

## Meal Replacements Are as Effective as Structured Weight-Loss Diets for Treating Obesity in Adults with Features of Metabolic Syndrome<sup>1,2</sup>

Manny Noakes,<sup>3</sup> Paul R. Foster, Jennifer B. Keogh, and Peter M. Clifton

Commonwealth Scientific Industrial Organization, Health Sciences and Nutrition,  
Adelaide, South Australia, 5000

**ABSTRACT** Meal replacements are widely used as a weight-loss strategy; however, their effectiveness outside controlled clinical trial environments is unknown. We compared meal replacements with a structured weight-reduction diet in overweight/obese Australians with raised triglycerides. In a randomized parallel design, 2 groups [meal replacement (MR) and control (C)] of 66 matched subjects underwent a 6000 kJ intervention for 3 mo (stage 1) and a further 3 mo (stage 2). The groups were provided oral and written information. The C group was supplied with shopping vouchers and followed a low fat/energy diet. The MR group was supplied with Slim-Fast™ products for 2 meals (1800 kJ) and consumed a low-fat evening meal. Clients were weighed every 2 wk and received structured supervision without professional dietary input, with compliance assessed by 3-d weighed food records. Blood biomarkers were used to assess fruit/vegetable intake and a questionnaire was used to assess attitudes to treatment. Fifty-five subjects completed stage 1 (withdrawals: 7 in the MR group, 4 in the C group) and 42 subjects completed stage 2. Weight loss was  $6.0 \pm 4.2$  kg (6.3%) for the MR group and  $6.6 \pm 3.4$  kg (6.9%) for the C group at 3 mo, and  $9.0 \pm 6.9$  kg (9.4%) for the MR group and  $9.2 \pm 5.1$  kg (9.3%) for the C group at 6 mo (different over time within but not between treatments). Serum folate and plasma  $\beta$ -carotene were higher in the MR group. Plasma homocysteine fell in both groups ( $P < 0.005$ ). Dietary fiber intake was higher in the C group ( $P < 0.02$ ) and calcium was higher in the MR group ( $P < 0.001$ ). We concluded meal replacement is equally effective for losing weight compared with conventional but structured weight-loss diets. Dietary compliance and convenience were viewed more favorably by participants who consumed meal replacements than by those in a conventional weight-loss program. *J. Nutr.* 134: 1894–1899, 2004.

**KEY WORDS:** • obesity • meal replacement • low-energy diet

The incidence of obesity in Australia and other developed countries is increasing at an alarming rate (1), with subsequent public interest in dietary strategies to reduce body weight and thereby reduce cardiovascular disease risk. Development of effective, minimal intervention, sustainable dietary strategies to achieve weight loss is important in providing public health benefits, addressing social needs, and minimizing the risk of quack, dangerous, and misleading dietary weight-loss practices (2–4). Formula meal replacements designed for weight loss represent a possible strategy for some individuals.

Meal replacements, in the form of a powder shake and a snack bar, each providing 900 kJ, have been used successfully in several weight-loss trials (5–8). Previous trials with these kinds of meal replacements have nearly always incorporated professional dietary input from either a dietitian, a physician, or a nurse, in addition to written information supplied with the meal replacements. However, daily intake of meal replace-

ment products by a consumer would mostly occur without professional input and feedback. One uncontrolled 12-wk study (9) evaluated meal replacements in a nonclinical work-site weight-reduction program and showed them to be effective in achieving weight loss in this environment.

Efficacy of weight loss programs has frequently referred to nutritional adequacy of diets in relation to general composition (10) or recommended daily intakes (RDI)<sup>4</sup> (11,12), or specific health measures [e.g., bone resorption (13)]. Weight-loss programs that use meal replacements have been anecdotally criticized for increasing the risk of inadequate macro- or micronutrient intake or for skewing energy distribution of the diet. The degree of inadequacy in weight-loss diets becomes more critical depending upon the length of time and the discipline with which the weight-loss program is applied. The efficacy of meal replacements, therefore, should consider, in addition to weight loss and nutrient quality and quantity, the structure of dietary information provided. Structure might include the presence or the absence of components such as professional nutrition advice, practical meal plans and recipes,

<sup>1</sup> Sponsorship: Unilever Australasia (a division of Unilever Australia Limited); Slim-Fast Nutrition Institute, U.S.

<sup>2</sup> Previously partially presented in Clifton, P. M., Noakes, M., Keogh, J. & Foster, P. (2003) How effective are meal replacements for treating obesity? *Asia Pac. J. Clin. Nutr.* 12 (Suppl.): S51.

<sup>3</sup> To whom correspondence should be addressed.  
E-mail: manny.noakes@csiro.au.

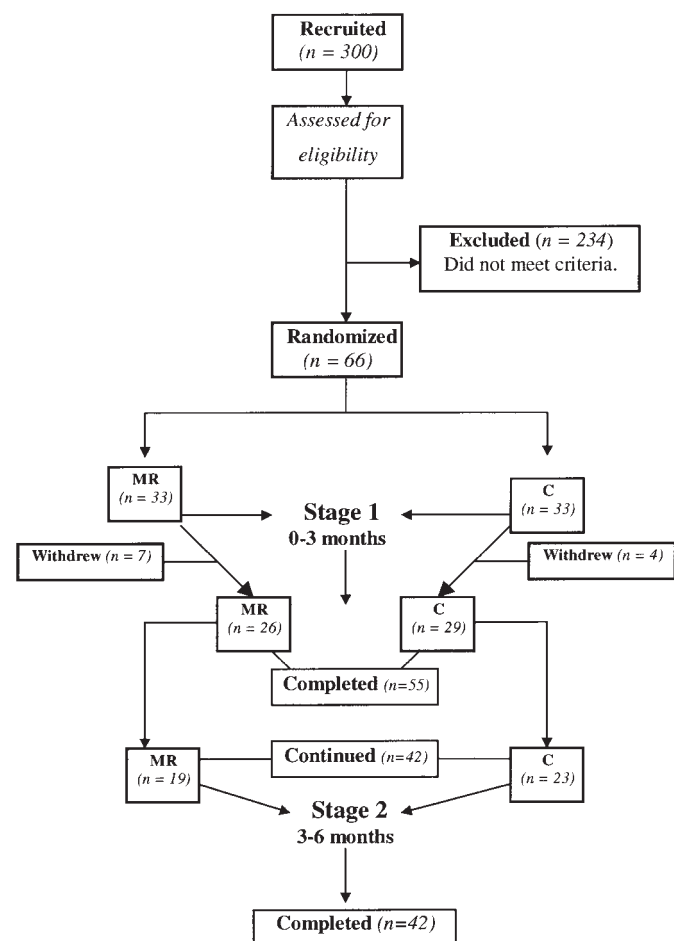
<sup>4</sup> Abbreviations used: C group, control group; MR, meal replacement; NQOL, nutrition quality of life; RDI, recommended daily intake; TG, triglyceride.

food-cost support (free product or food vouchers), as well as simplicity of instructional messages, frequency and intensity of visits or weight checks, and the duration of the program.

Nevertheless, even accounting for variations in structure of dietary interventions, there is little evidence that the meal replacement approach is effective if applied outside of the clinical environment, i.e., with no professional support, or, more importantly, how it compares with conventional dietary approaches applied in the same context. The efficacy of meal replacements as a nutritionally sound weight-loss strategy compared with a structured low-fat weight-loss plan under unsupervised conditions is unknown. The aim of this study was to compare, under field conditions, 2 weight-loss strategies—a meal replacement product and conventional dietary advice in written form. We hypothesized that meal replacements are more effective than the provision of standard written dietary advice in the absence of personal professional support.

## METHODS

**Design, subjects, and screening.** The study was a minimum intervention controlled design that mimicked consumers buying meal replacement products and accessing publicly available information in the marketplace, initially for 3 mo (stage 1), followed by an extension for a further 3 mo (stage 2). After screening and selection, subjects were randomized into 2 groups, the meal replacement group (MR group) and the conventional diet group (C group), and matched for age, gender, triglyceride (TG), and BMI (Fig. 1). The study was



**FIGURE 1** Study parallel design flow chart. MR, meal replacement, C, conventional low energy/fat.

approved by the Ethics Committee of the Commonwealth Scientific Industrial Research Organization, Division of Health Sciences and Nutrition, and subjects were informed of procedures and signed a consent form prior to commencement.

Subjects were included in the study if aged between 20 and 65 y, had BMI not >40 or <27, displayed a fasting TG >2.0 mmol/L (Cholestech LDX, Cholestech), had no abnormality of clinical significance on medical history, had no history of metabolic disease, and, if female, were not pregnant or breast feeding.

Subjects were excluded from the study if they suffered from type 1 or 2 diabetes, reported a history of heavy alcohol consumption (>5 standard drinks/d) and were unable to cease alcohol consumption for the duration of the study, had widely fluctuating exercise patterns, reported frequent dining out (>2 times/wk and were unable to cease), reported an inability to prepare meals or meet diet requirements, had a history of extended absences due to travel or other commitments, or were unable to comprehend or cope with study requirements.

Of the 300 screened overweight and obese subjects (BMI 27–40), 66 were selected and blocked into 2 groups of 33 each according to the above criteria. There were no significant differences between the MR group and the C group for age, TG, and BMI at baseline.

**Dietary treatment.** Both dietary treatment groups were restricted to  $6000 \pm 50$  kJ/d (about two-thirds of normal intake) for a planned weight loss of 6–12 kg.

The MR group was advised to consume 2 meal replacements with Slim-Fast™ products (1800 kJ total), in addition to a low-fat evening meal per day and at least 5 servings of fruit and vegetables per day (3500 kJ), as outlined in the Slim-Fast™ literature, with a sample meal plan and recipes (Table 1). Slim-Fast™ products were provided at 2-wk intervals. The C group was advised to follow a low-kJ/low-fat diet, and they were provided with an equivalent amount of written information (sample meal plan and recipes; Table 1). Minimal and equivalent oral advice was provided to each group.

Financial compensation equivalent to the cost of the Slim-Fast™ meals was provided every 2 wk to the C group only, as a shopping voucher to the value of \$A50. Both the MR group and the C group received structured supervision via 2-wk visits from administrative staff, but they did not receive professional nutrition support or advice at any stage.

Dietary macronutrient composition (3 d mean) (calculated by using Foodworks V3.1, Xyris Software dietary analysis program, Xyris Software Australia) for the MR group was as follows: 6026 kJ, 20.1 protein energy (%), 22.7 fat energy (%), 57.2 carbohydrate energy (%), and 24.4 g fiber. Dietary macronutrient composition (3 d mean) for the C group was as follows: 6047 kJ, 21.5 protein energy (%), 16.8 fat energy (%), 61.7 carbohydrate energy (%), and 27.8 g fiber.

**Weight and blood parameters.** Subjects were weighed every 2 wk. Venous blood samples were taken at wk 0, 4, 8, and 12 (stage 1) for serum folate and plasma carotenoids, as an index of fruit and vegetable intake. Plasma homocysteine levels were measured as a marker associated with changes in folate intake and weight loss. Blood samples were taken again at wk 24 from those subjects who continued for 6 mo (stage 2).

**Laboratory analysis.** Fasting blood samples were collected into 8-mL plain tubes for serum and 4-mL tubes containing  $\text{Na}_2\text{EDTA}$  (final concentration 1 g EDTA/L) for plasma. Plasma was isolated by centrifugation (Beckman GS-6 Series) at  $1500 \times g$  for 10 min. Serum samples were isolated by centrifugation at  $2000 \times g$  for 10 min. Plasma and serum aliquots were frozen at  $-80^\circ\text{C}$  until study completion. Serum TG concentrations were measured by using a Cobas-Bio clinical analyzer (Roche Diagnostics) and enzymatic in vitro test kits 2016648 (Roche Diagnostics Australia Pty). Plasma folate and homocysteine were measured by Institute Medical Veterinary Sciences, Adelaide. Carotenoids were measured as described by Khachik et al. (14) or Noakes et al. (15).

**Dietary intake and attitudes toward the treatment program.** Both groups reported to the clinical research unit every 2 wk over a 6-mo period for a supply of product or vouchers. Subjects returned 3-d weighed food records at 4-wk intervals, i.e., 9-d recording per 3-mo stage, to determine a mean nutrient intake per day per stage of study. Food records were not checked by a dietitian, nor were clients given

TABLE 1

Sample meal plan for dietary treatments of MR group and C group

Meal plan	MR group	C group
Breakfast	Meal replacement (shake) Fresh fruit	High-fiber cereal Sultanas Skim milk
Snack	Fresh salad/dip	Fresh fruit
Lunch	Meal replacement (bar)	Bread Cheese Salad
Snack	Fresh fruit	Fresh fruit
Dinner	Low-fat meal Vegetables—salad/cooked	Low-fat meal Vegetables—salad/cooked
Snack	Biscuits	Biscuits

feedback about their diet. This ensured that minimal and consistent dietary information was delivered to both groups.

Subjects completed a nutrition quality of life (NQOL) survey (devised by La Trobe University, Victoria) at the completion of stages 1 and 2, to determine their attitude toward the dietary program and the impact the treatment might have on aspects of their lifestyle.

**Dietary analysis.** Dietary analysis of food records was completed by using Foodworks V3.1.

**Statistical analysis.** Statistical analysis was completed by using SPSS V11.5 for Windows. Repeated measures ANOVA was calculated with the treatment period as the within-subject factor and with the diet as the between-subject factor. Age, baseline TG, BMI, and change in weight between periods were inserted into the model as covariates where appropriate. Student's *t* test was used to compare means for within-group paired samples and between-group independent samples. Data are presented as means  $\pm$  SEM unless stated otherwise.

## RESULTS

Of the 66 subjects that commenced the study, 55 completed and 11 withdrew (7 in the MR group and 4 in the C group) from stage 1 (Fig. 1). Most withdrawals occurred because of changes to personal circumstance rather than dislike of either diet. Forty-two subjects, 19 in the MR group and 23 in the C group, continued into stage 2 of the study. The MR group comprised 17 men and 9 women, with a mean ( $\pm$ SD) age  $49.3 \pm 8.8$  y, BMI  $31.8 \pm 2.8$  kg/m<sup>2</sup>, and serum TG of  $3.0 \pm 1.0$  mmol/L. The C group comprised 15 men and 14 women, age

$47.1 \pm 10.3$  y, BMI  $33.2 \pm 3.1$  kg/m<sup>2</sup>, and TG of  $3.2 \pm 1.1$  mmol/L.

**Weight changes.** Weight change for the MR and the C groups was similar throughout the duration of the study, although most weight loss occurred during the first 5 mo. There was a significant weight loss after 3 mo from baseline in the MR group of  $6.0 \pm 4.2$  kg ( $P < 0.001$ , range 1.5–16.3 kg,  $n = 26$ ) and in the C group of  $6.6 \pm 3.4$  kg ( $P < 0.001$ , range 0.3–11.1 kg,  $n = 29$ ). These represent a  $6.3\% \pm 0.8$  and  $6.9\% \pm 0.6$  loss in body weight for the MR group and the C group, respectively. At 6-mo postbaseline, there was a significant weight loss in the MR group of  $9.0 \pm 6.9$  kg ( $P < 0.001$ , range 0.5–28.2 kg,  $n = 19$ ) and in the C group of  $9.2 \pm 5.1$  kg ( $P < 0.001$ , range 0.6–17.5 kg,  $n = 23$ ). These represent a  $9.4\% \pm 1.5$  and  $9.3\% \pm 1.0$  loss in body weight for the MR group and the C group, respectively. No significant difference in weight change between the MR group and the C group was observed at baseline, 3 mo, or 6 mo. There was no interaction between gender, BMI, age, and treatment with the amount of weight lost.

## Blood biomarkers

**Folate.** Serum folate levels were maintained or were increased throughout the study in both treatment groups. Folate levels did not change significantly over time for the C group. However, the MR group folate levels increased significantly ( $P = 0.007$ ) from baseline ( $27.1 \pm 1.4$  nmol/L,  $n = 19$ ) to 6 mo ( $31.3 \pm 0.8$  nmol/L,  $n = 19$ ). No difference was found in folate levels between the C group and the MR group at baseline, 3-mo, or 6-mo time points. No significant difference in folate change occurred between the MR group and the C group at 3 mo, but a difference was evident at 6 mo ( $P < 0.05$ ).

**Homocysteine.** Homocysteine was reduced by 4% (C group) and 8% (MR group) ( $P < 0.005$  by repeated measures ANOVA), with no significant differences between groups in absolute level or in change with time. Most of the change within groups occurred between 3 and 6 mo.

**Carotenoids.** No change in lutein, lycopene, or  $\alpha$ -tocopherol plasma levels was observed over time within either the MR group or the C group, i.e., at stage 1 or stage 2. Plasma  $\alpha$ -carotene increased at 3 mo, then returned to baseline by 6 mo ( $P = 0.02$  for time effect), with no significant differences between groups.  $\beta$ -carotene levels increased significantly at both 3 and 6 mo (by 32–41%,  $P < 0.001$ ), with no differences between the groups. No significant differences in plasma ca-

TABLE 2

Plasma carotenoid levels for dietary treatments of MR group and C group at baseline, 3-mo, and 6-mo time points<sup>1,2</sup>

Plasma carotenoid $\mu\text{mol/L}$	MR group, $n = 18$			C group, $n = 22$		
	Baseline	3 mo	6 mo	Baseline	3 mo	6 mo
Lutein	$0.3 \pm 0.03$	$0.3 \pm 0.03$	$0.3 \pm 0.03$	$0.3 \pm 0.03$	$0.3 \pm 0.03$	$0.3 \pm 0.0$
Retinol <sup>3</sup>	$1.9 \pm 0.11$	$1.9 \pm 0.11$	$1.9 \pm 0.12$	$2.1 \pm 0.10$	$1.9 \pm 0.10$	$2.0 \pm 0.1$
$\alpha$ -Tocopherol	$32.8 \pm 2.33$	$33.7 \pm 2.24$	$32.9 \pm 1.91$	$33.3 \pm 2.11$	$29.1 \pm 2.03$	$30.8 \pm 1$
Lycopene	$0.5 \pm 0.05$	$0.6 \pm 0.14$	$0.5 \pm 0.05$	$0.5 \pm 0.04$	$0.7 \pm 0.13$	$0.5 \pm 0.0$
$\alpha$ -Carotene <sup>4</sup>	$0.1 \pm 0.01$	$0.1 \pm 0.02$	$0.1 \pm 0.01$	$0.1 \pm 0.01$	$0.1 \pm 0.02$	$0.1 \pm 0.0$
$\beta$ -Carotene <sup>5</sup>	$0.4 \pm 0.05$	$0.5 \pm 0.08$	$0.5 \pm 0.06$	$0.3 \pm 0.05$	$0.4 \pm 0.06$	$0.4 \pm 0.0$

<sup>1</sup> Values are means  $\pm$  SEM.

<sup>2</sup> MR, meal replacement; C, conventional.

<sup>3</sup> C group, baseline vs. 3 mo,  $P < 0.01$ ; baseline vs. 6 mo,  $P < 0.005$ .

<sup>4</sup> MR group, 3 mo vs. 6 mo,  $P < 0.01$ .

<sup>5</sup> MR group, baseline vs. 3 mo,  $P < 0.001$ ; baseline vs. 6 mo,  $P < 0.05$ .

TABLE 3

Micronutrient intake for dietary treatments of MR group and C group, 3-mo, and 6-mo duration<sup>1</sup>

Nutrient mg/d	Stage 1 3-mo completers		Stage 2 6-mo completers	
	MR group n = 24	C group n = 26	MR group n = 17	C group n = 23
Potassium	2834 ± 93.1	3158 ± 165.5	2936 ± 113.0	3135 ± 168.4
Magnesium <sup>2,3a</sup>	435 ± 9.2	301 ± 13.4	439 ± 10.6	295 ± 13.2
Calcium <sup>2,3a</sup>	1207 ± 42.4	700 ± 33.3	1224 ± 34.3	703 ± 33.5
Phosphorous <sup>3b</sup>	1498 ± 45.6	1375 ± 97.6	1525 ± 54.5	1332 ± 64.1
Iron <sup>2,3c</sup>	14.3 ± 0.36	12.1 ± 0.57	14.9 ± 0.40	12.2 ± 0.55
Zinc <sup>2-4a</sup>	14.9 ± 0.96	9.3 ± 0.44	15.2 ± 0.79	9.4 ± 0.38
Thiamine <sup>5c</sup>	1.7 ± 0.04	1.6 ± 0.08	1.7 ± 0.05	1.6 ± 0.12
Riboflavin <sup>2,3bc</sup>	2.1 ± 0.08	1.7 ± 0.10	2.2 ± 0.08	1.7 ± 0.14
Niacin <sup>2,5bd</sup>	20.1 ± 0.49	18.1 ± 0.80	20.7 ± 0.69	18.2 ± 1.03
Niacin equivalent <sup>5c</sup>	33.6 ± 1.00	33.1 ± 1.18	34.6 ± 1.35	33.1 ± 1.32
Ascorbic acid	117 ± 8.4	116 ± 9.0	121 ± 8.5	119 ± 10.5
Folate <sup>5b</sup> μg/d	320.8 ± 7.15	305.3 ± 12.04	330.5 ± 9.22	308.5 ± 13.45
Retinol	1330 ± 80.0	1115 ± 175.2	1332 ± 98.0	1135 ± 114.3

<sup>1</sup> Values are means ± SEM. Significance levels: <sup>a</sup>  $P < 0.001$ , <sup>b</sup>  $P < 0.05$ , <sup>c</sup>  $P < 0.01$ , <sup>d</sup>  $P < 0.02$ .

<sup>2</sup> Between group 3 mo.

<sup>3</sup> Between group 6 mo.

<sup>4</sup> Within group C.

<sup>5</sup> Within group MR.

rotenoid levels were found between the MR group and the C group at baseline, 3-mo, or 6-mo time points (Table 2).

### Dietary intake

**Macronutrients.** Energy intake did not differ between treatments at either 3 or 6 mo. Energy distribution of both treatment groups was similar at 3 mo (MR group: 22.6% protein, 21.4% fat, and 53.7% carbohydrate energy; C group: 22.7% protein, 21.3% fat, and 54.3% carbohydrate energy) and again at 6 mo (MR group: 23.1% protein, 20.6% fat, and 54.1% carbohydrate energy; C group: 22.9% protein, 21.2% fat, and 54.3% carbohydrate energy).

Dietary fiber intake was significantly lower in the MR group than in the C group at both 3 mo ( $23.2 \pm 0.8$  g, MR group;  $28.7 \pm 1.5$  g, C group;  $P < 0.01$ ) and 6 mo ( $23.3 \pm 1.0$  g, MR group;  $28.2 \pm 1.6$  g, C group;  $P < 0.02$ ). There was no significant difference in intake between the MR group and the C group for any other macronutrient at either 3 or 6 mo.

Within-group comparisons over time indicated a significant increase in energy intake for the MR group ( $P < 0.05$ ), although the increase was small. In the C group, there was a significant ( $P < 0.05$ ) but slight increase in absolute protein intake from 3 to 6 mo.

**Micronutrients.** Dietary intake of magnesium, calcium, iron, and zinc were all significantly higher in the MR group than in the C group at 3 and 6 mo (Table 3). Dietary phosphorous intake was significantly lower in the MR group than in the C group at 6 mo. The maximum RDI for calcium intake was surpassed by the MR group (153% of upper RDI) but not reached by the C group [87% of upper RDI (11)].

Dietary intakes of riboflavin and of niacin were both significantly higher in the MR group than in the C group at 3 mo, with the niacin also significantly higher in the MR group than in the C group at 6 mo (Table 3).

Within-group comparisons over time indicated a significant increase in dietary thiamine ( $P < 0.01$ ), niacin ( $P < 0.02$ ), niacin equivalents ( $P < 0.01$ ), and folate ( $P < 0.05$ ) intake in the MR group from stage 1 to stage 2 (Table 3). In the C

group, there was a significant increase in zinc intake ( $P < 0.02$ ) from stage 1 to stage 2.

**Attitudes to dietary intervention.** Differences in attitude between the groups to the dietary intervention (assessed by the NQOL survey instrument) were evident. The MR group scored significantly higher on poststudy questionnaire (as opposed to prestudy questionnaire) for ease of dining out than the C group ( $P < 0.01$ ). The MR group also found the diet strategy easier to comply with, scoring significantly higher on questions related to understanding of food amounts ( $P < 0.05$ ) and complying with food amounts ( $P < 0.05$ ) than did the C group respondents. For the MR group, 42% of respondents found the intervention better than other dietary strategies, and 12% would continue using it.

### DISCUSSION

Both meal replacement and conventional diet strategies were effective in achieving weight loss of 6 kg after 3 mo and 9 kg after 6 mo. Several other studies have used similar (5–8,16) or varied forms (17–19) of meal replacement to achieve weight loss. Similar reductions in weight (7 kg at 12 wk) were achieved in an uncontrolled study (5), in a 2-arm, 12-wk intervention study [1.5% weight loss in subjects on a conventional diet vs. 7.8% weight loss in subjects fed a diet incorporating meal replacements (8)], and in a 3 mo parallel study with losses in weight of  $7.1 \pm 3.5$  kg in their meal replacement group and  $1.3 \pm 2.2$  kg in their conventional diet group (6). These studies incorporated professional nutritional support into the program. However, their findings contrast with the present results in which both the conventional diet group and the meal replacement group lost a similar significant amount of weight.

Meal replacements have been examined in a small number of long-term studies that suggest weight loss is maintained by using this strategy (5–8,20–22). For example, in a 116-wk follow-up study that used meal replacements, weight loss was 6 kg overall (5). After 1 y, 77% of subjects maintained >80% of the initial weight loss and 62% maintained >80% of the

initial weight loss after 2 y, with only 7.4% of subjects above baseline weight. Flechtner-Mors et al. (8) found that after 4 y in a single-arm intervention study using meal replacements, which had an initial 12-wk 2-arm meal replacement and a conventional diet intervention period, the original conventional diet group had a 3.2% weight loss vs. 8.4% in the meal replacement group. Ditschuneit et al. (6) reported weight loss after an initial 3-mo phase ( $11.3\% \pm 6.8\%$  in the meal replacement group and  $5.9\% \pm 5.0\%$  in the conventional diet group) was continued over 24 mo.

However, various studies suggest that the "structure" of the dietary intervention influences the outcome. For example, a 1-y study (23) using 3 lifestyle-based treatments showed that a meal-replacement primary-care office intervention was as effective at achieving weight loss (4%) as a dietitian-led conventional dietary intervention (4% weight loss), whereas a meal replacement combined with a dietitian intervention was more effective (9%) than either intervention alone. In this case, the structure incorporated regular visits of differing durations and nutritional support. A self-managed community-based study of 5-y duration that used meal replacements, weekly weigh-ins at a village center (active weight-loss phase), 2 visits per year (maintenance phase), and no professional input found that males in the meal replacement group lost  $5.8 \pm 5.4$  kg, and females in the meal replacement group lost  $4.2 \pm 6.9$  kg, whereas male and female controls gained  $6.7 \pm 10.2$  kg and  $6.5 \pm 10.7$  kg, respectively (20). A 2-intervention study (meal replacement and restricted calorie diet) achieved similar weight losses in both groups by using a pharmacy setting, with structure built into visit times, incorporating the pharmacist as the focus for dietary advice, and by using a 3-wk visit program (24).

In this study, "structure" included 2-wk fixed visits (social component), some recompensing for food costs (financial component), regular checks on weight (physical component), regularity in blood measures sampled (health component), clear dietary guidelines (diet component), and useful recipes to accompany diet guidelines (food preparation/interest component). All contributed "structure" to the treatment program, coupled with conventional weight-loss diet information. Some or many of these features are not necessarily part of the "structure" of other conventional diet treatments in other studies.

Clearly meal replacements are as effective a strategy for losing weight as conventional weight-loss diets, over a variety of time spans, although the degree of success is influenced by a variety of methodology factors. In most studies, meal replacements resulted in a greater weight loss than conventional diets, even when professional nutritional support was incorporated into the program. However, the absence of professional nutritional support in the present study did not appear to reduce the effectiveness of either the conventional dietary approach or the meal replacement strategy, and both strategies resulted in significant similar weight losses over a short time span. Information delivered was controlled and was similar for both approaches (dietary summary, meal plan, sample recipes, 2 weekly weight checks and food pick ups). The "behavioral support structure" of both diets, therefore, was similar. The inclusion of the monetary food voucher in the C group was a sufficient matching incentive to the provision of a free meal replacement product, both of which provided the impetus for continued weight loss. The benefits of food provision in weight control studies have been reported previously (25–28).

What about other measures of effectiveness besides weight loss? The nutritional adequacy of the meal replacement diet, determined by examining blood biomarkers and dietary in-

takes, is supported by 2 findings. First, meal replacements maintained and enhanced the dietary adequacy of the weight-loss program compared with a conventional weight-loss strategy, particularly with some micronutrients. Dietary calcium intake was increased in the MR group, mostly as a consequence of the inclusion of milk-based shakes. Given that weight-loss diets are associated with increased bone resorption in obese adults (13), the increased calcium intake associated with meal replacements appears beneficial. Second, the dietary structure (food choice and meal pattern) of both programs resulted in similar energy distributions, i.e., moderate protein and carbohydrate intakes and relatively low fat intake, being maintained. The major negative dietary-quality feature of the meal replacement program was the low fiber intake compared with the conventional diet, although both diets were less than ideal (compared with RDIs) but were greater than the average intake for this nutrient in Australia (29). However, the inclusion of a bran cereal in the dietary plan of controls, accounts for much of the disparity in fiber intake. The effectiveness of the meal replacement program by a measure of "nutritional adequacy" thus is as sound if not somewhat nutritionally protective, compared with the conventional weight-loss program.

Commercial meal replacements have become increasingly popular as a strategy among people trying to lose weight. Many U.S. adults (15% of women and 13% of men) reportedly use meal replacements as their weight-loss strategy, suggesting that they can easily be incorporated into the lifestyle of the participant (30). In one study, two-thirds of 252 patients chose to use meal replacements at least once daily (31). After 6 mo, weight loss was  $8.62 \pm 1.81$  kg for women and  $7.03 \pm 3.72$  kg for men. Participants of the present study found the meal replacement strategy convenient to use and provided manageable dining out options. Management of and compliance on the diet, therefore, was good, supporting the notion that meal replacements offer an effective alternate strategy for long-term dieting. Given that more than half of adult Australians purchase and consume food or beverages away from home (29) and users of meal replacements find this strategy easy and convenient to use, the sustainability of meal replacement programs over conventional strategies may be of importance when selecting or advising strategies for weight loss. However, in Denmark, use of over-the-counter pills, diet pills, or meal replacements decreased from 1992 to 1998 (32).

In conclusion, in this minimally controlled study in Australian adults, meal replacements were as effective a strategy for weight loss as a conventional diet, maintained over both a 3- and 6-mo period. The nutritional adequacy of the meal replacement program was equal to (except for dietary-fiber intake) and, in the case of some micronutrients, superior to the conventional diet. Participants found meal replacement easy to comply with and found it easier to dine out on this plan. This may facilitate longer-term compliance with a weight-loss program and suggests that the program is nutritionally sound if applied appropriately.

## LITERATURE CITED

1. World Health Organization (2000) Obesity; Preventing and Managing the Global Epidemic. Technical Report Series 894. WHO, Geneva, Switzerland.
2. Jarvis, W. (1983) Food faddism, cultism, and quackery. *Annu. Rev. Nutr.* 3: 35–52.
3. Jeffery, R. W. (2001) Public health strategies for obesity treatment and prevention. *Am. J. Health. Behav.* 25: 252–259.
4. Sanders, T. A., Woolfe, R. & Rantzen, E. (1990) Controlled evaluation of slimming diets: use of television for recruitment. *Lancet* 336: 918–920.
5. Heber, D., Ashley, J. M., Wang, H. J. & Elashoff, R. M. (1994) Clinical

evaluation of a minimal intervention meal replacement regimen for weight reduction. *J. Am. Coll. Nutr.* 13: 608–614.

6. Ditschuneit, H. H., Flechtner-Mors, M., Johnson, T. D. & Adler, G. (1999) Metabolic and weight-loss effects of a long-term dietary intervention in obese patients. *Am. J. Clin. Nutr.* 69: 198–204.

7. Ditschuneit, H. H. & Flechtner-Mors, M. (2001) Value of structured meals for weight management: risk factors and long-term weight maintenance. *Obes. Res.* 9 (Suppl 4): 284S–289S.

8. Flechtner-Mors, M., Ditschuneit, H. H., Johnson, T. D., Suchard, M. A. & Adler, G. (2000) Metabolic and weight loss effects of long-term dietary intervention in obese patients: four-year results. *Obes. Res.* 8: 399–402.

9. Winick, C., Rothacker, D. Q. & Norman, R. L. (2002) Four worksite weight loss programs with high-stress occupations using a meal replacement product. *Occup. Med. (Lond)* 52: 25–30.

10. Freedman, M., King, J. & Kennedy, E. (2001) Popular diets: a scientific review. *Obes. Res.* 9 (Suppl 1): 1S–40S.

11. National Health and Medical Research Council (1991) Recommended Dietary Intakes for use in Australia. Australian Government Publishing Service, Canberra, Australia.

12. National Health and Medical Research Council. (2002) Draft Clinical Guidelines for Weight Control and Obesity Management in Adults. NHMRC, Canberra, Australia.

13. Bowen, J., Noakes, M. & Clifton, P. M. (2004) A high dairy protein, high-calcium diet minimizes bone turnover in overweight adults during weight loss. *J. Nutr.* 134: 568–573.

14. Khachik, F., Beecher, G. R., Goli, M. B., Lusby, W. R. & Smith J. C., Jr. (1992) Separation and identification of carotenoids and their oxidation products in the extracts of human plasma. *Anal. Chem.* 64: 2111–2122.

15. Noakes, M., Clifton, P., Ntanos, F., Shrapnel, W., Record, I. & McInerney, J. (2002) An increase in dietary carotenoids when consuming plant sterols or stanols is effective in maintaining plasma carotenoid concentrations. *Am. J. Clin. Nutr.* 75: 79–86.

16. Heymsfield, S. B., van Mierlo, C.A., van der Knaap, H. C., Heo, M. & Frier, H. I. (2003) Weight management using a meal replacement strategy: meta and pooling analysis from six studies. *Int. J. Obes. Relat. Metab. Disord.* 27: 537–549.

17. Mattes, R. D. (2002) Ready-to-eat cereal used as a meal replacement promotes weight loss in humans. *J. Am. Coll. Nutr.* 21: 570–577.

18. Fontaine, K. R., Yang, D., Gadbury, G. L., Heshka, S., Schwartz, L. G., Murugesan, R., Kraker, J. L., Heo, M., Heymsfield, S. B. & Allison, D. B. (2003) Results of soy-based meal replacement formula on weight, anthropometry, serum lipids and blood pressure during a 40-week clinical weight loss trial. *Nutr. J.* 2: 14.

19. Allison, D. B., Gadbury, G., Schwartz, L. G., Murugesan, R., Kraker, J. L.,

Heshka, S., Fontaine, K. R. & Heymsfield, S. B. (2003) A novel soy-based meal replacement formula for weight loss among obese individuals: a randomized controlled clinical trial. *Eur. J. Clin. Nutr.* 57: 514–522.

20. Rothacker, D. Q. (2000) Five-year self management of weight using meal replacements: comparison with matched controls in rural Wisconsin. *Nutrition* 16: 344–348.

21. Rothacker, D. Q., Staniszewski, B. A. & Ellis, P. K. (2001) Liquid meal replacement vs traditional food: a potential model for women who cannot maintain eating habit change. *J. Am. Diet. Assoc.* 101: 345–347.

22. Ashley, J. M., St Jeor, S. T., Schrage, J. P., Perumean-Chaney, S. E., Gilbertson, M. C., McCall, N. L. & Bovee, V. (2001) Weight control in the physician's office. *Arch. Intern. Med.* 161: 1599–1604.

23. Ashley, J. M., St Jeor, S. T., Schrage, J. P., Perumean-Chaney, S. E., Gilbertson, M. C., McCall, N. L. & Bovee, V. (2001) Meal replacements in weight intervention. *Obes. Res.* 9 (Suppl 4): 312S–320S.

24. Ahrens, R. A., Hower, M. & Best, A. M. (2003) Effects of weight reduction interventions by community pharmacists. *J. Am. Pharm. Assoc.* 43: 583–589.

25. Metz, J. A., Kris-Etherton, P. M. & Morris, C. D. (1997) Dietary compliance and cardiovascular risk reduction with a prepared meal plan compared with a self-selected diet. *Am. J. Clin. Nutr.* 66: 373–385.

26. National Diet-Heart Study Research Group (1969) The National Diet-Heart Study final report. *Circulation* 37 (Suppl): I1–I428.

27. Jeffery, R. W., Wing, R. R., Thorson, C., Burton, L. R., Raether, C., Harvey, J. & Mullen, M. (1993) Strengthening behavioural interventions for weight loss: a randomized trial of food provision and monetary incentives. *J. Consult. Clin. Psychol.* 61: 1038–1045.

28. Wing, R. R., Jeffery, R. W., Burton, L. R., Thorson, C., Nissinoff, K. S. & Baxter, J. E. (1996) Food provision vs structured meal plans in the behavioral treatment of obesity. *Int. J. Obes. Relat. Metab. Disord.* 20: 56–62.

29. Australian Bureau of Statistics (1999) National Nutrition Survey. Commonwealth of Australia, Canberra.

30. Levy, A. S. & Heaton, A. W. (1993) Weight control practices of U.S. adults trying to lose weight. *Ann. Intern. Med.* 119: 661–666.

31. Bowerman, S., Bellman, M., Saltsman, P., Garvey, D., Pimstone, K., Skootsky, S., Wang, H. J., Elashoff, R. & Heber, D. (2001) Implementation of a primary care physician network obesity management program. *Obes. Res.* 9 (Suppl 4): 321S–325S.

32. Bendixen, H., Madsen, J., Bay-Hansen, D., Boesen, U., Ovesen, L. F., Bartels, E. M. & Astrup, A. (2002) An observational study of slimming behavior in Denmark in 1992 and 1998. *Obes. Res.* 10: 911–922.