. Each 24-hour recall was completed using the Nutrition Data System for Research (NDS-R) software developed by the Nutrition Coordinating Center (NCC), University of Minnesota, Minneapolis, Minnesota. The 24-hour recalls were conducted over the phone, and interviewers used a computer and the NDS-R software to conduct the interview. The NDS-R software leads the interviewer through the recall, prompting the interviewer to obtain the necessary detail for the subsequent dietary analysis. Prior to the 24-hour recalls, participants were given two-dimensional portion size estimation tools to assist with accuracy in reporting portion sizes to interviewers. Self-reported mean nutrient data, including energy, weight, fat and fiber content of all foods and beverages consumed was computed from this information using the three recalled days.

Mean ED was calculated by three different methods using self-reported total energy and gram intake averaged over the three recalled days. ED was reported in kcal/g. The first calculation method included the weight and energy of all foods and all beverages consumed other than plain water (food + all beverages, F + AB), the second calculation method included the weight and energy of all foods and only energy-containing beverages consumed (food + caloric beverages, F + CB), and the third calculation method included only the weight and energy of all foods consumed and omitted beverages (food only, FO). These calculations were based upon previously reported methods (Ledikwe et al., 2005).

Using the NDS-R software food grouping system, each recalled item was assigned to one of nine main food groups (fruit, vegetable, grain, meat, dairy, added fats, added sugar/sweets, sweetened beverages, and alcohol). Subgroups for vegetables (dark green, yellow, and red vegetables; starchy vegetables and legumes; and fried potatoes) and grains (whole grains and refined grains) were used to quantify self-reported intake of foods in these main food group categories that were higher and lower in fat and fiber content. For self-reported items consisting of more than one component, each component was given a food group assignment. Serving sizes for each food group and subgroup were based on the *Dietary Guidelines for Americans 2005* (Department of Health & Human Services, 2005) recommendations and Food and Drug Administration standards.

2.4. Statistical analyses

One-way analysis of variance (ANOVA) and Chi-Square were used to examine differences between the three groups in baseline characteristics. Between group differences in the ED and nutrient intake were examined by multivariate analysis of covariance (MANCOVA) using baseline characteristic variables that were significantly different between groups and related to the dependant variables as covariates in the analyses (i.e., age, sex, and self-reported weekly energy expended from physical activity) (Tabachnick & Fidell, 1996). Between group differences in food group intake were also examined by MANCOVA adjusting for significant group differences in baseline characteristic variables and total energy intake. For significant outcomes, comparisons using Bonferroni adjustments, to maintain the a priori alpha level (0.05), were performed as post hoc analyses. Pearson product-moment correlations were conducted to examine the relationship between the three methods of calculating self-reported dietary ED and self-reported intake of energy, percent energy from fat, fiber, and food servings from fruits, vegetables, and whole grains. SPSS for Windows, version 16.0 (Chicago, IL) was used to perform statistical analyses. The alpha level was set a priori at $P<0.05$ per MANCOVA and correlational analysis.

3. Results

3.1. Descriptive characteristics

Baseline participant demographic characteristics are listed in Table 1. Mean age was 49.3 ± 11.2 y, with OW significantly older than NW ($p<0.05$). For the whole sample, 78.0% of participants were female, but there were significant differences in the percentage of females between all three groups ($p<0.05$), with OW having a lower percentage of females (58.8%) than the other two groups, as this trial had tried to recruit a balanced sample of males and females. As expected, BMI was significantly higher in OW compared to NW and WLM, and BMI in NW was also lower compared to WLM ($p<0.05$). Participants were 94.1% white, 97.6% non-Hispanic, 77.0% had a college degree, and 68.6% were married. There were no differences in race, ethnicity, education, or marital status between groups ($p>0.10$). Additionally, self-reported weekly energy expenditure from physical activity was significantly different between all three groups, ($p<0.05$), with WLM reporting the greatest amount of weekly energy expenditure from physical activity, and NW reporting significantly more than OW.

In regards to weight loss maintenance characteristics of WLM, this group self-reported a lifetime maximum weight of 91.6 ± 18.2 kg and a lifetime maximum BMI of 33.0 ± 6.0 kg/m^2. Self-reported weight loss from maximum weight was 29.7 ± 14.7 kg, which had been maintained for 12.5 ± 9.8 yrs. When compared to participants from the NWCR, WLM reported a similar amount of weight loss, but they reported maintaining that weight loss for a longer period of time (Wing & Phelan, 2005). Additionally, WLM self-reported a lower lifetime maximum BMI and a current lower BMI than participants in the NWCR (Wing & Phelan, 2005).

3.2. Dietary intake

3.2.1. Energy and nutrient intake

After adjusting for initial group differences in age, sex, and self-reported weekly energy expenditure from physical activity, self-reported energy intake from foods and beverages was significantly lower ($p<0.05$) in WLM compared to the OW group, with no difference in self-reported energy intake between NW and OW or NW and WLM (Table 2). WLM also self-reported consuming

Table 1
Baseline characteristics of weight loss maintainers (WLM), normal weight (NW), and overweight (OW) participants (M ± SD).

	Total sample (n = 287)	WLM (n = 105)	NW (n = 85)	OW (n = 97)	Main effect p-value
Age (y)	49.3 ± 11.2	49.8 ± 11.8[a,b]	46.3 ± 11.9 [b]	51.2 ± 9.4 [a]	<0.05
Sex (%)					
Female	78.0	82.9[a]	94.1[b]	58.8[c]	<0.001
Male	22.0	17.1	5.9	41.2	
BMI (kg/m^2)	26.0 ± 6.7	22.2 ± 1.7[a]	21.1 ± 1.4[b]	34.6 ± 4.1[c]	<0.001
Race (%)					
White	94.1	92.4	95.3	94.8	ns
Non-White	5.9	7.6	4.7	5.2	
Ethnicity (%)					
Non-Hispanic	97.6	98.1	97.6	96.9	ns
Hispanic	2.4	1.9	2.4	3.1	
Education (%)					
College degree or higher	77.0	79.0	83.5	69.1	ns
Some college or lower	23.0	21.0	16.5	30.9	
Marital Status (%)					
Married	68.6	68.6	70.6	67.0	ns
Not married	31.4	31.4	29.4	33.0	
Self-reported weekly energy expended in PA (kcal)	1998 ± 1965	2993 ± 2498[a]	2079 ± 1269[b]	850 ± 961[c]	<0.001

Values in a row for each group that do not have a shared superscript are significantly different ($P<0.05$).
BMI = body mass index; PA = physical activity.
ns = not significant.

significantly ($p<0.05$) more grams of food and beverages per day than the OW group, with no difference in self-reported gram intake between NW and OW or NW and WLM. Self-reported percent of energy intake from fat was significantly lower ($p<0.05$) and self-reported dietary fiber intake was higher ($p<0.05$) in WLM compared to NW and OW.

3.2.2. Energy density

After adjustment for baseline group differences in age, sex, and self-reported weekly energy expenditure from physical activity, there were significant differences ($p<0.05$) between groups in self-reported ED by all three calculation methods. For self-reported ED calculated as F + AB and F + CB, there were significant differences between all three groups, with WLM having the lowest self-reported ED, followed by NW, and then OW (Table 3). For self-reported ED calculated as FO, WLM had a significantly lower self-reported ED than NW and OW, with no difference in NW and OW occurring. As expected, of the three calculation methods for self-reported ED, F + AB produced the lowest self-reported ED, followed by F + CB, and then FO.

3.2.3. Food group servings

Self-reported food group servings are shown in Table 4. Using age, sex, self-reported weekly energy expenditure from physical activity, and self-reported total energy intake as covariates in the analyses, WLM self-reported consuming significantly ($p<0.05$) more servings per day of vegetables and whole grains than both NW and OW. WLM also self-reported consuming more servings per day of ($p<0.05$) fruits and dark green, yellow, and red vegetables than OW. Self-reported servings per day of fried potatoes were significantly ($p<0.05$) higher in OW compared to NW and WLM. OW also self-reported consuming more total daily grain servings than NW ($p<0.05$), but not as compared to WLM ($p>0.10$). Self-reported consumption of servings of refined grains per day was different for all three groups, with OW self-reported consuming significantly more servings compared to NW, and NW consuming significantly more than WLM ($p<0.05$). NW self-reported consuming more daily sweets/added sugar servings and alcohol servings than WLM and OW ($p<0.05$). There was no significant difference between the three groups in self-reported servings consumed per day from starchy vegetables/legumes, meat, dairy, added fats, and sweetened beverages ($p>0.10$).

3.2.4. Relationships between ED and other dietary variables

All three methods of calculating self-reported ED were positively related to self-reported energy and percent energy from fat intake ($p<0.001$), with correlations ranging from $r = 0.32$ (energy and ED: F + CB) to $r = 0.49$ (percent energy from fat and ED: FO). Two methods for calculating self-reported ED, F + CB and FO, were also negatively related to self-reported fiber intake, and self-reported daily servings consumed from fruits, vegetable, and whole grains ($p<0.05$), and self-reported ED calculated as F + AB was also negatively associated with the same self-reported dietary variables except daily servings consumed from whole grains. Significant negative correlations in these variables ranged from $r = -0.12$ (whole grain servings and ED: F + CB) to $r = -0.47$ (vegetable servings and ED: FO).

4. Discussion

The purpose of this preliminary investigation was to examine self-reported dietary ED in OW, NW, and WLM and to determine if WLM

Table 2
Mean dietary intake of weight loss maintainers (WLM), normal weight (NW), and overweight (OW), participants (M ± SD)*.

	Total sample (n = 287)	WLM (n = 105)	NW (n = 85)	OW (n = 97)	Main effect p-value
Energy intake from foods and beverages (kcal/d)	1830 ± 563	1700 ± 485[a]	1789 ± 410[a,b]	2006 ± 701[b]	<0.05
Gram weight of intake from foods and beverages (g/d)	2163 ± 725	2381 ± 862[a]	2071 ± 628[a,b]	2007 ± 577[b]	<0.01
Dietary fat percent energy (%)	32.0 ± 8.1	29.1 ± 9.3[a]	33.1 ± 7.1[b]	34.3 ± 6.6[b]	<0.01
Dietary fiber (g/1000 kcal)	13.1 ± 6.2	17.1 ± 7.1[a]	12.0 ± 4.3[b]	9.7 ± 3.8[b]	<0.001

*Adjusted for group differences in age, sex, and self-reported weekly energy expenditure from physical activity.
Values in a row for each group that do not have a shared superscript are significantly different ($P<0.05$).

Table 3
Mean dietary energy density of weight loss maintainers (WLM), normal weight (NW), and overweight (OW) participants calculated using three methods (M ± SD)*.

	Total sample (n = 287)	WLM (n = 105)	NW (n = 85)	OW (n = 97)	Main effect p-value
F + AB (kcal/g)	0.89 ± 0.27	0.77 ± 0.24[a]	0.91 ± 0.26[b]	1.01 ± 0.24[c]	<0.001
F + CB (kcal/g)	1.15 ± 0.33	1.02 ± 0.32[a]	1.15 ± 0.28[b]	1.29 ± 0.33[c]	<0.001
FO (kcal/g)	1.60 ± 0.47	1.39 ± 0.45[a]	1.60 ± 0.43[b]	1.83 ± 0.42[b]	<0.001

*Adjusted for group differences in age, sex, and self-reported weekly energy expenditure from physical activity.
Values in a row for each group that do not have a shared superscript are significantly different ($P<0.05$).
F + AB = food + all beverages; F + CB = food + caloric beverages; FO = food only.

had a self-reported diet lower in ED compared to OW and NW. Additionally, self-reported daily food group intake, specifically in those food groups that may contribute to a diet lower in ED, was examined in the three groups. As hypothesized, WLM self-reported consuming a diet lower in ED (calculated by F + AB and F + CB) than OW and NW, with differences in self-reported ED between all three groups. WLM's self-reported diet was also lower in ED, calculated as FO, than both NW and OW, with no differences between NW and OW. Importantly, self-reported ED mirrored self-reported energy intake, with both self-reported ED and energy intake lowest in WLM, followed by NW, and then OW, and all methods of calculating self-reported ED were positively related to self-reported energy intake. This finding is consistent with previous observational research that showed a positive relationship between ED and energy intake (Ledikwe et al., 2006a). Because diets characterized by low ED may reduce *ad libitum* energy intake, diets lower in ED may aid with maintaining a lower energy intake necessary to prevent weight regain following weight loss (Rolls, Drewnowski, et al., 2005). Low ED diets may be especially important for maintaining energy balance in individuals who were previously overweight/obese, as compared to individuals who are normal weight but have never been overweight, as they are accustomed to eating a larger amount of food, and consuming low ED foods allows individuals to continue to consume a high weight/volume of food relative to energy content. Importantly, these results also indicated that WLM self-reported consuming the largest gram weight of food and beverages, and this combined with their significantly lower self-reported energy intake does suggest that WLM followed an eating pattern that allowed a greater amount of food to be consumed relative to the energy content consumed.

There are several strategies that can be used to lower the ED of the diet, including consumption of low-fat, high-fiber foods. Dietary fat is the most energy dense macronutrient, and therefore has a greater influence on dietary ED than protein and carbohydrate (Rolls, Drewnowski, et al., 2005). While the contribution of dietary fiber to overall ED of the diet is less than that of fat (Rolls, Drewnowski, et al., 2005), the ED of a given food is affected by its fiber content, as fiber increases the weight of a food with minimal alterations in energy content. Our findings showed that in addition to lower self-reported ED, the self-reported diet of WLM was also characterized by lower dietary fat and higher dietary fiber compared to NW and OW, with daily percent calories from dietary fat ~5% lower and dietary fiber intake ~7 g/1000 kcal higher in WLM compared to OW. Self-reported dietary fat intake of WLM was also lower and self-reported fiber intake was higher than the national average (Food and Nutrition Board, 2005), and similar to the fat and fiber intake reported in the NWCR (Phelan et al., 2006; Shick et al., 1998), whose members are also successful at long-term weight loss maintenance. Self-reported dietary fat intake of both WLM and NWCR participants was <30% of total calories and in accordance with national guidelines regarding fat consumption (Department of Health and Human Services, 2005). Other investigations have also shown that a low-fat diet corresponds to a lower ED (Monsivais & Drewnowski, 2009; Schroder et al., 2008; Townsend, Aaron, Monsivais, Keim, & Drewnowski, 2009), suggesting that decreasing fat intake may be an effective dietary approach for prevention of weight regain through the influence of dietary fat on ED.

One method to both decrease dietary fat and increase dietary fiber intake is to focus on increasing consumption from food groups comprised of foods with these attributes and therefore low in ED, including vegetables, and whole grains. Vegetables also tend to have high water content, which further aids in reducing ED independently of fat and fiber. We found that WLM self-reported consuming significantly more servings of vegetables and whole grains, and also self-reported consuming significantly fewer servings of refined grains compared to OW and NW. Moreover, significant negative correlations were found between self-reported vegetables and whole grains and ED. These findings are consistent with previous studies showing that diets lower in ED are

Table 4
Mean daily food group servings of weight loss maintainers (WLM), normal weight (NW), and overweight (OW) participants (M ± SD)*.

	Total sample (n = 287)	WLM (n = 105)	NW (n = 85)	OW (n = 97)	Main effect p-value
Fruit servings	2.0 ± 2.0	2.8 ± 2.5[a]	2.0 ± 1.6[a]	1.2 ± 1.0[b]	<0.001
Vegetable servings	4.1 ± 2.4	4.9 ± 3.1[a]	3.9 ± 2.0[b]	3.4 ± 1.7[b]	<0.001
Dark green, yellow, red vegetable servings	1.8 ± 1.7	2.4 ± 2.2[a]	1.9 ± 1.4[a,b]	1.2 ± 1.0[b]	<0.01
Starchy vegetables and legume servings	0.6 ± 0.6	0.5 ± 0.6	0.5 ± 0.5	0.7 ± 0.7	ns
Fried potato servings	0.2 ± 0.4	0.1 ± 0.2[a]	0.2 ± 0.3[a]	0.4 ± 0.5[b]	<0.01
Grain servings	6.2 ± 2.9	5.6 ± 3.0[a,b]	5.6 ± 2.2[b]	7.3 ± 3.1[a]	<0.05
Whole grain servings	1.7 ± 1.5	2.2 ± 1.8[a]	1.4 ± 1.2[b]	1.3 ± 1.3[b]	<0.01
Refined grain servings	3.7 ± 2.6	2.5 ± 2.0[a]	3.5 ± 2.0[b]	5.3 ± 2.9[c]	<0.001
Meat servings	5.6 ± 2.8	5.2 ± 3.0	5.3 ± 2.7	6.2 ± 2.6	ns
Dairy servings	1.8 ± 1.1	1.9 ± 1.2	1.7 ± 1.0	1.8 ± 1.2	ns
Added fat servings	4.1 ± 3.9	4.1 ± 5.5	3.8 ± 2.2	4.3 ± 2.9	ns
Sweets servings	1.4 ± 1.8	1.2 ± 1.5[a]	2.0 ± 2.4[b]	1.3 ± 1.3[a]	<0.01
Sweetened beverages servings	0.3 ± 0.7	0.2 ± 0.8	0.3 ± 0.6	0.4 ± 0.6	ns
Alcohol servings	0.4 ± 0.9	0.3 ± 0.7[a]	0.7 ± 0.9[b]	0.4 ± 1.0[a]	<0.01

*Adjusted for group differences in age, sex, self-reported weekly energy expenditure from physical activity, and total energy intake. All values are servings per day.
Values in a row for each group that do not have a shared superscript are significantly different ($P<0.05$).
ns = not significant.

associated with higher intake of vegetables and whole grains (Ledikwe et al., 2006b; Schroder et al., 2008) and increased nutritional quality (Adam, Pablo, Matthieu, & Nicole, 2007; Maillot, Darmon, Vieux, & Drewnowski, 2007; Schroder et al., 2008). Further, RTs designed to decrease dietary ED have been successful in implementing the dietary intervention by promoting increased consumption of vegetables, rather than focusing on reducing overall dietary ED (Ello-Martin et al., 2007; Saquib et al., 2008). Therefore, emphasis on increased intake of vegetables and whole grains may be a simple, easy way to implement dietary strategy to decrease ED, as it decreases fat and increases fiber and water intake.

Results from this study indicate that a diet low in ED may be helpful for weight management. However, several recent prospective observational studies have shown that lower ED diets are not protective against weight gain over time (Bes-Rastrollo et al., 2008; Du et al., 2009; Iqbal, Helge, & Heitmann, 2006; Savage, Marini, & Birch, 2008). It is possible that low ED diets are only beneficial for long-term weight management in individuals consciously attempting to control their weight or participating in a weight loss program. That is, a low ED diet may only aid with weight control when energy intake is purposefully restricted. Another possibility is that low ED diets are only useful for weight management within the context of an overall diet high in nutritional quality. In the present study, WLM met or exceeded the recommendations for the number of servings of vegetables, including dark green, yellow and red vegetables, whole grains and, consequently, grams of dietary fiber according to the *Dietary Guidelines for Americans 2005* (Department of Health and Human Services, 2005). These results are in contrast to previous investigations, where individuals consuming the lowest ED diets, yet who were unsuccessful at body weight maintenance over time, did not meet these recommendations. In particular, dietary fiber intake for those consuming low ED diets in these studies ranged from 9.0 to 12.7 g/1000 kcal (Bes-Rastrollo et al., 2008; Du et al., 2009; Savage et al., 2008), below the recommended minimum of 14 g/1000 kcal, whereas in the present study, WLM consumed 17.1 g/1000 kcal.

A major strength of this study was that self-reported ED was calculated by three different methods, using all foods and beverages other than plain water, all foods and energy containing beverages only, and food only. Due to the lack of a standard method for ED calculation (Ledikwe et al., 2005), the inclusion of more than one calculation method allows for greater ability to compare ED values between studies using different methods. As expected, we found that ED was lowest with the inclusion of all foods and beverages and highest when all beverages were excluded from the ED calculation. This finding is consistent with previous investigations (Ledikwe et al., 2005), and reflects the influence of beverages, which generally have a low ED due to their high water content, on overall dietary ED. Mean ED values for food only in the present study of 1.39, 1.60, and 1.83 kcal/g for WLM, NW, and OW, respectively, with a mean value for all three groups of 1.60 kcal/g are also comparable to other observational studies where dietary intake and ED were assessed by the same method and ED tertile values ranged from 1.3 to 2.1 kcal/g with a mean of 1.7 kcal/g (Savage et al., 2008). Not all observational studies have yielded consistent results with regard to both absolute ED values and the relationship of beverages to overall ED (Bes-Rastrollo et al., 2008). Although differences in ED values may be due to differences in the study population characteristics and/or the use of different methods to assess dietary intake, a single standardized method for calculating dietary ED would allow for additional inference when directly comparing studies. As it is proposed that a diet lower in ED may help with weight loss and weight loss maintenance by increasing feelings of satiation (Rolls et al., 2006), and as beverages are not believed to contribute to increased satiation (Wolf, Bray, & Popkin, 2008), potentially the calculation of ED using food only may help best understand the relationship between ED and weight loss maintenance.

There are several limitations to this study that should be addressed. First, the three groups in this study were not recruited to participate in the same study, thus there may be differences in the characteristics of these participants that were not measured. However, it is important to note that the participants are generally from the same area (New England), recruited and assessed during the same time, and data were collected from all three groups using identical procedures for the dietary assessment. Also, due to the cross-sectional nature of the study, it was not possible to characterize ED in WLM over time as body weight status changed. This study also relied on self-reported weight data (for WLM and NW). The primarily white, middle-class, and middle-aged sample, as well as the treatment seeking OW group, limits the generalizability of the results to other populations. Moreover, because two of the groups were predominantly female, the influence of gender on ED within the differing weight groups could not be examined. Future research should investigate the influence of these variables on dietary ED and weight loss maintenance.

Additionally, the dietary data to assess energy, nutrient, and food group intake was self-reported. As there are many factors that are believed to influence the accuracy of self-reported dietary data (Maurer et al., 2006; Wansink & Chandon, 2006), it might be hypothesized that the OW group may under-report intake more so than the other groups, even though this group did report significantly greater energy intake, and significantly lower weekly energy expenditure in physical activity, which was controlled for in the analyses, than the other groups. One hypothesized variable to influence under-reporting is social desirability (Maurer et al., 2006). If social desirability was a factor for under-reporting in OW participants, then it might be expected that the OW participants would have presented with the lowest in self-reported energy and energy from fat intake, and highest in self-reported fruits, vegetables, and whole grains, which they did not. However, as overweight/obese individuals tend to under-report more so than individuals of other weight status for a variety of hypothesized reasons (Maurer et al., 2006; Wansink & Chandon, 2006), it is unclear how this may impact on dietary ED.

Additionally, the multiple pass 24-h dietary recall method that was utilized is currently considered the gold standard for dietary assessment and the large sample size minimizes intraindividual variation in dietary intake. This method of dietary assessment may also help reduce under-reporting since participants can suggest that occurrences of overeating or eating specific foods on any one day are “not usual” for them (Kristal, Andrilla, Koepsell, Diehr, & Cheadle, 1998). However, to better understand the relationship between ED and weight loss maintenance, future randomized controlled trials directly comparing an *ad libitum* low ED diet to an energy restricted diet with and without an emphasis on ED are needed to determine the effectiveness of a reduction in ED alone and a focus on ED within a calorie-controlled prescription for weight loss and/or weight loss maintenance.

Previously, we reported that WLM exercise more (Phelan, Roberts, Lang, & Wing, 2007) and use more fat restriction strategies to a greater extent than NW (Phelan et al., 2009). This preliminary study shows that, in addition to these previously mentioned strategies that can assist with weight loss maintenance, WLM also self-report consuming a diet lower in ED. A diet low in ED may be important to help keep energy intake low, while still allowing for a greater volume of food to be consumed, which may protect against weight regain after weight loss. The WLM's self-reported low ED diet was associated with self-reported consumption of a greater number of daily servings from food groups comprised of foods low in fat and high in fiber, including vegetables and whole grains. This suggests that consuming a diet low in ED via nutrient rich food groups low in fat and high in fiber may be another effective dietary strategy for successful long-term weight loss maintenance. However, as this investigation was cross-sectional, to clarify the relationship between dietary ED and weight loss maintenance, prospective randomized controlled trials are needed.

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Contributors

HAR developed the study concept; HAR, SP, and RRW were responsible for the design of the study; ELVW, JLB, and SML were responsible for coding data; HAR and ELVW conducted the statistical analyses, HAR and ELVW wrote the first draft of the manuscript; and all authors contributed to, provided a critical review, and approved the final manuscript.

Conflict of interest

The authors have no conflict of interest to declare.

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