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The Effect of Training in Reduced Energy Density Eating and Food Self-monitoring Accuracy on Weight Loss Maintenance

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Background: Failure to maintain weight losses in lifestyle change programs continues to be a major problem and warrants investigation of innovative approaches to weight control.
Objective: The goal of this study was to compare two novel group interventions, both aimed at improving weight loss maintenance, with a control group.
Methods and Procedures: A total of 103 women lost weight on a meal replacement–supplemented diet and were then randomized to one of three conditions for the 14-week maintenance phase: cognitive-behavioral treatment (CBT); CBT with an enhanced food monitoring accuracy (EFMA) program; or these two interventions plus a reduced energy density eating (REDE) program. Assessments were conducted periodically through an 18-month postintervention. Outcome measures included weight and self-reported dietary intake. Data were analyzed using completers only as well as baseline-carried-forward imputation.
Results: Participants lost an average of 7.6 ± 2.6 kg during the weight loss phase and 1.8 ± 2.3 kg during the maintenance phase. Results do not suggest that the EFMA intervention was successful in improving food monitoring accuracy. The REDE group decreased the energy density (ED) of their diets more so than the other two groups. However, neither the REDE nor the EFMA condition showed any advantage in weight loss maintenance. All groups regained weight between 6- and 18-month follow-ups.
Discussion: Although no incremental weight maintenance benefit was observed in the EFMA or EFMA + REDE groups, the improvement in the ED of the REDE group's diet, if shown to be sustainable in future studies, could have weight maintenance benefits.

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INTRODUCTION

Obesity is a chronic condition that raises the risk for diabetes, hypertension, cardiovascular disease, respiratory dysfunction, and certain cancers (1,2). Unfortunately, most weight lost in comprehensive weight loss programs is regained within several years (3) and the health benefits dissipate. Therefore, new programs to facilitate long-term weight loss maintenance are greatly needed.

This study focused on two approaches to improve weight loss maintenance. The first involved improving the accuracy of obese individuals' food intake self-monitoring records. Self-monitoring is sometimes referred to as the "cornerstone" of lifestyle change programs because it can identify problematic eating patterns and provide feedback about behavior change efforts (3,4). Because obese individuals substantially underreport their intake (e.g., 5,6), improving the accuracy of self-monitoring may be particularly important. As such, one purpose of this study was to test a new program designed to improve monitoring accuracy and reduce underreporting of intake.

A second approach to improving weight loss maintenance is based on reducing the energy density (ED) of the habitual diet (7). The rationale for reduced energy density eating (REDE) is based on research showing that the volume (or, in some studies, weight) of food that people eat every day remains fairly constant regardless of the ED of the food (8,9). Reducing ED of a diet can reduce intake without increasing hunger or producing short-term caloric compensation (8). There is preliminary evidence that a specific focus on reducing the ED of the diet through increased intake of fruits, vegetables, and whole grains (10,11), and through the use of sugar (12,13) and fat substitutes (14) facilitates long-term weight control. However, research on the ability to maintain a diet reduced in

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ED in order to improve the maintenance of weight loss is just beginning. One recent study examined the long-term effects of a reduced ED diet on weight loss and weight loss maintenance (15). This study prescribed consumption of either one or two low-ED soups per day, two dry, high ED snacks, or no daily prescribed foods. Results indicated that the two-soup group lost more weight after 1 year than the dry snack groups, but did not lose more weight than the control group; in fact, at 6-month follow-up, the control group had lost more significantly more weight than the two soup and one soup groups. It is possible that this occurred because the soup and dry snack conditions all involved adding compulsory foods and that the control group was therefore simply better able to restrict calories during the weight loss period. Hence, the use of a REDE approach to weight maintenance requires further study.

In this study, after a period of weight loss, participants were assigned at random to one of three weight loss maintenance conditions. The first condition was a cognitive-behavioral control group. The second group was an enhanced food monitoring accuracy (EFMA) condition that also received materials during maintenance designed to improve the accuracy of self-monitoring of food consumed. The third condition received the EFMA intervention plus instruction on REDE. We predicted that both the EFMA and REDE conditions would report their food intake more accurately and show better weight loss maintenance than the control condition, and that the REDE group would show better weight loss maintenance than both the other groups.

METHODS AND PROCEDURES

Enrollment

Participants were recruited into the study through a newspaper story by a local columnist, advertisements in local newspapers, and through affiliated physicians. The study recruited only women because men seldom volunteer for weight loss studies in numbers that would be sufficient to analyze their data separately and because most existing studies with which we would compare our results have been conducted only on women.

Applicants were initially screened to determine that they met the following criteria: a BMI of ≥27; no history in the past 10 years of eating disorders; no history of bipolar disorder or a major depressive episode; not currently taking any psychotropic medications that impact weight; not scoring ≥26 on the Beck Depression Inventory; no history of a substance-abuse or dependence disorder; and absence of other major psychiatric disorders. Those applicants who met the above criteria provided their family physician with a description of the study and its inclusion/exclusion criteria. Exclusion criteria were any disease, condition, or use of medication that could be expected to impact weight or near-term life expectancy. The physician then signed a physician permission form if he or she approved a patient for participation.

Orientation meetings were held during which researchers described the study, answered any questions, and scheduled interested individuals for an initial assessment. Participants signed an informed consent form at the initial assessment and agreed not to seek any additional weight control treatments for the duration of the study.

This study was approved by the Institutional Review Board of MCP Hahnemann University.

Assignment of participants to treatment conditions

When enrollment was completed, participants were blocked into groups of three based on similar BMIs and were then assigned randomly to one of the three intervention conditions (described below). Participants then received treatment in groups of 10–12. Neither the group leader nor the participants were aware of the group assignments until week 7; all three groups received identical weight loss treatment for the first 8 weeks.

Treatment phases

Weight loss phase. The weight loss phase was based on an Optifast meal replacement (MR)–supplemented, 1,100 kcal/day diet similar to one successfully implemented at the University of Pennsylvania (16). Four servings daily of meal replacement were combined with an evening meal of normal foods, comprising a frozen food entree (from a list provided), two cups of salad with low fat or nonfat dressing, and a piece of fruit. Each serving of the meal replacement provided 240 kcal, 16 g protein, 37 g carbohydrate, and 6 g fat (Novartis Nutrition; Minneapolis, MN). Each of the frozen food entrees provided ~250 kcal, 25 g protein, 25 g carbohydrate, and 7 g fat. Subjects purchased their own entrees but were provided the meal replacements free of charge. Subjects were instructed to avoid all other foods. They were also advised to review the diet plan with family members, co-workers, and friends as well as to prepare their homes for the diet (e.g., to dispose of tempting foods).

Meal replacements were provided weekly to maximize attendance. The OPTITRIM manual (17) was provided to all participants at week 1 and formed the foundation of treatment for all groups. The OPTITRIM manual is similar to the more familiar LEARN manual (18), but the OPTITRIM manual is more structured and more suitable for patients who consume meal replacements as part of their diet. The OPTITRIM manual covers all the major cognitive-behavioral topics contained in the LEARN manual, including environmental control of food cues, changing eating behaviors, modification of problematic beliefs and thought patterns, increasing exercise (to at least 30 min on most days of the week), healthful eating guidelines, and social support for weight control.

The weight loss phase of the study lasted for 8 weeks. All groups focused primarily on adherence to the diet, food monitoring, and gradually increasing physical activity. Toward the end of the weight loss phase, the intervention shifted to preparing participants for maintenance, which began at the end of week 8.

Weight loss maintenance phase. This 14-week period emphasized helping participants learn how to maintain the weight loss they achieved on the controlled diet. Participants gradually replaced meal replacements with regular foods during weeks 9–12. Participants were told that the goal of the weight maintenance phase of the program was to help them adopt an all-regular food diet while learning how to eat in a way that would maintain their weight losses. All participants continued to attend group sessions, during which the OPTITRIM manual continued to be taught but with a focus on weight maintenance rather than weight loss. The total program duration of 22 weeks (with 14 weeks of maintenance) facilitated comparisons with prior studies, which have been of similar length.

Experimental conditions

The three conditions in this study were cognitive-behavior therapy (CBT), CBT plus EFMA, and CBT plus EFMA plus a REDE program. An additive design was used because the primary goal of this study was to achieve optimal success in weight loss maintenance. Because the EFMA and REDE approaches represent qualitatively different ways of achieving this goal, it was hypothesized that they might provide good complementary effects in combination (e.g., if participants became more aware of their entire food intake, they might be able to reduce the ED of a greater proportion of their diet).

Control. The CBT group acted as the control group in this study. The individuals in this group received instruction during weeks 9–22 about nutrition, focusing on exchange lists, portion sizes, macronutrients, vitamins and minerals, reading food labels, and dietary guidelines according to the food pyramid. This group also received instruction in behavioral and lifestyle modifications (as per the OPTITRIM manual), such as environmental control of food access, self-reward, increasing physical activity, social support, having a positive attitude, and dealing with "slips." The OPTITRIM manual was supplemented with detailed information about protein, carbohydrates, and fats, an explanation of the exchange system for meal planning, provision of menu plans, instructions for interpreting food labels, and how to follow the food guide pyramid and the *Dietary Guidelines for Americans* from 2000 (19). The participants in this group attended 14 sessions, 5 of which included nutrition components, and all of which included cognitive-behavioral training. Weekly homework specific to this condition included traditional behavioral techniques, such as self-monitoring and practicing eating all meals in one place at home.

EFMA. Self-monitoring of food intake is one of the most consistent correlates of successful weight control (4,20,21) and is a standard component of cognitive-behavioral weight loss interventions. In this group, participants received the same group lessons on nutrition and behavioral changes as did the CBT group but also received additional lessons (which the CBT group did not receive) to enhance skills for accurate food recordings and reduce possible psychological sources of underreporting. This training consisted of several components. First, participants were given detailed instructions on how to measure and judge food portions, sizes, and ingredients accurately, and to translate this information into calories. Second, participants received written materials that described the relationship between obesity and decreased awareness or reporting of overeating; personal historical influences on eating style and awareness; and the problems with unplanned eating. For example, participants in this group were instructed about how feelings of shame or embarrassment could lead to underreporting of food intake, were taught cognitive-behavioral methods to counter these thoughts through self-talk that emphasized the benefits of accurate reporting, and were taught to review their food intake at the end of each day and add in instances of food intake they may have overlooked.

Third, participants practiced food monitoring every day and were given individualized feedback on their food records about potential instances of underreporting to improve the accuracy of their subsequent food monitoring. Also, this intervention focused on identifying potential sources of underreporting in food records repeatedly throughout treatment, in contrast to standard CBT's focus on training in food monitoring accuracy at the beginning of treatment. Fourth, this instruction included a series of live demonstrations in a research kitchen conducted by the group leader who demonstrated appropriate portion sizes of various foods. This allowed participants to learn and practice the strategies for estimating portion sizes with the guidance of the group leader. Participants had the opportunity to serve their own portion sizes and receive feedback on them, estimate the size of and number of calories in each food, and then compare their own estimates with the actual values. Because the duration of each weekly session was held constant across treatment groups, more time in this group focused on food measurement principles than on CBT behavioral principles, although all of the CBT principles were addressed, at least briefly. EFMA principles were addressed during six sessions.

REDE. The goal of the REDE intervention was to introduce participants to the concept of REDE and its advantages as a method of weight control and to introduce methods for reducing the ED of one's habitual diet. In this study, participants assigned to this condition were given the book *Volumetrics* (7) as a guide to the principles introduced during group meetings and were assigned specific readings from this book each week. This approach was taught using real foods, for example, by demonstrating the high- and low-ED versions of similar foods (e.g., a small handful of raisins vs. a whole bowl of grapes, each with the same number of calories). The specific REDE principles were taught during 10 of the 14 sessions using food demonstrations. Because the duration in group sessions was held constant across the three groups, a greater proportion of time was spent learning REDE and EFMA principles in this group relative to learning the CBT behavioral principles. Participants learned: how to calculate the ED of foods, multiple ways in which food and ingredients lower in ED can be substituted for those higher in ED, how to reduce ED of foods eaten outside the home, how to incorporate more foods low in ED and high in water content (e.g., soups and salads) into the diet and how to choose beverages. The REDE intervention also consisted of weekly homework assignments and spot-checking participants' food records each week. Spot-checking of the food records involved commenting on participants' success incorporating REDE concepts into their diet and/or suggesting further ways of doing so.

Outcome measures

Assessments were conducted at baseline, postweight loss (week 8), postintervention (week 22), 6- and 18-month follow-up. During these in-person assessments, physical measurements were taken, and questionnaires were collected, as described below. Only weight and blood lipids were measured at week 8.

Body weight. Participants' weight was measured on a digital scale without shoes to the nearest 0.1 pound and converted to kilograms for analysis. Height was determined (at baseline) to the nearest half-inch using a stadiometer.

Lipid analyses. After an overnight fast, blood samples were obtained via venipuncture to measure total cholesterol, triglycerides, high-density lipoprotein, and low-density lipoprotein cholesterol. The three interventions would have been expected to have differential effects on lipids to the extent that they produced different weight losses, differences in nutritional intake, or both.

Five-day food records. Standard 5-day food records were collected at all assessment points except for week 8. These records were also used for food monitoring accuracy evaluations in the EFMA and EFMA + REDE groups. Participants recorded a description of all food consumed (brand and ingredients), portion size/amount, and how the food was prepared for 5 consecutive days (Wednesday through Sunday). Participants were given detailed instructions for estimating amounts of foods consumed and were encouraged to provide as much detail as possible (use of condiments, uses of sauces or toppings, etc.). Food records were entered into Nutritionist V (FirstDataBank, San Bruno, CA) to obtain nutritional information.

Inclusion of the food records allowed us to calculate ED of participants' diets. ED is calculated by dividing the number of calories in a food by the food's weight (in grams). The optimal method of calculating ED has not firmly been established; the concern is how and whether to include beverages in the calculations. A full review of this issue can be found in Ello-Martin *et al.* (22). For this study, ED was calculated using two methods: foods only and foods plus "caloric" beverages (defined as those having >20 calories per serving).

Statistical analyses

One-way ANOVAs (for continuous dependent measures) and χ^2 (for categorical dependent measures) were used to evaluate group differences at baseline. Attrition rates were analyzed using χ^2. Changes during the weight loss phase for the entire sample were evaluated using paired *t*-tests. All analyses of outcomes reflecting change in weight and other measures over the course of the study were conducted using mixed model repeated measures ANOVAs (multivariate, Pillai's Trace method). Time served as the within-subjects factor in the model. Intervention group (CBT, EFMA, and EFMA + REDE) was the between-subjects factor. For analysis of weight change over time, baseline weight was covaried out of the calculation. Evaluation of findings between two specific time points in the repeated measures ANOVA was conducted using tests of within-subjects contrasts; post-hoc analyses testing for specific group differences were conducted using Tukey's honestly significant differences test. Two-tailed tests are used for most analyses; however, one-tailed tests are used for analyses in which a directional hypothesis was relevant (weight maintenance, self-reporting accuracy, and ED).

All analyses were conducted using the Statistical Package for the Social Sciences (SPSS for Windows, version 15.0; SPSS, Chicago, IL).

For analysis of weight, week 8 measures served as the starting point for analysis because all participants had received the same intervention (controlled diet based on meal replacements) up to that point. Baseline (week 2) was the starting point for repeated measures analysis of all other measures.

We conducted two separate statistical analyses for all outcome measures—one with completers only and one "intent-to-treat" analysis, in which data for missing values were imputed using "baseline-carried-forward" (BCF) imputation. Although a common method for intent-to-treat analysis is the "last observation carried forward" method, this method has been shown to lead to erroneous conclusions in some weight loss studies (23), because the assumption that weight lost before dropout is maintained is probably too liberal (i.e., most dropouts probably start regaining weight).

The BCF imputation method assumes that all participants who do not complete the study have returned to their baseline condition for that outcome measure, measured at week 1 of the study. Because most participants who lose weight in weight loss trials usually do not regain all their weight back within 18 months, this approach is potentially too conservative, but provides a "worst case scenario" interpretation.

All results are reported for both the BCF method and completers. Results are reported as mean ± s.d.

RESULTS

Baseline characteristics and attrition

Of 103 adults enrolled in this study; 35 were randomly assigned to the control group, 35 to the EFMA group, and 33 to the REDE group. At baseline, there were no statistically significant differences between intervention groups in age, weight, height, BMI (see **Table 1**), or proportions of participants of different ethnic groups or educational backgrounds. The average age of participants was 43.9 ± 10.5 years, and 61.2% were whites, 35.9% were African Americans, and 2.9% were Asians.

The attrition rate during this study (defined as participant contributing data to the study at baseline but not at the indicated follow-up time) was 12% at week 9, 22% at postintervention, 31% at 6 months, and 40% at 18 months. There was no differential attrition rate at any time point by intervention condition. Analyses indicated that those dropping out at all time points were significantly more likely to be African Americans than whites (Ps < 0.005) and more likely not to have a college degree (Ps < 0.01). Completers of the entire study on average attended 19 of 22 group sessions (range: 13–22); participants in the control and EFMA group each attended an average of 19, and participants in the REDE group attended, on average, 17 sessions.

Table 1 Participants' baseline characteristics

Variables	CBT (n = 35)	CBT and EFMA (n = 35)	CBT, EFMA, and REDE (n = 33)
Age (years)	41.4 ± 11.0	44.7 ± 9.8	45.7 ± 10.5
Height (cm)	162.7 ± 6.8	164.0 ± 6.6	164.4 ± 6.6
Weight (kg)	85.2 ± 10.6	85.2 ± 8.2	86.0 ± 9.8
BMI (kg/m^2)	31.5 ± 2.6	31.7 ± 2.7	31.9 ± 2.6

Values shown are mean ± s.d.
There were no statistically significant differences among the three groups.
CBT, cognitive-behavior therapy; EFMA, enhanced food monitoring accuracy; REDE, reduced energy density eating.

Descriptive statistics

Classified using the World Health Organization obesity guidelines, 35 participants (34%) presented in the "Overweight" range (BMI 25–29.9), 53 (51.5%) presented in the "Obesity Class I" range (BMI 30–34.9), and 15 (14.6%) presented in the "Obesity Class II" range (BMI 35–39.9). No participant presented as severely obese (BMI ≥ 40). Mean weight in this sample was 85.5 ± 9.5 kg and mean BMI was 31.9 ± 2.6.

Weight change

Weight change over the study is shown in **Table 2**. Participants who attended the second assessment between weeks 8 and 9 (postweight loss phase) had lost a mean 7.6 ± 2.6 kg, or 8.8 ± 2.8% of their initial weight, a statistically significant decrease ($t_{(90)}$ = 27.96, P < 0.001). There was no significant difference in weight loss among the three groups (which is unsurprising because they were on identical weight loss regimens) and no significant difference in weight change between African Americans and whites. Of those completing the study up to 18-month follow-up, 41.9% regained all the weight they had lost earlier.

The repeated measures analysis from week 8 using the BCF imputation indicated no significant time-by-condition interaction on weight change over the 18-month period ($F_{(6,172)}$ = 0.99, one-tailed P = 0.22). The same was true when analyzing completers only, although there was a statistical trend ($F_{(6,114)}$ = 1.52, one-tailed P = 0.09) (see **Figure 1**). A closer look at the data suggested that the trend toward an interaction stemmed from two sources: slower weight regain in the REDE group compared with CBT from post-treatment to 6-month follow-up, and a discrepancy between weight gain patterns for the control group and EFMA groups from 6- to 18-month follow-up, with the EFMA group showing more weight gain. Although graphically it appears that there is a main effect of time on weight, with baseline weight covaried out of the equation, this statistical finding disappears.

Table 2 Percentage weight change by intervention group

	CBT		EFMA		REDE	
Weight loss from week 8 assessment[a]	Completers	Baseline carried forward	Completers	Baseline carried forward	Completers	Baseline carried forward
Week 22	−2.89 ± 3.16	−1.31 ± 4.71	−2.42 ± 2.88	−0.32 ± 4.72	−2.70 ± 3.65	−2.22 ± 4.15
6 Months	0.24 ± 5.36	2.71 ± 6.21	0.04 ± 5.26	2.26 ± 5.80	−1.87 ± 7.74	1.16 ± 8.39
18 Months	2.53 ± 6.05	5.01 ± 6.19	5.52 ± 6.96	6.17 ± 6.09	2.53 ± 9.77	4.75 ± 8.88

CBT, cognitive-behavior therapy; EFMA, enhanced food monitoring accuracy; REDE, reduced energy density eating.
[a]Negative numbers indicate mean weight loss. Positive numbers indicate weight gain.

Blood lipids

Results using both BCF and completers consistently indicated that there was no group-by-time interaction on blood lipid levels. However, there was a significant main effect of time on blood lipids, such that all measures of blood lipid levels decreased during the weight loss phase, and then gradually returned toward baseline during weight loss maintenance and follow-up ($Ps < 0.001$). These results are shown in Table 3 for completers.

ED

This study postulated that weight regain would have been slower in the EFMA + REDE group because of the impact of a lower energy dense diet in this group, which presumably leads one to feel fuller on fewer calories. Food records may provide valuable information as to whether ED actually decreased in the EFMA + REDE group relative to the two other groups. We therefore conducted a repeated measures time-by-condition analysis including three time points: baseline, postintervention, and 6-month follow-up. Analysis was not conducted using 18-month follow-up because an insufficient number of food records were collected for reliable analysis of all four time points (48.5% of controls, 42.9% of EFMA, and just 30.3% of REDE participants completed food records for all time points). For completers analysis, 49 of 81 participants who fully received the intervention were included (18 in CBT, 20 in EFMA, and 11 in REDE).

When ED was calculated using only solid foods and excluding all beverages, there was a trend toward a time-by-condition interaction for the BCF analysis ($F_{(4,116)} = 1.86$, one-tailed $P = 0.06$) and a statistically significant interaction for completers only ($F_{(4,92)} = 4.35$, one-tailed $P < 0.005$), such that participants

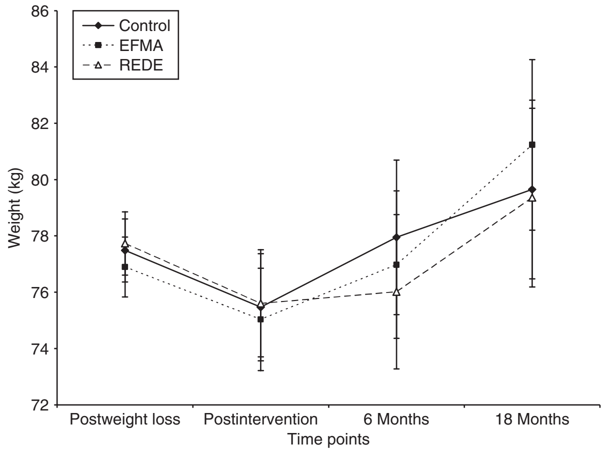

Figure 1 Weight change over 18 months—completers only. EFMA, enhanced food monitoring accuracy; REDE, reduced energy density eating.

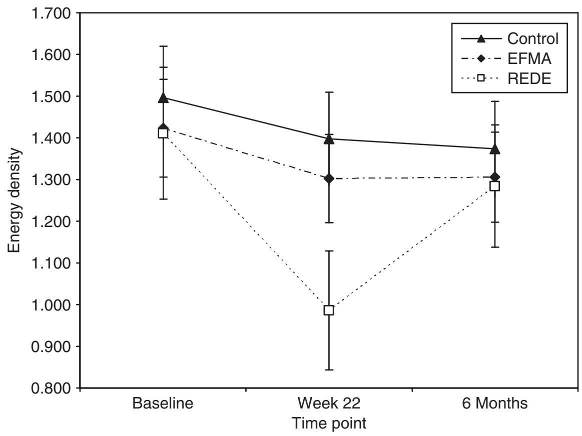

Figure 2 Energy density change over time: completers only. EFMA, enhanced food monitoring accuracy; REDE, reduced energy density eating.

Table 3 Other findings: means across groups at each time point for completers only

	Week 2	Week 22	6 Months	18 Months
5-Day food records:				
Total number of calories per day (kcal)	2,164.18 ± 631.33	1,735.37 ± 417.29	1,757.19 ± 390.83	
% Total calories from fat	35.79 ± 6.23	29.05 ± 6.29	29.92 ± 5.66	
% Total calories from protein	16.45 ± 3.46	18.37 ± 3.10	17.53 ± 2.91	
% Total calories from carbohydrates	46.67 ± 7.19	52.46 ± 6.71	52.36 ± 6.72	
Food groups: vegetables	2.46 ± 1.15	2.45 ± 1.18	2.23 ± 1.12	
Food groups: fruits	1.51 ± 1.10	1.79 ± 1.18	1.63 ± 1.10	
Food groups: meats	2.17 ±0.91	1.71 ± 0.64**	1.84 ± 0.71	
Food groups: dairy	2.26 ± 1.51	1.88 ± 0.86	1.75 ± 0.94	
Food group: fats and oils	11.90 ± 7.03	6.21 ± 4.15**	6.76 ± 5.17	
Blood cholesterol	212.53 ± 37.73	183.78 ± 34.66**	192.31 ± 32.22*	193.74 ± 30.00
Blood HDL	64 ± 15.80	54.22 ± 14.05**	59.18 ± 13.49**	61.62 ± 15.07*
Blood LDL	127.12 ± 31.16	112.64 ± 28.32**	115.71 ± 27.34	111.36 ± 27.06
Blood triglycerides	106.63 ± 53.17	84.48 ± 38.79**	86.98 ± 46.59	99.64 ± 53.83

Note: 18 month data not reported for food records because of the high attrition and low food record completion rate at that time point.
HDL, high-density lipoprotein; LDL, low-density lipoprotein.
$^*P < 0.005$; $^{**}P < 0.001$ change from the previous time point.

in the REDE group decreased their ED from baseline to postintervention (week 22) significantly more than did the other two groups. However, from the postintervention assessment to 6-month follow-up, the REDE group's ED rebounded back to values on par with the other two groups. These same patterns also held true when ED was calculated using both solid foods and caloric beverages, but only for the completers' analysis ($F_{(4,92)} = 8.64$, one-tailed $P = 0.01$) (see **Figure 2**).

Owing to the likelihood of selective attrition of less successful participants over time, completers' analyses were also conducted that included baseline and postintervention time points only, but did not include 6-month follow-up data as in the earlier analysis. This increased the sample size from 49 to 62 and demonstrated the same pattern of results for food only ($F_{(2,59)} = 4.98$, $P < 0.01$) and foods plus caloric beverages ($F_{(2,59)} = 4.18$, one-tailed $P = 0.01$).

Self-reported calorie intake

Food records were used for these analyses. Completers' analyses only include follow-up to 6 months because of substantial attrition; the completers analyses below include 55 participants (22 control, 20 EFMA, and 13 REDE). According to both analytical methods, there were no significant time-by-group interactions on caloric intake (BCF: $F_{(6,194)} = 0.56$, $P = 0.76$). There was a statistically significant decrease in caloric intake over the weight loss and weight loss maintenance phases, but no changes were noted over the rest of the study (BCF: $F_{(3,96)} = 16.64$, $P < 0.001$). At baseline, the average reported daily caloric intake among participants, as estimated from the 5-day food records, was 2,164.2 ± 631.3 kcal. At week 22, at the end of the weight maintenance phase, the average daily caloric intake was reported as 1,735.4 ± 417.3.

The EFMA intervention, if successful, was hypothesized to improve weight control by making participants more aware of all their food consumption. To evaluate whether this happened, we looked at the ratio of reported calories eaten per day divided by their current body weight using the 5-day food record. This ratio provides the reported number of calories eaten per kilogram of body weight. Pre and postintervention calorie-weight ratios were compared. All participants should have decreased this ratio because, on the diet, they would be expected to eat fewer calories per pound of body weight. However, if all participants were underestimating their calorie intake at baseline, and if food monitoring training in the EFMA and EFMA + REDE groups led to improved accuracy, then these two groups should report more calories ingested, and hence, less of a decrease in the calorie/body weight ratio score post-treatment than the CBT group.

A repeated measures analysis of completers showed no statistically significant interaction between group and time on calorie-weight ratio over the course of weight loss and maintenance training ($F_{(2,63)} = 0.89$, $P = 0.41$) or up to 6-month follow-up ($F_{(4,102)} = 0.46$, $P = 0.77$). There was a significant inverse correlation between calorie-weight ratio and weight change for the EFMA group in the expected direction, such that those individuals who reported eating more calories per kilogram experienced better weight control during the weight loss maintenance phase ($r = -0.43$, $P < 0.05$); however, this same pattern was demonstrated for the control group as well ($r = -0.43$, $P < 0.05$), but not for the EFMA + REDE group ($r = -0.01$, $P = 0.99$). When calculated across all participants, no significant correlation was observed ($r = -0.19$, $P = 0.12$). The results of this analysis, although intriguing, do not provide consistent support for the hypothesis that training in food monitoring accuracy changed the reported ratio of calories ingested to weight.

Nutritional measures

Because the weight loss maintenance interventions evaluated in this article were nutritionally based, it is particularly important to analyze the patterns of changes (if any) in specific nutritional parameters. The 5-day food records were used for this purpose. There was no significant interaction effect for any nutrition variables for either the BCF or completers only analyses. There were, however, some main effects over time (see **Table 3**). A main effect was apparent in both analyses in which percentage of calories from protein gradually increased across all groups between baseline and postmaintenance assessment, but not over other time points in the study (BCF: $F_{(3,96)} = 11.24$, $P < 0.001$). Percentage of calories from carbohydrates increased for all groups between baseline and postmaintenance assessment, but not over follow-up (BCF: $F_{(3,96)} = 8.52$, $P < 0.001$). A corollary decrease in percentage of calories from fat was also observed over the same period (BCF: $F_{(3,96)} = 14.92$, $P < 0.001$).

The number of servings of specific food groups was also analyzed (see **Table 3**). There were no significant time-by-groups interactions using either of the analytical methods. There were some significant main effects of time observed: both meats and dairy products showed such an effect, such that the number of servings of both decreased significantly during the weight loss and weight loss maintenance phases (BCF meat: $F_{(3,95)} = 4.80$, $P < 0.005$; BCF dairy: $F_{(3,95)} = 3.72$, $P < 0.05$); the effect for dairy was only found using BCF imputation. When fats were analyzed as a food group, there was a significant main effect using both analytical methods (BCF: $F_{(3,95)} = 12.98$, $P < 0.001$), such that number of fat servings decreased significantly during weight loss and weight loss maintenance, and then, according only to BCF imputation, increased significantly during 6–18-month follow-up. There were no significant main effects for fruit or vegetable servings.

DISCUSSION

The purpose of this study was, first, to evaluate the effects of improving the accuracy of food self-monitoring on weight loss maintenance and second, to evaluate the efficacy of a reduced ED diet to help maintain weight loss. We predicted that if the accuracy of food monitoring was improved, it would enhance participants' awareness of their eating habits, which in turn would facilitate more comprehensive improvements in eating behavior and thus in weight maintenance. We also predicted that REDE, because it leads to feeling full on fewer calories, would also produce better weight loss maintenance. The net result of these hypotheses would be that we would expect the EFMA group to demonstrate better weight loss maintenance than the control group, and the EFMA + REDE group to demonstrate better weight loss maintenance than both the other groups. Unfortunately, these hypotheses were not substantiated.

In the first, 8-week phase of the study, participants lost an average of 7.6 kg, or 8.8% of their initial weight. This amount of weight loss, if maintained, can lead to substantial health benefits, such as lower blood pressure and cholesterol, and better control of blood sugar levels (24,25). Indeed, significant reductions in blood cholesterol were found during this period. The amount of weight loss in this study approached the amounts seen in balanced deficit diet programs that last more than twice as long as this one (3), and the findings of our study are consistent with other studies evaluating meal replacements plus dietary restriction (26). Therefore, the use of meal replacements and dietary restriction appears to be a relatively simple, efficient way to effect clinically meaningful weight loss.

The assumption upon which the EFMA intervention was based—namely, that it would lead to improved self-monitoring accuracy—was not supported. Because there was no improvement in self-monitoring (as inferred from the caloric intake-to-body weight ratio before vs. after the intervention period), there was no opportunity to test whether such improvements could facilitate weight loss maintenance. If future research establishes a method to improve the accuracy of self-monitored food intake, then its ability to facilitate weight loss maintenance could be tested. One possible way of improving the accuracy of food monitoring would be through the use of ecological momentary assessment—the use of technology, such as personal digital assistants to remind participants to record food intake throughout the day (e.g., 27,28).

We demonstrated that the REDE diet intervention led to a differential reduction in the ED of the diet. The effect was strongest during the weight loss maintenance phase, during which both the BCF and completers analyses demonstrated that the REDE group decreased their ED significantly more than did the other two intervention groups. These findings suggest that the REDE manipulation was successful, and that a combination of group education, demonstrations, and individualized feedback, along with the prescription of the book *Volumetrics,* is an effective intervention method for modifying the ED of the diet. However, given the multiple components used, we cannot determine the relative impact of the different components to the outcome. This finding, combined with the finding of no significant group differences in kilocaloric intake or weight change, and the rebound in ED of food during follow-up in the REDE group, suggests that methods must be found to sustain the adoption of reduced ED diets during weight loss maintenance. There appeared to be a nonsignificant trend for the REDE group to regain less weight than the CBT group from post-treatment to the 6-month follow-up. Although these differences were not statistically reliable, it is possible that the greater improvement in the ED of the diet in the REDE group contributed to this difference but that we did not have sufficient power to detect it. Even if this were the case, a short-term benefit in terms of weight maintenance is rendered clinically insignificant given the rapid relapse seen in the REDE group from the 6- to 18-month follow-up.

Prior research has shown that weight regain usually begins shortly after formal treatment sessions end, and indeed, this pattern was replicated in this study. Group sessions did not appear to provide enough of a protective effect to encourage participants to extend their increased knowledge to their home environment once the intervention was complete. If the improvement in the ED of the diet shown by the REDE group could be maintained once treatment ends, then the observed trend among REDE completers in slower weight gain to 6-month follow-up might be further extended. It may be necessary to train participants how to alter the foods they surround themselves with in their daily life (their "personal food environment") (29) to achieve this goal.

There were some interesting patterns of findings from the food recalls: the percentage of calories from protein increased in all groups during the intervention. However, servings of meat decreased during this same period. This seemingly contradictory finding may be explained by the fact that percentage of calories from fat decreased (as it does in many diets), leading to an automatic concomitant increase in percentage of protein and carbohydrates, but not a true increase in protein (or carbohydrate) intake. This conclusion is supported by the fact that grams of protein reported on food records decreased during weight loss and weight loss maintenance for all groups. However, because the relative amount of protein in their diets increased, it is possible that the previously reported satiating effects of protein may have contributed to weight loss and weight loss maintenance in this study (30–32). Dairy intake decreased also during weight loss maintenance, but there was no change in fruit or vegetable intake, suggesting that while people were decreasing their caloric intake, they did so through lower consumption of higher calorie and fat items, while maintaining their status quo intake of lower calorie items such as fruits and vegetables.

Some limitations of this study are worth noting. First, a relatively high attrition rate contributed to reduced statistical power in this study. Particularly notable was the high attrition rate among African-American and lower-educated participants. Previous longitudinal weight loss studies have also noted attrition rates among African Americans that are similarly high (33–35); therefore the higher attrition rate we observed might not reflect the specific nature of our interventions. However, of those who completed the study, there was no racial difference in weight loss. Second, although the second phase of the intervention was aimed at weight loss maintenance, on average, participants continued to lose a small amount of weight. Strictly speaking, participants were not learning how to maintain their weight loss (because they were still losing weight), so it is possible that this phase was less successful than it could have been in preparing members for the cognitive and behavioral shift to weight maintenance.

Future research should test methods of extending the durability of nutritional changes achieved during weight loss treatment rather than just teaching the concepts in isolated class environments (29). More long-term research is also needed comparing the REDE approach to other weight control approaches and combining the REDE approach with other methods that may prevent weight regain. It will also be important to test these methods in samples from lower socioeconomic groups than the one tested here. Intervening successfully in underserved communities is a particular challenge since high fat food is often the least expensive and most easily available. Finding ways to encourage low-ED eating in such populations, which is a generally healthy approach to eating whether or not weight loss is a goal, warrants further investigation.

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DISCLOSURE

The authors declared no conflict of interest.

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