Original Research

Ready-to-eat Cereal Used as a Meal Replacement Promotes Weight Loss in Humans

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Key words: meal, body weight, human, cereal, hunger, food

Objectives: The primary aim was to determine whether ready-to-eat cereal used as a portion-controlled, meal replacement promotes weight loss. Additional aims were to determine whether weight loss differed if the cereal was provided as a single brand or variety of brands and whether this use of ready-to-eat cereal promotes continued weight loss following transition to a high-fiber, high-volume (Volumetric) diet.

Methods: Body composition was measured and diet records, appetite questionnaires and activity logs were completed during baseline and end of intervention weeks 2 and 6. Participants were assigned to one of four treatment groups. Group 1 (6 M, 22 F, mean age 43.0 ± 1.9 years, mean initial BMI 28.9 ± 0.4 kg/m^2) consumed a serving of a single brand of ready-to-eat cereal with 2/3 C skim milk and a 100 Kcal portion of fruit for breakfast and as a replacement for either lunch or dinner for weeks 1 and 2. No restrictions were placed on the non-cereal meal. They then followed the Volumetric diet for weeks 3 to 6 with a target energy restriction of 500 kcal/day. Group 2 (3 M, 25 F, mean age 40.9 ± 2.3 years, mean initial BMI 29.39 ± 0.6 kg/m^2) followed the same protocol, but was permitted to select from a variety of ready-to-eat cereals during weeks 1 and 2. Group 3 (7 M, 19 F, mean age 41.6 ± 2.4 years, mean initial BMI 29.3 ± 0.6 kg/m^2) received no dietary instruction during the six-week study and Group 4 (9 M, 18 F, mean age 38.2 ± 2.8 years, mean initial BMI 29.3 ± 0.6 kg/m^2) received no intervention prior to adoption of the Volumetric diet for weeks 3 to 6.

Results: The cereal interventions resulted in 640 ± 109 and 617 ± 105 kcal/day reductions of energy intake in Groups 1 and 2, respectively, during the two-week cereal intervention. This led to comparable mean weight losses (1.91 ± 0.19 kg—Group 1, 1.37 ± 0.15 kg—Group 2) that were significantly greater than that observed in Group 3 (0.08 ± 0.15 kg). The losses were primarily of fat mass. No significant changes of total body water were observed. Weight loss continued during the Volumetric diet in Groups 1 and 2. The changes were comparable to those observed in Group 4, and all were significantly greater than that of Group 3. Self-reported hunger was slightly, but significantly higher than baseline in Groups 1 and 2 during the cereal intervention, but similar to baseline in Groups 1, 2 and 3 during the Volumetric diet. Based on predicted weight loss, compliance with the Volumetric diet was similar and limited in all three intervention groups.

Conclusions: Ready-to-eat cereals may be used to promote weight loss when consumed as a portion-controlled, meal replacement. Provision of a variety of brands does not compromise efficacy. Weight losses may be maintained or increased after transition to the Volumetric diet. The later regimen effectively controls hunger and may lead to weight loss, but compliance is limited.

INTRODUCTION

It is widely accepted that the recent, marked increases of overweight and obesity in the population have a substantive behavioral component. Decreased leisure time energy expenditure [1], increased reliance on convenience foods [2] and increased portion sizes [3] are commonly implicated. Although the efficacy of dietary interventions intended to moderate energy intake generally is limited, it remains the mainstay of weight management. An increasingly popular dietary intervention entails the use of portion-controlled meal replacements. That is, substitution of, typically, a fixed portion of a single product that contributes less energy than the foods customarily consumed at a given meal. The energy differential between the

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Presented in part as a poster at American College of Nutrition Annual Meeting, Orlando, FL, October, 2001.

Journal of the American College of Nutrition, Vol. 21, No. 6, 570–577 (2002)
Published by the American College of Nutrition

replacement meal and the meal that would have been customarily consumed facilitates weight maintenance or loss. The appeal of meal replacements is that they are palatable, convenient and portions can be more easily controlled. Evidence of their efficacy at promoting and sustaining weight loss is accumulating [4–9]. One objection to their use is that they foster reliance on a specialty product. However, this need not be the case. The distinction between meal replacement products and conventional foods is arbitrary from a nutritional perspective. Thus, conventional foods may also be effective if used appropriately. One aim of the proposed work was to test the efficacy of a conventional food, ready-to-eat cereal, in the context of a meal replacement, energy-restricted diet plan.

Ready-to-eat cereal is a suitable food for evaluation for several reasons. First, a pilot study from the United Kingdom indicated cereal used in a meal replacement regimen was well tolerated and led to significant weight loss [10]. Second, the preponderance of studies exploring the efficacy of meal replacement products used liquids [4–9]. Solid foods and drinks with higher viscosity are more satiating [11–12] so should enhance compliance and weight loss. Third, ready-to-eat cereal was regarded by the researchers as a food that would be acceptable to consume at different times of the day by dieters, and the protocol called for its use at two meals each day. Fourth, ready-to-eat cereal is palatable, widely available and relatively inexpensive. Palatable foods are more resistant to monotony effects [13–14] that may compromise dietary compliance and weight loss. Still, dietary variability and nutritional balance was a concern, so the trial was limited to two weeks and dietary compliance, and weight loss outcomes were monitored in participants provided only a single brand of cereal daily or who were permitted to freely select cereals from an array of brands.

Finally, this study provided an opportunity to test the efficacy of a new high-fiber, high volume (Volumetric) diet regimen [15]. This diet was developed on the premise that individuals consume a fixed weight or volume of food so energy dense items will promote higher energy intake. Conversely, foods lower in energy density due to higher water and fiber content (e.g., fruits and vegetables), are believed to provide adequate satiety while contributing fewer calories. Whether this diet curbs hunger during energy restriction and leads to weight loss has not been tested in a chronic feeding trial. This was examined in individuals adopting the diet directly as well as in those who had followed the cereal intervention. It was hypothesized that the short-term, meal replacement phase would help to break customary eating habits and build motivation due to rapid weight loss, thereby promoting greater compliance and success with the Volumetric diet.

MATERIALS AND METHODS

General Protocol

Participants were recruited through public advertisements and, during week 1, were screened for eligibility based on health and demographic data as well as measurement of body weight and composition. All were required to keep diet records on three days (two random weekdays and one weekend day). Two-thirds completed a hunger (one-third) or activity (one-third) log concurrently. Training was provided on the method for recording portion sizes using food models. At the completion of this baseline period, participants were randomly assigned to one of four treatment groups (Fig. 1). Group 1 (single cereal group) was instructed to eat a serving of a single brand of ready-to-eat cereal (Special K, Kellogg Co., Battle Creek, MI) with 2/3 C skim milk and a 100 Kcal portion of fruit for breakfast and as a replacement for either lunch or dinner for 14 days. No restrictions were placed on the non-cereal meal. Participants were encouraged to use fruits and vegetables for snacks when desired. Group 2 (variety group) followed the same protocol, but was permitted to select from a variety of ready-to-eat cereals manufactured by the Kellogg Company (Battle Creek, MI). All ready-to-eat cereals were provided to participants in these two groups. Group 3 (non-diet control group) received no dietary instruction for these first two weeks of the treatment period. Three days of diet records were kept over the second week of this phase for Groups 1, 2 and 3. Body weight and composition measurements were repeated at the end of week 2. Group 4 (diet control group) had baseline measurements taken, but did not engage in any other activities (i.e., completion of diet records or appetite questionnaires) prior to initiating the Volumetric phase. This was based on concern that these activities could influence motivation prior to adoption of the diet and thereby confound interpretation of the role of the cereal phase in promoting better compliance and success with the Volumetric diet.

During weeks 3 and 7, participants in Groups 1, 2 and 4 were provided a complimentary copy of the book, "Volumetrics" (2000) and received personalized instruction on how to follow the diet. Basically, this is a nutritionally-balanced diet emphasizing the consumption of foods with low energy density. The aim is to curb hunger while restricting energy. The diet in this trial was designed to provided approximately 500 kcals less than each individual's estimated requirements (based on baseline diet records). Group 3, received no dietary instruction. Three diet records were kept during week seven and two-thirds of the participants kept concurrent hunger or activity logs. At the end of study week seven, a final measurement of body weight and composition was made. Upon completion of the study, Group 3 participants received the same dietary guidance provided to the other participants and were encouraged to

Baseline Week			Group Assignment	Weeks 1 & 2				Weeks 3 to 7			
DR	Log	BC		Diet	DR	Log	BC	Diet	DR	Log	BC
X	X	X	Single Cereal	C	X	X	X	V	X	X	X
X	X	X	Variety	C	X	X	X	V	X	X	X
X	X	X	Non-Diet Control		X	X	X		X	X	X
X	X	X	Diet Control					V	X	X	X

Fig. 1. Schematic of study activities. DR = 3d diet records, Log = 24 hour hunger or activity logs (kept by 1/3 of participants each), BC = body weight and composition, diet intervention (C = cereal, V = Volumetric diet).

adhere to the Volumetric diet plan and report back to the lab for a final assessment. This protocol was approved by the Human Research Subjects Committee at Purdue University.

Participants

Eligibility criteria included A) 20–60 years of age, B) body mass index between 25 and 35 kg/m^2, C) weight stable (no deviation greater than 3 kg over the prior 3 months), D) good health, E) not initiating or terminating the use of medications reported to influence appetite or body weight during the proposed study period, F) stable activity level (no deviation $> 1\times$/wk @ 30 min/session), G) low dietary disinhibition ($\leq$8 on the Three Factor Eating Questionnaire [16], H) regular eating habits (i.e., $\geq$3 meals per day, including breakfast) and I) lactose tolerance. Both genders and all ethnic groups were sought.

Body Weight/Composition

Body weight was determined on a clinical scale with subjects in a gown after voiding at a consistent time of day for the individual. Fat mass, lean body mass and total body water were determined by bioelectrical impedance analysis.

Dietary Analyses

Diet records were analyzed using Version 7.6 of the Food Processor nutrient database (ESHA Research, Salem, OR).

Hunger/Activity Assessment

One-third of the participants (determined by random number table) completed a short questionnaire eliciting information about hunger, desire to eat, prospective consumption and fullness at hourly intervals during waking hours while keeping their diet records. Responses were recorded on nine-point category scales. End anchors were Hunger—"Not at all hungry" and "As hungry as I have ever felt;" Desire to eat—"Very Weak" and "Very Strong;" Prospective consumption—"Nothing at all" and "A Large Amount;" Fullness—"Not at all full" and "Very Full." Participants were provided timers to remind them to make entries. Activity logs were completed at the same intervals by another third of participants and the remainder of participants did not keep a log. This division of recording was included to determine if tracking of hunger would alter food choice or recording accuracy. This was not the case.

Statistical Analysis

The primary hypotheses tested were

1. The ready-to-eat cereal-based meal replacement regimen (single cereal or variety) would lead to significant weight loss relative to baseline (within-subject analysis for Groups 1 and 2) and participants receiving no dietary intervention (Groups 1 and 2 *versus* Group 3).

2. The ready-to-eat cereal-based meal replacement regimen (single cereal or variety) would lead to a high level of compliance and success with the Volumetric diet regimen as determined by continued reduction of body weight over the four week intervention (within-subject analysis for Groups 1 and 2). Further, retention and weight loss would be greater among those initially following the cereal-based meal replacement regimen than those following the Volumetric diet without prior intervention (Groups 1 and 2 *versus* Group 4).

The secondary hypotheses tested were

1. The ready-to-eat cereal-based meal replacement regimen involving a variety of cereals would lead to greater retention and weight loss at the end of week two relative to the regimen involving a single cereal (Group 1 *versus* Group 2).

2. Hunger ratings during the Volumetric diet period would be similar to ratings provided during baseline for individuals participating in this dietary intervention (within-subject analysis for Groups 1, 2 and 4).

Within-subjects analyses (repeated measures analysis of variance) were conducted with time as the within subject factor and treatment as a between-subject factor. Paired *t* tests were used for *post-hoc* analysis following significant F-tests. Data were analyzed by the Statistical Package for the Social Sciences, Version 10.0 (SPSS, Inc., Chicago, IL). The criterion for statistical significance was $p < 0.05$, two-tailed.

RESULTS

A total of 133 individuals were recruited. Thirty-three were assigned to the single cereal group, two withdrew prior to initiating the ready-to-eat cereal phase, and three withdrew during the Volumetric phase resulting in a sample of 28. Thirty-seven were assigned to the variety group, but three failed to report for the first testing session, three withdrew during the ready-to-eat cereal phase, two withdrew during the Volumetric phase, and one failed to return the final questionnaires resulting in a sample of 28. Thirty-six were assigned to the non-diet control group, but two dropped during the first week, two dropped during the next two weeks, four failed to complete the next four weeks, and two did not return their final questionnaires resulting in a sample of 26. Thirty individuals were assigned to the diet control group. All completed the study assessments, but three indicated they did not follow the Volumetric diet. Thus, they were not included in analyses leaving a sample size of 27. The groups did not differ on any of the baseline characteristics listed in Table 1.

Weight Change

Mean group changes of body weight during the two-week ready-to-eat cereal diet intervention are shown in Fig. 2-A. Relative to baseline, significant weight loss was achieved by the single cereal and variety groups (95% confidence interval

Table 1. Participant Baseline Characteristics (Mean ± SE)

	Single Cereal	Variety	Non-Diet Control	Diet Control
Age (years)	43.0 ± 1.9	40.9 ± 2.3	41.6 ± 2.4	38.2 ± 2.8
Gender (M/F)	6/22	3/25	7/19	9/18
Race (Caucasian/African American/Asian/Other)	26/0/1/1	25/0/1/2	24/1/0/1	23/2/1/1
Body Mass Index (Kg/m^2)	28.9 ± 0.4	29.3 ± 0.6	29.3 ± 0.6	29.3 ± 0.6

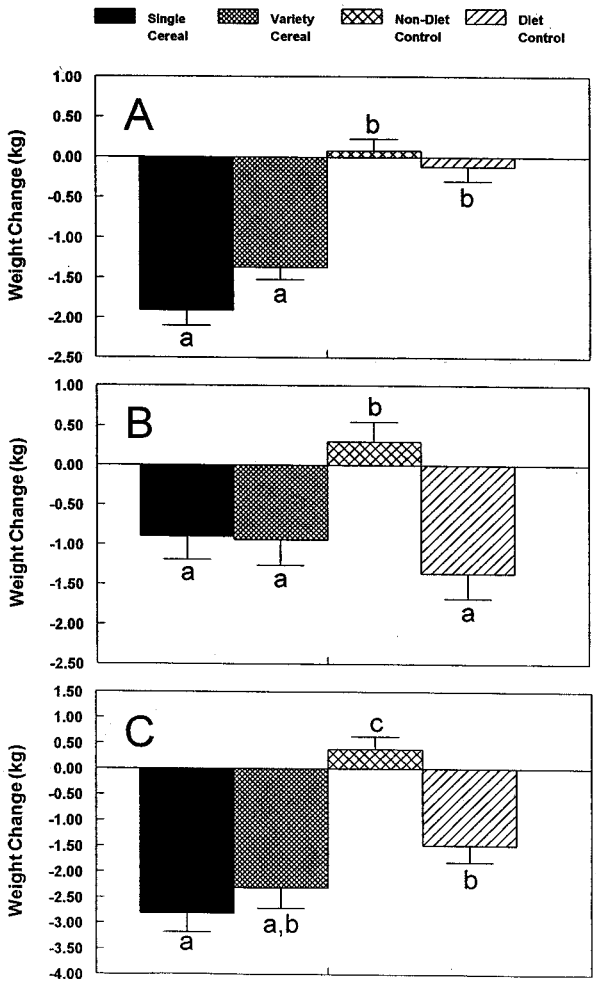

Fig. 2. Mean (SE) weight loss (kg) during the two week cereal intervention phase (A), Volumetric diet phase (B) and total intervention (C) for participants consuming a single cereal or variety of cereals for breakfast and a second meal daily or receiving no dietary intervention (both control groups) prior to implementation of the four week Volumetric diet phase. The Diet control group adhered to the Volumetric diet for the final four study weeks whereas the non-diet control group received no dietary intervention. Bars with different letters are significantly different.

(CI) = −2.29 to −1.52 and −1.69 to −1.06, respectively). No significant changes were observed for the non-diet or diet controls (95% CI = −0.23 to 0.38 and −0.49 to 0.26, respectively). The change of weight was significantly greater for the single cereal group and variety group compared to either control group. Every participant in the single cereal group and all but one participant in the variety group lost weight (ranges −4.2 to −0.1 kg and −2.9 to 0.4 kg, respectively). The weight change for the single cereal group was greater than that of the variety group ($p = 0.025$).

Mean group changes of body weight during the four week Volumetric diet phase are shown in Fig. 2-B. Significant weight loss was observed in the single cereal, variety and diet-control groups (all $p \leq 0.005$) (95% CI = −1.50 to −0.30, −1.58 to −0.29, −2.02 to −0.71, respectively). The non-diet control group did not experience a significant change of body weight relative to baseline (95% CI = −0.22 to 0.82). The weight change was significantly greater for the three groups adhering to the diet compared to the non-diet control. The changes for the diet intervention groups were comparable. The ranges of weight change for the single cereal, variety and diet-control groups were −5.1 to 2.5 kg (82.1% lost), −4.8 to 2.5 kg (78.6% lost) and −6.2 to 1.4 kg (77.8% lost), respectively.

Mean group changes of body weight during the entire six week study (two-week cereal phase plus four-week Volumetric diet phase) are shown in Fig. 2-C. The single cereal, variety and diet-control groups experienced significant weight loss (all $p \leq 0.001$) (95% CI = −3.57 to −2.05, −3.13 to −1.49, −2.16 to −0.79, respectively). The single cereal and variety groups lost similar amounts of weight. The single cereal group lost significantly more weight than the non-diet control group ($p < 0.001$) and diet control group ($p = 0.007$). The variety group lost significantly more weight compared to the non-diet control group ($p < 0.001$) but not more than the diet-control group ($p = 0.09$). The ranges of weight change for the single cereal, variety and diet-control groups were −7.7 to 1.3 kg (96.4% lost), −7.2 to 2.3 kg (85.7% lost) and −5.2 to 1.2 kg (74.1% lost), respectively.

Fat Mass Change

Mean group changes of fat mass during the two-week ready-to-eat cereal intervention are shown in Fig. 3-A. Relative to baseline, significant reductions of fat mass were observed in the single cereal group (95% Confidence Interval (CI) = −1.91 to −0.68) and variety group (95% CI = −1.36 to −0.19). No significant changes were observed for the non-diet (95% CI = −0.76 to 0.55) or diet controls (95% CI = −0.13 to 0.83). The change of fat mass was significantly greater for the single cereal group and variety group compared to the diet control group. The single cereal group lost significantly more fat mass than the non-diet control group, but there was only a trend for the variety group to have lost more than the non-diet controls

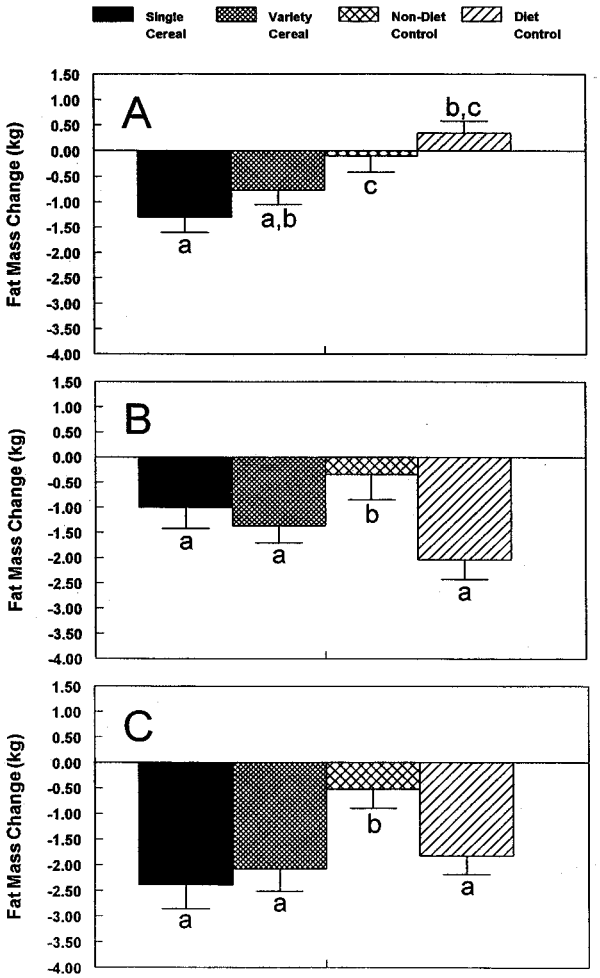

Fig. 3. Mean (SE) loss of fat mass (kg) during the two week cereal intervention phase (A), Volumetric diet phase (B) and total intervention (C) for participants consuming a single cereal or variety of cereals for breakfast and a second meal daily or receiving no dietary intervention (both control groups) prior to implementation of the four week Volumetric diet phase. The Diet control group adhered to the Volumetric diet for the final four study weeks whereas the non-diet control group received no dietary intervention. Bars with different letters are significantly different.

($p = 0.094$). The fat mass change for the single cereal and variety groups were comparable. Eighty-eight percent of the single cereal and 81.5% of the variety participants lost fat mass whereas only 48% of the non-diet group and 44% of the diet control group participants lost fat mass.

Mean group changes of fat mass during the four week Volumetric diet phase are shown in Fig. 3-B. Significant losses of fat mass were observed in the single cereal, variety and diet-control groups (all $p \leq 0.005$) (95% CI = −1.88 to −0.13, −2.07 to −0.65, −2.83 to −1.24, respectively). The non-diet control group did not experience a significant change of body weight relative to baseline. The change of weight during the Volumetric diet phase was significantly greater for the three groups adhering to the diet compared to the non-diet control. The changes for the diet intervention groups were comparable.

Mean group changes of fat mass during the entire six week study are shown in Fig. 3-C. The single cereal, variety and diet-control groups lost significant amounts of body fat (all $p \leq 0.001$) (95% CI = −3.34 to −1.44, −2.96 to −1.20, −2.55 to −1.08, respectively). The single cereal, variety and diet control groups lost significantly more body fat overall than the non-diet control group. The single cereal, variety and diet control groups lost similar amounts of body fat. The ranges of fat mass loss for the single cereal, variety and diet-control groups were −7.2 to 1.9 kg (87.5% lost), −5.0 to 4.0 kg (84.6% lost) and −4.4 to 0.9 kg (76.0% lost), respectively. The range of fat mass change in the non-diet control group was −6.4 to 1.4 kg (41.7% lost).

Total Body Water

Mean group changes of total body water during the cereal intervention are shown in Fig. 4-A. Relative to baseline, only the participants in the variety group lost a significant amount of body water (95% CI = −0.94 to −0.094). The changes of total body water did not differ between groups. The proportions of participants in the single cereal, variety, non-diet and diet groups that lost body water were 51.9%, 72.0%, 48.0% and 50.0%, respectively. Mean changes of total body water during the Volumetric diet phase are shown in Fig. 4-B. No significant loss was observed in any group and the changes between groups were comparable. Mean group changes of total body water during the six week study are shown in Fig. 4-C. The non-diet control group experienced a significant increase (95% CI = 0.06 to 1.23), but no changes were noted in the other groups. Changes between groups were not significant.

Energy/Macronutrient Intake

There was no significant difference in energy intake across groups during baseline. Values for the single cereal, variety, non-diet control and diet control groups were: 2213 ± 120, 2066 ± 133, 1975 ± 106 and 2437 ± 162 kcal/day, respectively. Mean group changes of energy intake during the ready-to-eat cereal and Volumetric diet phases are shown in Table 2. Dietary data were not collected at the end of the cereal intervention phase for the diet control group. Participants in the single cereal and variety groups achieved similar reductions of energy intake, both of which were greater than the non-diet control group during the cereal intervention. The single cereal, variety and diet-control groups had comparable reductions of energy intake all of which were significantly greater than that noted in the non-diet control group during the volumetric phase.

During the ready-to-eat cereal phase, daily carbohydrate, protein and fat intake were reduced significantly less in the non-diet control group compared to the single cereal and variety groups (Table 2). The non-diet control group also reduced their carbohydrate, protein and fat intakes less than the other

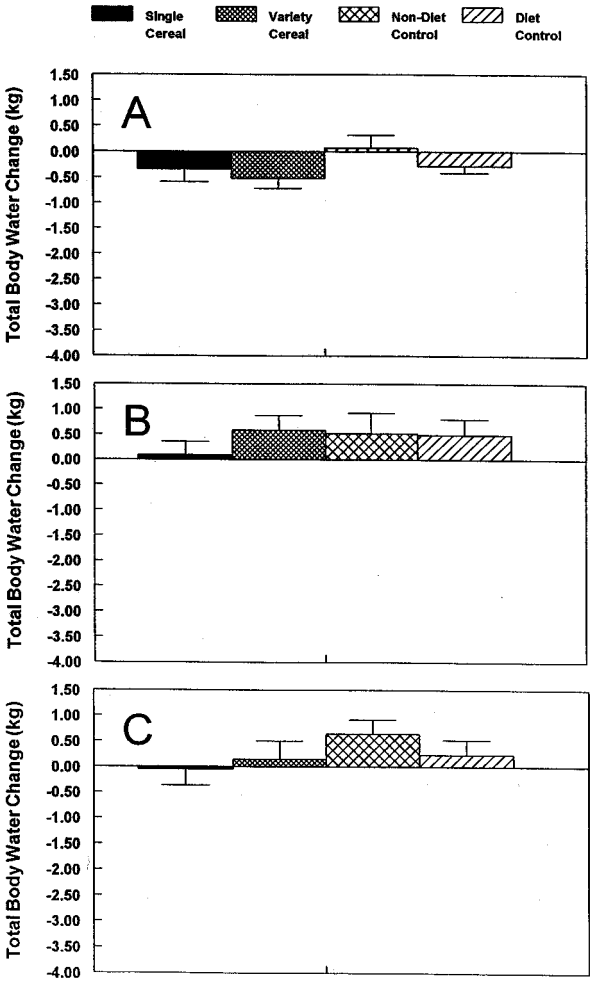

Fig. 4. Mean (SE) loss of total body water (kg) during the two week cereal intervention phase (A), Volumetric diet phase (B) and total intervention (C) for participants consuming a single cereal or variety of cereals for breakfast and a second meal daily or receiving no dietary intervention (both control groups) prior to implementation of the four week Volumetric diet phase. The Diet control group adhered to the Volumetric diet for the final four study weeks whereas the non-diet control group received no dietary intervention.

groups during the volumetric phase. No significant differences were noted among the other groups for any macronutrient.

Appetite/Thirst

Mean (SE) daily group hunger ratings were similar during baseline in the four groups. Values on a nine-point category scale (1 = not at all, 9 = extremely) were 3.25 ± 0.23 single cereal, 3.34 ± 0.23 variety, 3.07 ± 0.32 non-diet control and 3.29 ± 0.14 diet control, respectively. There was a significant change across the phase of the study with higher ratings reported during the cereal phase (3.63 ± 0.22) compared to baseline (3.25 ± 0.10) and the Volumetric diet phase (3.30 ± 0.14). Reports during the baseline and Volumetric phases were comparable. There was no significant group difference (single cereal, variety and non-diet control) and no significant group by phase interaction. Participants in the four groups also reported comparable ratings during the Volumetric phase 3.48 ± 0.66 single cereal, 3.31 ± 0.24 variety, 3.10 ± 0.43 non-diet control and 3.33 ± 0.14 diet control. The pattern of "desire to eat" reports was similar to those of hunger. Reported fullness, prospective consumption and thirst did not differ between groups at any time point nor did they change over the phases of the study.

Compliance

Only three of 65 (4.6%) participants assigned to a cereal intervention withdrew from study during that phase. An additional five of the remaining 62 (8.1%) of these participants withdrew during the Volumetric diet phase. This was similar to the attrition rate in the non-diet controls, 2/34 (5.9%) and 4/32 (12.5%) withdrew at the same times. There were no withdrawals in the diet control group, but three participants reported they did not follow the diet. Participants in the single cereal, variety and diet-control groups were prescribed diets supplying roughly 500 kcals less than their estimated need. Predicted weight loss was 1.82 kg over the four-week intervention. Losses of at least 0.91 kg (50% of predicted) were observed in only 10 (39.3%), 10 (50.0%) and 15 (59.3%) participants of the single cereal, variety and diet control groups, respectively. The most common informal comment was that the diet was highly acceptable, but too expensive and time demanding.

DISCUSSION

A wide array of weight loss approaches may serve as a prelude to long-term maintenance of reduced body weight [17]. One popular approach with documented efficacy entails the use of meal replacement products, most commonly beverages [4–9]. They provide a conceptually simple regimen, high palatability, relatively low cost and wide availability. Further, they interrupt the individual's customary dietary pattern enabling adherents to break less desirable eating habits. However, there is a lack of consensus regarding the suitability of meal replacements as a long-term weight management approach. The principal concerns are that they do not promote the adoption of dietary practices to better meet energy needs using conventional foods and chronic use may be accompanied by monotony leading to decreased compliance. The concept tested here was whether short-term use can capitalize on the strengths while avoiding the drawbacks. To maximize the attributes of simplicity, palatability, low cost and availability, the regimen involved the use of commercially available ready-to-eat cereals. A recent pilot study reported a 2 kg weight loss among twenty-two individuals consuming a serving of ready-to-eat cereal as

Table 2. Mean ± SE Group Changes of Daily Energy and Macronutrient Intake during the Two-Week Ready-to-Eat Cereal and Volumetric Diet Phases (Data Not Available for the Non-Diet Control Group during the Ready-to-Eat Cereal Intervention Phase)

	Single Cereal	Variety	Non-Diet Control	Diet Control
Cereal Phase				
Energy (Kcal)	−640 ± 109	−617 ± 105	215 ± 122	NA
Carbohydrate (g)	−51.8 ± 21.2	−41.9 ± 17.0	16.8 ± 17.0	NA
Protein (g)	−16.4 ± 7.2	−29.0 ± 9.4	7.7 ± 4.6	NA
Fat (g)	−39.3 ± 5.1	−35.7 ± 4.3	3.8 ± 9.6	NA
Volumetric Phase				
Energy (kcal)	−691 ± 96	−695 ± 132	6 ± 106	−936 ± 160
Carbohydrate (g)	−82.1 ± 15.7	−61.7 ± 18.7	−5.9 ± 14.0	−106.4 ± 21.0
Protein (g)	−18.6 ± 8.2	−31.3 ± 9.5	5.8 ± 5.7	−22.8 ± 6.5
Fat (g)	−32.6 ± 6.6	−36.5 ± 6.2	−6.08 ± 10.3	−42.4 ± 7.8

breakfast and one other major meal of the day for two weeks [10]. The present findings confirm and extend these observations. Similar results were obtained for mean weight losses in this study. Our data indicate the magnitude of weight loss during the ready-to-eat cereal phase agreed reasonably well with the reported reduction of energy consumption, was treatment-related (no shifts were observed in the non-diet control group) and was primarily attributable to reduced fat mass. The proportions of participants losing weight and adhering to the diet intervention were also comparable between studies. In longer-term trials of meal-replacement regimens, attrition rates of 40% have been reported [5,19]. Whether the low attrition observed here reflects an advantage of the use of ready-to-eat cereal over formulas or is simply due to the short duration of use warrants further evaluation.

Ready-to-eat cereal may be an especially effective meal replacement because it possesses attributes that reportedly mitigate monotony effects. First, it is highly palatable, and such foods are more resistant to hedonic shifts with repetitive presentations [13]. Second, ready-to-eat cereal is a dietary staple, and acceptance ratings for staple foods are well maintained with repeated use [14]. Indeed, earlier work revealed acceptance ratings of ready-to-eat cereals increased with repeated servings [13]. Third, a wide array of ready-to-eat cereals are available, and recent studies with military personal document that, given a choice, repetitively eaten foods may not decrease in acceptability [20]. This has been observed through in-home product tests with civilians as well [21]. However, with respect to the latter point, increased variety has also been associated with increased energy intake [22–23]. This could undermine adherence to the portion-controlled meal replacement regimen. We observed no significant difference in compliance between the single cereal and variety groups. Some individuals choose to eat foods repetitively, and others seek more variety [20]. Our findings suggest that use of ready-to-eat cereal as a meal replacement can be customized to individuals to address these different preferences without compromising weight loss success.

Strong hunger sensations may compromise adherence to an energy restricted diet. The use of ready-to-eat cereal as a meal replacement may also help to minimize this problem relative to beverages since semi-solid and solid foods hold higher satiety value than less viscus drinks [11–12]. A direct comparison between products varying in rheological properties would be valuable. This trial revealed hunger was significantly, but only slightly higher during the ready-to-eat cereal phase compared to baseline in the single cereal and variety groups. The change of hunger did not differ significantly between the single cereal, variety and non-diet control groups. Further, changes of fullness, desire to eat and prospective consumption were similar across groups. This effective control on appetitive sensations may aid in dietary compliance.

In the prior study testing ready-to-eat cereal as a meal replacement, participants transitioned to a high carbohydrate diet and were allowed to eat *ad libitum* for four weeks [10]. Some level of weight loss was maintained in 18 of 22 (81.8%) individuals at the end of this time. In this study, participants switched to the Volumetric diet, but were counseled to ingest about 500 kcal less than estimated energy requirements. During this phase, 25 of 28 (89.3%) participants lost weight from the single cereal group and 22 of 28 (78.6%) lost in the variety group. Mean reductions in both groups were comparable to those achieved by the diet controls and minimal changes were observed in the non-diet control group. Thus, the meal replacement protocol did not reduce the efficacy of adoption of the Volumetric diet.

It was hypothesized that the ready-to-eat cereal intervention would augment compliance and weight loss with a subsequent energy restricted diet regimen by building motivation through early weight loss success. This was not observed. Compliance, as measured by retention, was very high in all groups, 89% to 92%. However, evaluation based on weight loss was less positive. Assuming participants reduced their energy intake by the targeted 500 kcal/day, the predicted weight loss would have been 1.82 kg. The two ready-to-eat cereal intervention groups achieved only about 50% of this goal. The diet-control group lost only 25% of the predicted amount. Only 39.3%, 50.0% and 59.3% of participants in the single cereal, variety and diet control groups, respectively, lost even 50% of this amount. This may reflect the nature of the diet selected. While the Volumetric diet did effectively curb appetitive sensations, its emphasis

on consumption of fresh fruits and vegetables entails a greater time commitment, as such items must be purchased more frequently and require more preparation (e.g., washing, cooking, clean-up) than many convenience foods, and they can be more expensive. Indeed, the most frequent comment from participants was that the diet was useful for teaching improved dietary habits and was palatable, but was simply too time-demanding. It may have been especially problematic following the ready-to-eat cereal intervention because it could have provided a strong contrast in time demands. It is possible another diet plan would facilitate a more successful transition. The reported reductions of energy intake would have been expected to yield greater weight loss during this phase. However, the diet was associated with a small increase in body water that partially offset the reductions of fat mass.

CONCLUSION

This trial demonstrated that ready-to-eat cereal may be used to promote weight loss when consumed as a portion-controlled meal replacement. Further, it extends knowledge generally on the meal replacement approach to weight management. It suggests a broad array of foods may be used in this manner, thereby facilitating individualized dietary prescriptions that will best meet personal preferences. Second, it indicates meal replacements can vary in sensory properties without compromising compliance and weight loss. Third, this work confirms earlier findings [10] on the efficacy of a novel use of meal replacements as a means to transition individuals to diets that promote adoption of improved life-long dietary habits. Thus, it is an additional weight management option that may be especially suitable for individuals where portion control is problematic.

ACKNOWLEDGMENTS

The author would like to acknowledge the technical assistance of Mark Hagquist and Dana Wislocki in all aspects of this project. This work was supported by the Kellogg Company.

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Received April 22, 2002; revision accepted September 9, 2002.