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Translation of Evidence to Clinical Practice for Use of Meal Replacements in Weight Loss and Obesity-lessons Learned from Research Studies

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Abstract

Meal replacements have been shown to be effective in assisting weight loss in many clinical trials; however, adherence is a major determinant of the reported success. Characterizing how meal replacements were used for weight loss in clinical studies can assist healthcare providers to replicate efficacy and improve adherence to achieve successful weight loss. This narrative review characterizes the treatment conditions that support meal replacements use for weight loss from 45 clinical trials. From these studies, the key treatment conditions that support the successful use of meal replacements include contact with healthcare providers; structured education and counseling sessions; and close monitoring of progress. Weekly contacts with healthcare providers that included a physician with dietitian/nutritionist team for at least three months were needed in the initial phase of using meal replacements. Education and counseling sessions should be conducted at individual and group level to provide structured diet plans which included healthy eating, exercise plan and incorporation of cognitive/psychological motivation components. Frequent monitoring of progress included weekly to monthly weight monitoring, the use of food and exercise records, and self-monitoring of blood glucose in subjects with diabetes. In conclusion, similar with other lifestyle interventions, intensive follow ups and monitoring are required to ensure the success of using meal replacements for weight loss in everyday clinical practice.

Keywords: Weight loss; Meal replacements; Clinical practice; Treatment conditions

Introduction

Meal replacements are pre-packaged vitamin-mineral fortified products, used either as sole source of energy within a meal or in combination with fresh foods [1]. Within a low calorie diet, use of meal replacements generally produce significant and sustainable moderate weight loss over a period of six months or longer [2-5]. Given its usefulness, the incorporation of meal replacements within a weight loss regimen has gained attention among healthcare providers, commercial weight loss programs, and individuals seeking self-help weight loss. Indeed, the global retail value from sales of meal replacements is on a positive growth with greatest expansion seen in Asia Pacific and Eastern Europe [6].

Effective adherence to meal replacement use is critical and recognized as a major determinant of weight-loss success [7]. Davis et al. reported an overall attrition rate of 43.2% in obese adults receiving meal replacements as a result of dietary fatigue [8]. Adherence has been recorded as highest only during the initial first month of use and often could not be retained during subsequent weeks [9].

Hence, characterizing how meal replacements were used to achieve weight loss from clinical studies is essential to provide information on the conditions needed to improve adherence and replicate efficacy under real life every day clinical settings and reduce the risk of failed weight loss, the latter which, leads to repeated weight loss attempts, weight cycling and its negative health consequences [10].

We conducted a narrative review of clinical trials to characterize the successful use of meal replacements for weight loss among adults with overweight/obesity, and discuss how these can be translated into every day clinical practice.

Methods

Data sources and study selection

A literature search was conducted using online databases CINAHL, MEDLINE, Science Direct and the Cochrane Central Register of Controlled Trials. Title subject headings included 'meal replacement*' and 'weight'. Studies were selected to include original research articles published in the English language and involving adults aged ≥ 18 years with a Body Mass Index (BMI) ≥ 25. The search limited to prospective clinical trials with at least one intervention arm using meal replacements and weight loss as an outcome. Studies where meal replacements were used only as a very low calorie diet (VLCD) or concurrently with weight loss medications were excluded because these situations require very close medical supervision and are less frequently utilized in a healthcare, commercial, or individual setting independent of a physician. From a potential list of 192 publications, 45 unique studies with 50 publications were included.

Results

Overview of studies

Table 1 shows an overview of the studies included in this review. The majority of studies reporting use of meal replacements for weight loss were conducted in North America and Europe, with a small sample from Australia and Asia. The longest and largest studies were from North America and Europe. These studies lasted up to five years [11-16]. The North American Look AHEAD multicenter trial involved

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Study	Location	Study length Weeks	Sample size n	Age[a] years	Type of meal replacements	Weight loss[a] Kg (%)	Retention %	Treatment Conditions			Challenges reported
								HCP expertise	Education/Counselling	Monitoring of progress	
Without obesity related co-morbidities											
Kim et al. [46]	Asia	6	47	-	Liquid-White-rice powder Liquid-ixed-rice powder	~6.1 (~8.5)	85	Researcher	-	HCP monitoring **Weight:** Start, mid-point and end of study.	-
Tsai et al. [57]	Asia	12	60	42.0	Liquid-green tea	6.8 (8.4)	90	-	**Type:** A single dietary counselling session and individual sessions 6 weeks once to monitor compliance and encourage use of MR. **Support tools:** Food weight loss practices literature, meal plans and food exchange lists.	HCP monitoring **Weight:** Start and end of study.	**Adherence :** Diarrhea associated with use of MR product.
Khoo et al. [53]	Asia	40	24	40.2	Liquid	4.1 (4.1)	58	-	**Type:** Nutrition and exercise advice. **Support tools:** Written plan with detailed diet information, menu plan and advice on cooking and eating out.	HCP monitoring **Weight:** Monthly. **Diet adherence:** Monthly for first 12 weeks.	**Retention:** Highest dropout occurred during weight maintenance.
Brindal et al. [50]	Australia	8	58	42.0	Liquid	- (~3.2)	76	None	**Support tools:** Information on the MR regimen from phone app.	Self-monitoring using phone app **Weight:** Up to three times daily. **Diet:** Up to three times daily.	
Kirk et al. [58]	Europe	6	29	39.6	Breakfast cereal	1.9 (2.3)	76	-	**Type:** Dietary protocol information at baseline followed by personalized dietary advice after four weeks until end of study.	HCP monitoring **Weight:** Start, mid-point and end of study. **Food diary:** Start, mid-point and end of study.	**Adherence :** Differences in dietary compliance and individual motivation to lose weight.
König et al. [64]	Europe	6	60	47.0	Liquid	6.4 (7.1)	98	Expert in nutritional counselling; Physician	**Type:** Nutrition and exercise advice in two counselling sessions. **Support tools:** Educational pamphlets on diet and physical activity.	HCP monitoring **Weight:** Start and end of study.	-
Jensen et al. [41]	Europe	16	30	50.7	Shakes Soups Porridge	15.8 (~14.8)	90	Dietitian	**Type:** Dietary advice and encouragement via group sessions (every	HCP monitoring **Weight:** Monthly.	-

									two weeks).		
Vazquez et al. [83]	Europe	26	31	52.4	Liquid	3.1 (3.2)[b]	87	Dietitian	**Type:** Nutritional counselling via individual sessions (monthly).	HCP monitoring **Weight:** Monthly.	
Deibert et al. [62]	Europe	48	76	43.7	Liquid	~6.7 (~7.8)	95	Trained exercise counsellor	**Type:** Diet instructions via two individual counselling sessions and supervised exercise sessions (twice weekly during the first six months). **Support tools:** Educational pamphlets to improve dietary behavior.	HCP monitoring **Weight:** Start and end of study. **Food records:** At baseline, three months and six months.	
Packianathan et al. [21]	Europe	52	70	48.5	Liquid	5.1 (5.3)	66	Dietitian; Physician	**Type:** Dietetic and cognitive behavioral therapy via individual sessions (bi-weekly for first 16-weeks) and diet/lifestyle therapy via group sessions thereafter (monthly for first six months, and bi-monthly for next six months).	HCP monitoring **Weight:** Monthly.	**Retention:** Dropout was higher than expected and it was challenging to find ways to improve retention.
Hemmingsson et al. [17]	Europe	52	4588	50.0	Liquid	8.8 (10.2)	77	Company trained health coach	**Type:** Personalized diet and behavior change advice via individual sessions (baseline, three, six, and 12 months) and group sessions (weekly for first three months, and monthly thereafter); After first three months, exercise sessions two to three times a week and encouragement to increase daily physical activity. **Support tools:** Pedometer.	HCP monitoring **Weight:** Start, three months, six months, and 12 months.	
Flechtner-Mors et al. [11], Ditschuneit et al. [12]	Europe	221	50	44.8	Liquid	9.5 (10.3)	-	Nutritionist	**Type:** Personalized diet and behavior modification advice via individual sessions (monthly). **Support tools:** Personalized menu plan, recipes and food exchange lists.	HCP monitoring **Weight:** Monthly. **Food diaries:** Monthly.	-
VanderWal et al. [19]	N. America	4	124	46.7	Cereal Bar	~3.2 (~3.2)	78	Dietitian; Physician	**Type:** Diet advice via individual sessions (at start, mid-point and end of study).	HCP monitoring **Weight:** Start, mid-point and end of study.	**Retention:** High dropout rate in men due to unknown reasons.

										Program compliance: At start, mid-point and end of study.	
VanderWal et al. [45]	N. America	4	91	50.0	Shake Bar	~2.8 (~2.9)	90	Dietitian; Physician	**Type:** Diet advice via individual sessions (at start, mid-point and end of study).	HCP monitoring **Weight:** Start, mid-point and end of study.	-
VanderWal et al. [18]	N. America	8	80	46.1	Cereal Bar Shakes	~3.9 (~3.9)	77	Dietitian; Physician	**Type:** Instruction on dietary protocol at start of study and monitoring of appropriateness of diet via individual sessions (fortnightly).	HCP monitoring **Weight:** Fortnightly.	-
Winick et al. [51]	N. America	12	492	38.6	Liquid	~7.9 (~8.5)	80	None	**Support tools:** Information on nutrition and exercise from MR package and insert instructions.	HCP monitoring **Weight:** Weekly.	**Adherence:** Minimal and transient gastrointestinal discomfort from MR use.
Anderson and Hoie [59]	N. America	12	90	47.5	Liquid-Soy-based Liquid-Milk-based	- (~8.5)	58	Dietitian	**Type:** Baseline instructions (containing limited nutrition information) and individual dietary sessions to encourage subjects and answer their questions (fortnightly). **Support tools:** Lifestyle diary.	HCP monitoring **Weight:** Fortnightly.	**Retention:** Dropout rates were higher than expected. Early withdrawals were partly due to gastrointestinal discomfort associated with use of MR product.
Allison et al. [60]	N. America	12	50	50.4	Liquid	7.0 (7.6)	74	-	**Type:** Single session of dietary counseling. **Support tools:** Pamphlet on good weight loss practices, meal plan, food exchange list.	HCP monitoring **Weight:** Monthly. **Program compliance:** Monthly	**Retention:** Dropout partly attributed to gastrointestinal discomfort associated with use of MR product.
Treyzon et al. [56]	N. America	12	100	49.5	Liquid – protein supplemented Liquid – with placebo	4.0 (-)	85	Dietitian	**Type:** Diet and physical activity instruction (baseline) and follow-up to assess dietary compliance via individual sessions (two, four, and eight weeks); Exercise goal of 30 minutes per day.	HCP monitoring **Weight:** Start, two weeks, four weeks, and eight weeks.	-
Poston et al. [20]	N. America	24	100	40.6	Liquid	~2.7 (~3.3)	-	Dietitian	**Type:** Diet counselling via individual sessions (weekly). **Support tools:**	HCP monitoring **Weight:** Weekly.	**Retention:** High dropout rates despite

									Behaviorally- and/or food-oriented hand-outs.		minimal complaints about the MR product. **Adherence :** There was variability in weight changes.
Bowerman et al. [63]	N. America	26	252	-	Liquid	~7.8 (~8.0)	48	Dietitian; Physician	**Type:** Medical individual sessions (baseline, four, 24, 36, and 52 weeks) where personalized advice based on subject-completed worksheet to assess patient's readiness for behavior change, and dietary consultation via telephone follow-up (weekly for first 12 weeks, and monthly thereafter). **Support tools:** Education pack containing meal plans, caloric values for food, information on the use of MR, avoidance of trigger foods, materials on the value of regular exercise; and recorded encouraging messages.	HCP monitoring **Weight:** Start, four weeks, 24 weeks, 36 weeks, and 52 weeks.	
Smith et al. [54]	N. America	26	55	28.9	Liquid	3.8 (3.9)	52	Dietitian; Physical therapist	**Type:** Three educational sessions within two-weeks – one dietetic-based group session, one exercise education group session, and one dietetic-based individual session. **Support tools:** Brochure containing basic nutrition education for weight management.	HCP monitoring **Weight:** Monthly. **Food record:** Start and end of study. **Exercise log:** Start and end of study.	**Adherence :** Subjects overate on noncompliant days – suggesting compensatory behavior.
Davis et al. [8]	N. America	40	45	43.0	Liquid	8.0 (7.2)	58	Dietitian	**Type:** Dietary advice via individual sessions (bi-weekly for first 16 weeks and at 28 and 40 weeks thereafter); and recommended maximum of 45 minutes of exercise per day above normal daily activities for first 16 weeks. **Support tools:** Self-study module focusing on	HCP monitoring **Weight:** Bi-weekly for first 16 weeks and at 28 and 40 weeks thereafter.	**Retention:** Dropout rate may be due to taste fatigue.

									behavioral component of weight loss.		
Rothacker et al. [52]	N. America	52	158	36.1	Liquid	6.3 (8.4)	89	None	-	HCP monitoring **Weight:** Start, three-months, and one-year.	-
Ashley et al. [55]	N. America	52	48	36.7	Liquid	5.0 (6.3)	73	Dietitian	**Type:** Dietetic based group education sessions (fortnightly for first six months and monthly thereafter. **Support tools:** Dietetic based instruction materials and manual for weight control and MR use.	HCP monitoring **Weight:** Start, mid-point and end of study.	
Rothacker [49]	N. America	261	158	40.9	Liquid	~5.0 (~5.4)	89	None	-	HCP monitoring **Weight:** Weekly for the first 3-months and twice a year thereafter.	-
Alves et al. [40]	S. America	5	27	35.0	Liquid-nutrient supplement Liquid-without nutrient supplement	~0.8 (~1.1)	81	Nutritionist	**Type:** Dietary advice based on recommended nutrient intakes and instructions to maintain a habitual physical activity profile. **Support tools:** List of replacements foods organized by food groups and guidelines on healthy food choices.	HCP monitoring **Weight:** Start, mid-point and end of study.	-
With diabetes											
Sun et al. [31]	Asia	24	100	51.0	Liquid – Diabetes specific	2.1 (2.8)	96	Dietitian; Physician	**Type:** Diet and physical activity information via individual sessions (weekly) and group meetings (monthly). **Support tools:** Meal-plans and diabetes education materials.	HCP monitoring **Weight:** Start, mid-point and end of study. Self-monitoring Blood glucose	**Retention:** Dropout associated with gastrointestinal discomfort with MR use.
Khoo et al. [22][d]	Australia	8	19	58.1	Liquid	9.5 (8.4)	-	-	**Type:** Nutrition advice. Subjects maintained their usual daily activity. **Support tools:** Written plan with detailed diet information, menu plan, recipes, and advice on cooking and eating out.	HCP monitoring **Weight:** Every two weeks for eight weeks and monthly thereafter. **Diet adherence:** Two- to Four-	-

										weekly intervals using food diaries.	
Keogh et al. [28]	Australia	26	60	60.9	Liquid	5.8 (5.7)	72	None	**Support tools:** Product materials, access to website.	HCP monitoring **Weight:** Monthly	-
Kempf et al. [32]	Europe	12	22	64.1	Liquid	6.1 (5.2)	68	Diabetologist	**Type:** Design of study explained at start of study. **Support tools:** Manual to record SMBG and amount of meal replacements taken.	HCP monitoring **Weight:** Start and end of study.	**Retention:** Dropout rates indicated that changes in diet are harder to apply than injecting insulin and achieving insufficient metabolic adjustment.
Yip et al. [30]	N. America	12	50	58.8	Liquid-with sugar Liquid-without sugar	6.1 (6.4)	82	Dietitian	**Type:** Dietary consultation via individual sessions (baseline, two, four, eight, and 12 week).	HCP monitoring **Weight:** Monthly.	-
Li et al. [27]	N. America	48	52	54.4	Liquid	4.4 (4.6)	81	Dietitian	**Type:** Dietary counselling via individual sessions (fortnightly for first eight weeks, and monthly thereafter).	HCP monitoring **Weight:** Start, three months, six months, and 12 months.	**Adherence :** Taste fatigue was reported particularly after 6 months.
Hamdy and Carver [24]	N. America	52	85	54.2	Liquid – Diabetes specific	8.3 (7.7)	-	Dietitian; Physician; Exercise physiologist: Psychologist	**Type:** Personalized dietary advice via individual session and weight loss education via group sessions (weekly for first 12 weeks), supervised exercise sessions (weekly), and cognitive behavioral support via individual sessions (weekly for first 12 weeks and monthly thereafter). **Support tools:** Meal plans, exercise plans to conduct independently at home, and education materials on weight management and diabetes.	HCP monitoring **Weight:** Throughout the study. **Dietary logbook:** Throughout the study.	**Treatment conditions:** Study treatment conditions challenging to apply in primary care practice settings where time and resources are traditionally limited.
Cheskin et al. [29]	N. America	86	54	54.6	Liquid – Diabetes specific	5.7 (5.6)	57	Dietitian	**Type:** Dietary counselling via individual sessions (at start, mid-point and end of 34-week weight loss phase) and nutrition, exercise or diabetes	HCP monitoring **Weight:** Fortnightly during 34-week weight loss phase and	

									education via group sessions based on social cognitive theory (fortnightly during 34-week weight loss phase and monthly thereafter).	monthly thereafter.	
Ashley et al. [25,26]	N. America	117	76	41.0	Liquid	~5.5 (~6.2)	67 [c]	Dietitian; Physician; Nurse	**Type:** During the first year of active weight loss the dietitian led group received lifestyle advice via 26 group sessions (weekly for first three months, biweekly for second three months, and monthly thereafter), while the physician/nurse led group received lifestyle advice via 26 individual sessions (fortnightly); In the second year (weight maintenance), both groups attended monthly dietitian-led seminars.	HCP monitoring **Weight:** Throughout the active weight loss phase of the study and monthly during the second year of weight maintenance.	
LookAHEAD [13-16]	N. America	209	2570	58.6	Liquid – various formulations including diabetes specific	4.9 (4.7)	94	Dietitian; Behavioral psychologists; Exercise specialists	**Type:** Diet, exercise, and behavioral consultations with HCPs via individual sessions (monthly) and group sessions (weekly up to 3 sessions per month for the first six months, and fortnightly thereafter for next six months); Subjects were recommended a goal of 175 minutes of moderate physical activity per week; In year 2 and beyond-Individual sessions (monthly), telephone or e-mail contact support (monthly, two weeks after individual session), open-group sessions (monthly), refresher courses (yearly), and national campaigns where subjects received a small prize for achieving specific goals.	HCP monitoring **Weight:** Monthly. Self-monitoring **Daily food intake:** Daily for the first year of the study. **Physical activity**: Daily for the first year of the study.	

									Support tools: Education materials.		
With metabolic syndrome											
Lee et al. [33]	Asia	12	75	48.0	Liquid-with protein powder Liquid-with placebo	~5.5 (~6.5)	89	Dietitian; Nurse	**Type:** Nutritional, lifestyle, and exercise counselling via individual sessions (fortnightly) and telephone calls (every other week).	HCP monitoring **Weight:** Start and end of study.	-
Noakes et al. [34]	Australia	26	33	-	Liquid	9.0 (-)	58	None	**Support tools:** Minimal oral advice, MR literature, a sample meal plan and recipes provided at start of study.	HCP monitoring **Weight:** Every two weeks.	
Flechtner-Mors et al. [35][d]	Europe	13	55	49.3	Shakes-high protein Bars-high protein	7.4 (7.5)	89	Nutritionist	**Type:** Nutrition advice via individual sessions (weekly in the first month) and group and individual sessions (monthly thereafter); Advice to maintain usual physical activity.	HCP monitoring **Weight:** Weekly in the first month and monthly thereafter.	**Retention:** Dropout rates were higher than expected but not due to lack of acceptability of the diet regimen.
With cardiovascular disease											
Keogh and Clifton [36]	Australia	52	127	50.0	Liquid-with whey-protein isolate Liquid-with skim milk	~10.3 (~10.7)	57	Dietitian; Researcher	**Type:** Dietary consultation at baseline, three, and 24 weeks.	HCP monitoring **Weight:** Monthly.	-
Metzner et al. [37]	Europe	12	51	49.8	Shakes Soups Bars	6.0 (7.1)	84	Nutrition advisor	**Type:** Nutrition education via four individual visits and ten group training sessions. **Support tools:** Instruction manuals with meal plans, recipes, and information on physical activity.	HCP monitoring **Weight:** Start and end of study.	
With impaired glucose regulation											
Xu et al. [38]	Asia	52	46	60.4	Liquid – low glycemic	1.8 (2.6)	89	Dietitian; Physician	**Type:** Nutrition, exercise, and blood glucose control advice at baseline and complemented with personalized eating instructions via scheduled sessions (weekly).	HCP monitoring **Weight:** Weekly for three months and monthly thereafter. **Compliance to MR plan:** Weekly.	
With polycystic ovary syndrome											
Moran et al. [39][d]	Australia	8	43	32.7	Liquid	5.6 (5.8)	79	Dietitian	**Type:** Nutrition and exercise advice via individual meetings (every two weeks). Diet advice personalized to compliance and weight loss, and encouragement to take 8000 steps a day. **Support tools:** Weight-loss literature, meal plans, recipes and a pedometer.	HCP monitoring **Weight:** Every two weeks.	**Adherence:** Dietary adherence decreased in the last 3-months of the study despite supportive treatment conditions.
With knee osteoarthritis											
Christensen et al. [23]	Europe	16	96	63.3	Liquid	12.2 (~11.9)	93	Dietitian	**Type:** Nutritional and dietetic instructions via group sessions (weekly). **Support tools:** List of recommended food, food shopping guide and recipes.	HCP monitoring **Weight:** Weekly.	-

[a]Age and weight loss are average values of the meal-replacement intervention arms. For studies with more than one meal replacement intervention arm, age nad weight loss represents the estimated average value across all meal replacement arms; [b]Reported weight loss for Vazquez'09 represents additional weight loss after subjects lost at least 5% of weight through diet prior to randomization into meal replacement arm; [c]Subject retention for Ashley'01 is at 1-year post intervention as no data was available for subject retention at 2-years; [d]Descriptions for Moran'06, Khoo'01, and Flechtner-Mors'10 are for the first phase of the study, during which meal replacements were used to initiate weight loss [N. America: North America; S. America: South America; HCP: Healthcare Provider; -: Data Unavailable for Review.

Table 1: Overview of studies (45 studies).

2570 subjects using meal replacements as part of an intensive lifestyle intervention [13-16]. In Europe, Hemmingsson et al. conducted an observational cohort study involving 4588 subjects using meal replacements [17].

Most studies involved middle aged subjects and recruited both genders, with a higher ratio of women to men. The subjects ranged in average starting weight between 68 kg and 116 kg. Compared to their Western counterparts, Asian subjects were lighter in weight and BMI.

Meal replacements were prescribed as part of a low-calorie diet containing 800 kcal to 1900 kcal daily. While the majority of studies instructed their subjects to substitute one to two main meals a day with meal replacements, three studies used meal replacements as a snack [18-20]. Generally, meal replacements formed part of a structured meal that contained low-fat dairy products, fruits and vegetables. In studies prescribing ≤ 1000 kcal a day, meal replacements were used within a meal as sole source of energy or mixed with milk [21-23].

Weight loss and health outcomes

Studies on the use of meal replacements for weight loss have been primarily conducted among overweight but otherwise healthy subjects. These meal replacements have been used to manage obesity related co-morbidities including diabetes [13-16,22,24-32], metabolic syndrome [33-35], cardiovascular disease [36,37], impaired glucose regulation [38], polycystic ovary syndrome (PCOS) [39], and knee osteoarthritis [23]. Across the 45 studies, weight loss averaged at six percent from baseline and is similar to results from two previous meta-analyses that showed that meal replacement use resulted in an average weight loss of seven percent to nine percent of body weight, with maximum weight loss attained at six months [2,3]. The weight loss seen can be as low as one percent to as high as 14.8% [40,41] and is dependent on type of analysis, follow-up duration, and subject health status. Use of meal replacements with higher protein content produced higher fat loss while maintaining lean muscle mass [8,35]. Preservation of lean body mass during weight loss is important especially with an increasing prevalence of sarcopenic obesity among older adults [42,43]. Two studies, involving older adults, used high protein meal replacements within their dietary regimen [23,32]. Christensen et al. found that loss of lean body mass was lower than expected and attributed this to adequate protein intake and increased physical activity among the meal replacers [23].

Studies using meal replacements in individuals with diabetes reported improvements in blood lipid profile, blood pressure, fasting blood glucose and glycated hemoglobin (HbA1c) levels accompanied the weight loss [13-16,22,24-30]. These cardio-metabolic risk reductions are also shown in subjects with impaired glucose regulation, metabolic syndrome, PCOS, and cardiovascular disease [33,36-39].

The use of nutrient specific meal replacements conferred cardio-metabolic benefits independent of weight loss. For example, use of high protein meal replacements resulted in reduction in carbohydrate intake and a corresponding drop in HbA1c at three months in subjects with diabetes [28]. This benefit of carbohydrate restriction on glycemic control is well documented but evidence remains weak on the type of carbohydrates to be removed [44]. When use of two meal replacements were compared-one containing simple sugars in the form of fructose and sucrose and the other with equivalent amounts of maltodextrins, both groups had comparable changes in weight, insulin, HbA1c and lipid levels [30]. In a study comparing use of moderate carbohydrate meal replacements with low carbohydrate meal replacements and with a control diet consisting of conventional foods, the low carbohydrate meal replacers had the greatest improvement in lipid profile [45]. In testing the use of meal replacements made with either wholegrain rice or white rice, both groups of meal replacers lost weight but those consuming the wholegrain rice product had higher high-density lipoprotein cholesterol (HDL-C) and improved antioxidant enzyme activity [46]. The health benefits of dietary fiber and bioactive compounds found in plant based foods was further supported by studies that showed increased HDL-C levels and reduction in two-hour plasma glucose and abdominal obesity from use of meal replacements made from cereals, seeds and grains [38,40]. Commercially available diabetes specific products have been used as meal replacements to provide immediate glycemic control alongside progressive weight loss. These products are generally carbohydrate modified and/or low in glycemic index [24,31].

Dietary benefits

Use of meal replacements improve convenience and dietary structure by reducing the number of decisions required for food choices [47,48]. Dietary structure supports weight loss even with minimal professional intervention. Among the studies reviewed, six studies gave minimum support to subjects and had good weight loss outcomes [28,34,49-52]. In simulating natural conditions, the subjects used meal replacements on their own accord and received only basic information on the meal replacement regimen.

Meal replacements are nutrient fortified and portion controlled food products. This limits energy intake while maintaining nutrient adequacy. Compared to conventional food, using meal replacements resulted in daily energy intake that was lower by up to 250 kcal [53,54]. Nutritional intake of meal replacers were also lower in fat and cholesterol [12,31], and higher in fiber and nutritional adequacy [26,31,55].

Over time, dieting can result in hunger or taste fatigue. This can be addressed by modifying the composition of meal replacements. Studies have tested products that are protein enriched or modified for added satiety [35,36,56]. Commercial meal replacement products are also available in different flavors and physical forms for food texture and mouth-feel. Meal replacements range from liquid shakes to snack bars, cereals and porridge [18,19,35,37,41,45]. In Asia, meal replacements have been modified to suit local taste preferences and include products made from rice and green tea [46,57].

Data reporting subject satisfaction with the meal replacement regimen complements the health and dietary benefits seen [51,54,58]. Among meal-replacers with high-stress occupations, 90% said the regimen was convenient, tasty, and provided good energy levels while 79% reported hunger satisfaction [51]. Similarly, 91% of the army soldiers involved in the study by Smith et al. found the meal replacement regimen to be an effective weight loss program [54]. While weight loss in Kirk et al.'s study was modest at 2.3%, the majority of the meal-replacers in this study reported that the meal replacement regimen was easy to follow and 84% would use the meal replacement again [58]. The meal replacement used was breakfast cereals-a familiar daily food, which could have enhanced dietary acceptance.

Adherence

The use of meal replacements were associated with side effects that were primarily transient gastrointestinal (GI) complaints [31,51,57,59,60]. These GI complaints were most likely associated with the use of meal replacements containing six to seven grams of

dietary fiber per serving [23,57,59,60]. The use of lactose-and soy-based products were comparable across the meal replacement studies.

Despite the success reported in clinical trials, the rate of weight loss among patients using meal replacements have not been as good in actual clinic settings. Several studies have reported poor adherence to using meal replacements up to 50 to 70% in uncontrolled settings [9,61]. As shown in Table 1, subject retention varied between 48% and 100%.

Treatment conditions

Healthcare provider expertise: We reviewed 34 studies for the type of health-care disciplines that provided support. More than three quarters included a dietitian or nutritionist as the expert provider, and 41% provided multi-disciplinary support. The most frequently involved discipline combination was a physician-dietitian/nutritionist team. In comparing the use of meal replacements supported either by a single and multi-disciplinary team, Ashley et al. showed that single-disciplinary support provided by a dietitian resulted in loss of 9.1% body weight as compared to 4.3% when provided by a multi-disciplinary team lead by a physician and nurse [25,26]. The difference in weight loss attainment could perhaps be attributed to time spent with the subjects. While both groups had similar frequency of follow-up and education, time spent with subjects by the physician-nurse team was patterned after brief clinic visits lasting 10-15 minutes but the dietitian-led group provided support via one-hour small group sessions.

Frequency of healthcare provider contact: In the reviewed studies, frequency of contact progressively decreased from weekly to monthly within a period of one year. After one year, frequency of follow-up remained at a monthly basis till end of study. Increased frequency of contact appeared to improve study retention and weight loss.

Three studies provided high follow-up contact and retained more than 90% of their subjects. Deibert et al. and Hamdy et al. in their one year studies provided health-care support about twice a week for the initial three to six-month period of the study, and tapered the follow-ups to once a month for the remaining study period [24,62]. Hamdy et al. also provided support during the evening hours for better subject accessibility [24]. The Look AHEAD study started off with weekly healthcare provider support for the first six months, after which frequency of support was maintained at three times a month up to four years [16].

In contrast, two studies provided the least frequency of contact and retained less than 60% of their subjects. Khoo et al. designed a nine month study during which the researchers met with subjects once a month for three months, with no other follow-ups for the remaining study period [53]. In the Keogh study, subjects met the dietitian three times within the study period of one year: at baseline, three weeks and six months [36].

In contrast with other studies, Hemmingsson et al.'s one-year study increased frequency of contact with time. Subjects met with their healthcare provider four to five times a week during the first three months of active weight loss. After that, subjects entered a nine month long weight-maintenance program, which included: exercise sessions two to three times a week; monthly group sessions; and three to six-monthly face-to-face counselling sessions [17]. In this study, subject retention was 77% with an average of 10.2% weight loss achieved within the one year period.

Education and counseling: Diet, exercise and behavioral components were addressed during individual and group meetings with healthcare providers. While the majority of studies provided follow-up via individual sessions, group meetings were included in most studies lasting one year and longer [16,17,21,24,25,29,35,55]. Subjects in all of these studies managed to maintain weight loss at ≥ 5% and this success could be attributed to the social support provided by group meetings [17,23,29]. Several studies provided lifestyle education and counselling through telephone calls [16,33,63]. Educational materials either in printed or electronic format were given when there was no healthcare provider follow-up [28,34,50,51].

Dietary sessions centered on restriction of energy intake. Dietary advice was individualized to subject's lifestyle [12,17,24,38,39], and included topics such as portion control [12,17,27,63], food exchanges [38,57,60], eating out, and cooking [22,53]. Structure was reinforced with provision of meal plans, recipes, food shopping guides [12,23,34,39,58], and a list of recommended foods to eat [23,40].

Most studies provided general advice on the importance of physical activity and to either increase physical activity or include moderate intensity exercise. Other strategies included: prescribing specific time goals for exercise-given as daily goals ranging from 30 to 45 minutes a day, or a weekly goal of 175 minutes [8,16,17,24,38,56], and the use of pedometers [17,39]. Three studies provided supervised exercise sessions at the study centre [17,24,62].

In five studies, behavioral aspects were addressed by the dietitian who either used Cognitive Behavior Therapy, reinforced positive behaviors, addressed barriers to dietary adherence, or dispensed materials with behavioral components of weight loss [8,12,20,21,23]. Cognitive behavioral support was provided by psychologists or behavioral therapists in studies with healthcare providers from these disciplines [16,24]. One study used a subject-completed worksheet that allowed the physician to assess patient readiness for behavior change [63].

Monitoring of progress: Another recurring theme was for subjects to monitor their progress made. Monitoring strategies included frequent weight monitoring, the use of food and exercise records, and self-monitoring of blood glucose (SMBG) in subjects with diabetes.

With the exception of six studies [32,33,37,57,62,64], most studies incorporated frequent weight monitoring, either at the study center or by the subjects themselves. The studies either maintained similar frequency of weighing throughout the study period–weekly to monthly; while others tapered the weigh-in sessions as study progressed-weekly or bi-weekly at initial stage to monthly or three-monthly during weight maintenance. The use of frequent weight monitoring was also seen in minimal intervention studies, which had good weight loss results. These studies did not provide follow-up contact with a healthcare provider but monitored body weight at weekly [49,51], bi-weekly [34], or monthly intervals [28]. Brindal et al. used a phone application that provided up to three prompts daily to encourage self-monitoring of body weight and dietary intake [50].

Food diaries, including use of meal replacements, helped the dietitians monitor subject progress, individualize advice given, and encourage adherence to the meal replacement regime [29,54,57,58]. Kempf et al. monitored meal replacement intake to adjust insulin therapy as needed [32]. The use of food diaries kept on a daily basis [12,24], or as a three-day record once every three months [62], was also incorporated in some studies. Longer running studies such as the Look AHEAD trial requested their subjects to keep a daily diet and physical activity diary for the first year of the study [16].

In studies involving subjects with diabetes, SMBG was encouraged [24,31,32,38]. In three of these studies, the subjects reviewed their blood glucose management with the study physician [24,32,38].

Discussion

Meal replacements for weight loss in clinical practice

Our review identified 45 studies which used meal replacements in various forms and reported successful weight loss of six percent from baseline in minimum time of three to six months. We have also identified that there are limited studies on meal replacement use and weight loss in Asian populations. Figure 1 summarizes as an overview the treatment conditions which support the use of meal replacements in the 45 studies reviewed.

Most of the reviewed studies included ongoing contact with healthcare providers from disciplines relevant to lifestyle change as part of the treatment condition. Provider expertise enhances patient role clarity, ability, and motivation to adhere to the treatment regimen by restructuring the information environment [65]. Individualized advice is needed to address the changes in dietary behavior and cognition seen with continued use of meal replacements [66]. Given that obesity is a multifactorial disease, a multidisciplinary approach as opposed to a single-clinician one, should be more effective in terms of weight loss and co-morbidities improvement [67,68]. Interestingly, a review of studies applying the findings of the Diabetes Prevention Program (DPP) found that change in body weight was similar regardless of whether the intervention was delivered by clinically trained professionals or lay educators [69]. This implies that the costs related to use of provider expertise can be eased without sacrificing effectiveness, by using lay

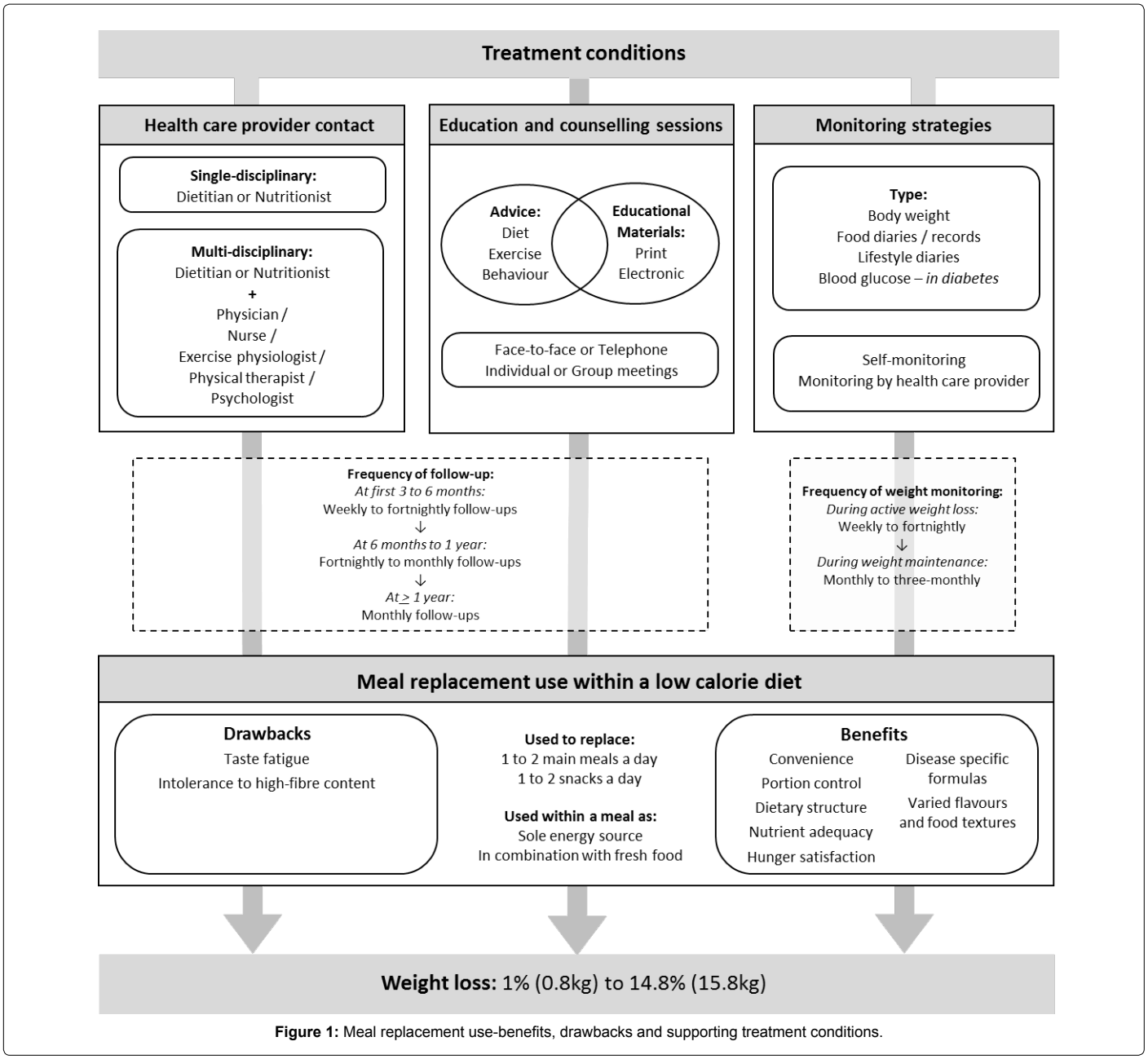

Figure 1: Meal replacement use-benefits, drawbacks and supporting treatment conditions.

educators to deliver the constant contact needed for weight loss.

Our review also showed the occurrence of constant contact between subjects and the intervention provider. This finding is consistent with other studies which show that ongoing contacts on a biweekly to monthly frequency promotes weight maintenance [70-72]. In a six-month study comparing different frequency of contact for weight loss, subjects who received either high-frequency face-to-face or telephone contact with a dietitian lost more weight than those who received either low-frequency face-to-face contact with a dietitian or those assigned to a self-help intervention [73]. Behavioral literature indicates that constant contact with a coach is important to provide subjects with the support and motivation needed to practice weight control behaviors [70].

Several studies in our review included structured education or counselling sessions delivered either on an individual or group basis. A structured intervention simplifies the decision making process and helps the individual identify how to change; and the use of meal replacements to provide such structure can enhance dietary adherence [47]. Indeed, when compared to self-help, a structured approach to weight loss that included specific plans for diet, physical activity and cognitive-behavioral restructuring, given in addition to weekly group meetings, resulted in better weight loss [74]. Wing et al. showed that provision of structured meal plans and grocery lists complement the use of meal replacements and improve outcomes in a behavioral weight control program [75]. The delivery of education/counselling via group or individual basis has shown weight loss benefits. When matched to individual preference, group meetings provided better weight loss than individual meetings [76]. In managing chronic conditions, group meetings facilitate social support during which the exchange of resources helps a person increase feelings of well-being and cope with the change in lifestyle needed [77]. An Australian study showed that retention rates were better in subjects attending group meetings but weight loss was greater in subjects attending individual therapy. In explaining the weight loss difference, the authors stated that the bigger short-term weight loss seen with individual therapy may result from more intensive assessment and follow-up of individual habits required to be modified for weight loss [78].

Our review also showed that minimal intervention by healthcare providers, but with frequent monitoring strategies produced similar rates of weight loss and retention compared to studies with healthcare provider contact. The use of self-monitoring to support behavior changes necessary for weight loss has sound theoretical and empirical basis. Self-monitoring contributes to behavior changes necessary for weight loss as it enables the individual to develop self-regulatory skills such as evaluating and reinforcing progress made towards a goal behavior [79]. Two reviews of lifestyle and behavioral based studies also showed that self-monitoring of diet, physical activity, and weight change enhanced weight loss [80,81].

Our review has showed that intensive and extensive support strategies supplements the efficacy seen in meal replacement based weight loss studies. Extending these findings into real-life practice can have negative implications in an already burdened health-care system. Within a minimum contact situation, empowering patients with self-monitoring skills that complement the use of meal replacements could create an environment which supports weight loss. Another viable solution would be a partnership between clinicians and commercial weight loss programs to provide the necessary support needed for weight loss [82].

This review should be construed within its methodological limitations and subjective weighing of the studies chosen for the review. Firstly, the treatment conditions identified are based on secondary data from studies designed with weight loss at the main outcome. There was considerable heterogeneity in the reporting of treatment conditions, limiting our ability to identify conditions that act as major determinants of study success. Secondly, this review is biased towards the apparently healthy, Western, middle-to older aged female demographic. There is a lack of studies within the Asian region and also among adults with co-morbidities associated with obesity. Socio-demographical and cultural differences in illness behavior and medical care, exists within countries of the Asian region and between Asian and Western counterparts. Additionally, the presence of co-morbidities associated with obesity presents a need to manage multiple behavior changes simultaneously. Both situations can influence factors that constitute optimal treatment conditions. As such, more translational research is needed to find viable methods of integrating the use of meal replacements for weight loss within these communities.

Conclusion

The use meal replacements has to be provided as part of a low calorie diet plan that supports overall lifestyle change to maximise weight loss. Incorporation of cognitive or psychological approaches are needed to motivate participants for better adherence and success in weight loss achievements. The treatment conditions to support meal replacement use are no different from any other lifestyle intervention programs and would require intensive intervention and monitoring approaches. Health care providers should be aware of these treatment conditions when delivering a weight loss program using meal replacements.

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