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Dietary modifications for weight loss and weight loss maintenance

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ABSTRACT

Worldwide obesity rates remain at a rise, and to treat obesity is at the top of the global public health agenda. In 2013, the AHA/ACC/TOS obesity management guidelines were published, in essence suggesting that any dietary scheme seems to be effective for weight loss, as long as it can induce a sustainable energy deficit. In the present review, we update and critically discuss available information regarding dietary modifications for weight loss and weight loss maintenance, published after the 2013 guidelines. Regarding weight loss, we found no proof to support that a single dietary scheme, be it nutrient-, food group- or dietary pattern- based, is more efficacious of the other for achieving weight loss. For weight loss maintenance, published interventions point towards the same direction, although inconclusively. Most research explores the effect of weight loss regimes on weight loss maintenance and not the effect of the diet during weight loss maintenance, and this literature gap should be more thoroughly investigated.

Contents

1. Introduction

With the worldwide trends of Body Mass Index (BMI) at a rise [1], obesity remains an important public health problem. Prevention of obesity at a societal level calls for a series of environmental interventions; and for the obese individual a number of lifestyle changes are required for achieving and maintaining a healthy body weight. Research regarding dietary weight loss regimens is abundant: there are thousands of studies on the more or less effective ways to achieve a lower body weight. In 2013 the American College of Cardiology/American Heart Association Task Force on Practice Guidelines reviewed the available evidence from observational studies, randomized trials and meta-analyses, and produced a report updating the guidelines for the

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management of overweight and obesity [2]. The report strongly recommends the prescription of a hypocaloric diet for obese or overweight individuals who would benefit from weight loss, as part of a comprehensive lifestyle intervention. It has been acknowledged that there are several techniques for reducing dietary energy intake, using a variety of dietary approaches and patterns: in essence, any dietary scheme is effective for weight loss, as long as it can induce a negative energy balance. The key points of these guidelines are summarized in Table 1.

Once the period of weight loss is carried out, ex-obese individuals face new challenges related to weight loss maintenance. Several physiological alterations that occur after weight loss, i.e. reductions in fat-free mass and possibly persistence of the adaptive thermogenesis phenomenon, changes in leptin, ghrelin and other gut peptides and imbalances in neural responses, predispose, more or less, to weight regain [3,4]. Thus, it is important to identify the behavioral and/or clinical characteristics of successful weight loss maintainers in order to provide specific dietary advice for weight loss maintenance. Data from weight control registries provide important information in this area, but sufficient clinical trials in this area are still lacking. In relation to dietary intake, the US National Weight Control registry indicates that maintainers adhere to a restrictive dietary plan, similar to that followed for weight loss [5]. European maintainers, on the other hand, appear to be less modest in energy intake: a large Mediterranean cohort of maintainers reported mean energy intake of ~1800 cal per day [6], and successful participants of the Portuguese registry consumed ~2200 cal per day [7]. High protein intake has also been recorded as a frequent behavior among maintainers in several weight control registries [6,7].

In the present review, we update and critically discuss available information regarding dietary modifications (by providing either food and/or dietary advice) for weight loss and weight loss maintenance following the 2013 guidelines. We searched PubMed for studies published after 01/2013, to avoid overlap with the latest guidelines mentioned above [2]. We focused on macronutrients, food groups or whole-diet approaches. Combinations of the following keywords were used: diet (low/high carbohydrate, low/high fat, high protein), food groups (namely dairy, fruits, vegetables, cereals, grains, legumes, pulses, nuts, oils, red/white meat, animal products, beverages, alcohol), dietary patterns, weight loss, weight loss maintenance. In addition, the references of the retrieved studies were scanned for similar research. In order to include the most powerful evidence, we reviewed data only from intervention studies and clinical trials in obese/overweight individuals with a major outcome weight loss. To minimize the possibility of insufficient power or type 2 error and we further applied the following selection

Table 1
Key points of the AHA/ACC/TOS guideline for the management of overweight and obesity in adults [2].

	Weight loss	Weight maintenance
Assessment of need to lose weight	Yes: BMI ≥ 30 kg/m^2 or BMI between 25.0 and 29.9 kg/m^2 with additional risk factors No: BMI < 25 kg/m^2 or BMI between 25.0 and 29.9 kg/m^2 without additional risk. Advice to avoid weight gain.	Not applicable.
Goal of intervention	Weight loss of 5% to 10% of baseline weight within 6 months.	Not specified.
Baseline clinical evaluation	• Assessment of risk for cardiovascular disease and diabetes (physical examination, fasting blood glucose and lipids, blood pressure, waist circumference if BMI < 35 kg/m^2) • Weight and lifestyle history: may assist in providing appropriate advice on lifestyle change • Assessment of readiness to make lifestyle changes	Not applicable.
Essential components of intervention	• Prescription of moderately reduced-calorie diet • A program of increased physical activity • Use of behavioral strategies to facilitate adherence to diet and activity recommendations	Not specified.
Intensity and type of intervention	The most effective behavioral weight loss treatment is an in-person, high-intensity (i.e. ≥14 sessions in 6 months). Electronically delivered interventions (e.g. by the phone or internet) that provide personalized feedback may be effective, although to a lesser extent.	Patients should be advised that participation in a long-term (≥1 year) comprehensive weight loss maintenance program, with monthly or more frequent contact, in person or by the telephone, can improve successful weight maintenance.
Energy intake recommendations	One of the following strategies: • 1200–1500 kcal/day for women and 1500–1800 kcal/day for men • Energy deficit of 500 kcal/day or 750 kcal/day or 30% energy deficit • Ad libitum approach, where a specific energy deficit is not prescribed, but lower energy intake is achieved by restriction or elimination of particular food groups or provision of prescribed foods.	Consumption of a reduced-calorie diet (needed to maintain lower body weight) is associated with better weight maintenance.
Type of diet	A variety of dietary approaches can produce weight loss, if reduction in energy intake is achieved.	Not specified.
Physical activity recommendations	Increasing aerobic physical activity (such as brisk walking) at ≥150 min per week (equal to ≥30 min/day most days of the week).	Higher levels of physical activity, approximately 200–300 min per week are recommended to maintain lost weight or minimize weight regain in the long term (>1 year).
Behavior therapy strategies	A structured behavior change program that includes regular self-monitoring of food intake, physical activity and weight. Frequent (i.e. weekly or more often) monitoring of body weight in the maintenance phase.	
Suggestions for the intensity of the interventions	At least 14 face-to-face sessions (either individual or group) over a period of at least 6 months.	Not specified.
Pharmacotherapy	May be helpful for achieving weight loss. Should be considered as an adjunct to comprehensive lifestyle intervention, to reinforce lifestyle change and help achieve targeted weight loss and health goals.	Not specified.
Bariatric surgery	Proposed as an option in those individuals with BMI ≥ 40 kg/m^2 or BMI ≥ 35 kg/m^2 with obesity-related comorbid conditions who are motivated to lose weight and have not responded to behavioral treatment (with or without pharmacotherapy).	Not applicable.

criteria: a minimum sample size of ≥50 adults with BMI ≥ 25 kg/m^2, a minimum duration of 2 months for weight loss studies and of 1 year of follow-up for weight loss maintenance studies and an appropriate control group, when feasible. Secondary outcomes, in specific cardiovascular and metabolic risk reduction, body composition assessment, as well as safety issues, are also reviewed, as an index of the quality of each dietary modification. Meta-analyses published during this time frame were also included, as they may provide a robust estimate, especially when controversy exists between single studies.

2. Dietary Modifications During Weight Loss

2.1. Modification of Macro-Nutrient Composition of the Diet

In the context of calorie restriction, available research has investigated the impact of schemes that deviate from current recommendations for the composition of diet. Hereafter, we attempt to roughly categorize these approaches in relation to increases or decreases of specific macronutrient intake.

2.1.1. Dietary Schemes Based on Alterations in Carbohydrate and Lipid Composition of the Diet

Low- or very low-carbohydrate ketogenic diets have been popular in weight management. There is some evidence that these diets maybe associated with increased satiety and decreased hunger and desire to eat [8], and with a lower decrease in the satiety peptide YY, compared to low fat diets [9]. Despite the apparent difficulties in the implementation of very low-carbohydrate diets, it has been shown that adherence to such restricting schemes is similar with a low fat diet, assessed as a composite score combining attendance to counselling sessions and urine ketone presence [10]. Similarly, adherence rates to low-carbohydrate and low-fat diets were found to be comparable, irrespective of whether or not participants were allowed to choose the intervention arm [11].

Four [12–15] out of five [12–16] clinical trials that have employed a very low carbohydrate diet (typically less that 50 g of carbohydrates daily) reported a greater weight loss compared to a moderately energy restricted diet within a time period ranging from 4 to 12 months. Similarly, four meta-analyses have concluded that very low-carbohydrate ketogenic diets [17,18], with <20% of energy intake as carbohydrates [19] and all low carbohydrate diets [18,20] may be superior compared to a low fat diet. A major issue in these trials is the selection of the appropriate control group, as low carbohydrate diets may typically not have a specific calorie restriction goal. In most cases the control diet was a low fat diet, with [12,13] or without [14,15] energy restriction. Thus, it is possible that the beneficial effects of the low carbohydrate intake observed in most of these trials is the result of a profound decrease in energy intake, compared to the control diet, and the concomitant energy deficit that would inevitably produce a greater weight loss.

Some other clinical trials have assessed the impact of variations in carbohydrate and lipid content of a hypocaloric diet on weight loss, using higher amounts of carbohydrates compared to very low carbohydrate ketogenic diets. All these trials have consistently shown that a low carbohydrate diet (ranging from 14% to 45% of energy provided) produced equal weight loss compared to an isocaloric diet with higher carbohydrate content [21–24]. In agreement with these results, three published meta-analyses do not support a beneficial effect of moderate low carbohydrate diets on weight loss, either in short or longer term, compared to an isocaloric control diet [18,25,26].

The effects of very low carbohydrate diets on cardiovascular risk factors have been examined in many meta-analyses. Their results suggest that these diets produce a significant decrease in serum triglycerides; compared to the low fat diets, with a concomitant higher decrease in LDL-cholesterol, but also a decrease in HDL-cholesterol [17,19]. On the other hand, a meta-analysis that compared low fat versus low carbohydrate diets concluded that low fat diets produced higher decreases in LDL-cholesterol, but also in HDL-cholesterol and lower decreases in serum triglycerides [27]. Unfortunately, the two dietary approaches used in the aforementioned comparisons (i.e. very low or low carbohydrate diets compared to low fat diets) were not matched for energy intake and thus the observed results could be attributed, at least in part, to differences in energy intake during the trials. Interestingly, in a clinical trial testing a low fat diet (20% of energy) and a low carbohydrate (40% of energy) diet for 52 weeks in overweight women, favorable changes in serum triglycerides, LDL- and HDL-cholesterol were reported at the middle of the trial for both intervention arms, while at the end of the trial levels were not different compared to baseline [24]. In parallel, body weight decreased until the middle of the trial, with a plateau and a small regain thereafter. Thus it is possible that the cardio-protective effect of a weight loss diet could be the result of the degree of calorie restriction per se, with the contributions of carbohydrate and of fat intake having rather minor influence.

The safety of very low carbohydrate diets has been also questioned. A four-month very low carbohydrate ketogenic diet did not produce significant alterations in blood levels of liver alanine and aspartate aminotransferase, plasma uric acid and total bilirubin, or acid base status compared to low calorie diet [12,28]. Some adverse events, such as asthenia, headache, nausea, muscle weakness and fatigue are transitory, while others, such as hair loss and constipation have been reported by some volunteers even after 4 or even 12 months [13]. Long-term safety of these diets has not been well documented, and their longitudinal endorsement may not be an option, especially in light of a recent meta-analysis suggesting a U-shaped relationship between long-term carbohydrate consumption and mortality [29]. However, they may be the method of choice for weight loss management in the short term, when combined with a dietary scheme that could provide nutrient adequacy. In this context, a biphasic 40-day low carbohydrate diet with an intermittent 4-month period of a normocaloric Mediterranean type diet led to ~15 kg of weight loss in obese individuals over a total of 12 months [30].

2.1.2. Protein Intake for Weight Loss

A high protein intake during a weight loss diets has been thoroughly studied, mainly as a means to spare lean mass. However, evidence from clinical trials published following the 2013 guidelines is not consistent. A study that allocated a diet with a protein content of 1.34 g/kg body weight over 6 months [31] and another one a protein intake of 34% of total energy intake over 9 months [32], compared with isoenergetic standard-protein diets, concluded that increased protein intake is associated with higher percentage of weight loss. A secondary analysis of the POUNDS lost study, the largest single study to date in terms of sample size and duration to examine the question of diet composition on weight loss, concluded that a high urea to creatinine excretion ratio, used as a marker of protein intake, was associated with a higher weight loss [33]. On the other hand, many studies of duration ranging from 2.5 to 24 months have failed to detect a beneficial effect of a high protein hypocaloric diet on weight loss, as compared to a standard protein, isoenergetic diet [34–40]. Similarly, supplementation of a hypocaloric diet with milk protein did not result in greater loss, compared to a standard protein diet [41] and a high protein diet supplemented with 3 extra servings of soy protein produced also the same weight loss with a control high protein diet with non-soy proteins [42]. Finally, omnivore diets have been found to produce similar results in weight loss compared to lacto-ovo-vegetarian diets [43–45].

The effect of a high protein hypocaloric diet on body composition has also been examined. The two trials that have shown a beneficial effect of a high protein diet on weight loss have failed to detect a beneficial effect on sparing of fat free mass or decreases in abdominal fat, waist circumference or waist to hip ratio [31,32]. Interestingly, when a hypocaloric diet was combined with resistance exercise for 4 months, the gains in lean mass were similar in the high protein or the control diet [46]. Trials that have failed to observe a beneficial effect on weight loss [36,37,47] and a relevant meta-analysis [48] have also found similar changes in

body composition indices in a high and a standard protein diet. In a trial with a pre-determined goal of a weight loss of 10% of initial body weight, body composition changes were evaluated under a hypocaloric standard protein diet, supplemented or not with whey protein [49,50]. Lean body mass decreased in both groups; however, the contribution of fat free mass on weight loss was higher in the standard protein group [50]. Thigh muscle volume decrease, as assessed by magnetic resonance imaging, was higher in standard protein group at 5% weight loss, but differences between groups were not significant at 10% weight loss [49].

Regarding cardiovascular risk factors, all clinical trials [31,32,41,51] and a meta-analysis [48] have concluded that a high protein diet does not confer a benefit regarding changes in serum triglycerides, HDL- and LDL-cholesterol over a standard diet during weight loss. Most studies have also found similar effects of both diets in blood pressure and surrogate measures of insulin resistance [31,51], and glycated hemoglobin in diabetic individuals [35] or individuals with the metabolic syndrome [31]. One study that reported a higher weight loss in the high protein arm found a greater decrease in systolic blood pressure in this group and also a greater decrease in insulin resistance, assessed by the homeostatic model [32]. On the contrary, a trial that included a goal of weight loss of 10% of initial body weight found that a high protein diet prevented the weight loss induced improvement in insulin sensitivity that was observed in the standard protein group [50]. In this trial insulin sensitivity was assessed as rate of glucose uptake during a hyperinsulinemic, euglycemic conditions. In addition, a high protein hypocaloric diet was associated with increased systemic inflammatory status in another trial, an effect that was exacerbated by increased consumption of animal protein [39]. Finally, diets high in protein have not been found to beneficially impact hunger and desire to eat [44], food cravings [52] or well-being overall [35].

In summary, a balanced hypo-caloric diet, containing at least the recommended protein intake, irrespective of food sources, seems adequate for weight loss management, with relevant literature not fully supporting an advantage of higher protein intake.

2.2. Energy Intake Manipulations

2.2.1. The Case of Intermittent Fasting for Weight Loss

Intermittent fasting refers to a repeated dietary scheme where energy intake is restricted by varying degrees for a predetermined short time period (typically a few days), followed by a short time period where energy intake is provided ad libitum, or near or in excess of energy requirements. Many studies have examined the efficacy of this scheme in weight management in overweight and obesity. Their findings, as well as the results from two meta-analyses [53,54] agree that intermittent fasting does not produce additional benefits on weight loss compared to a continuous energy restriction diet. Schemes that have been examined include an alternate day of energy provision of 25% and 125% of requirements [55,56] or a weekly program including 3 days of moderate energy restriction, 3 days of severe energy restriction and an ad libitum intake day [57]. Duration of interventions varied from 4 months to 1 year.

There is some evidence that participants in intermittent fasting protocols may experience difficulties in adhering to such a strict protocol. Indeed, in a study of one-year duration, dietary assessment every three months revealed that individuals in the intermittent fasting group consumed more energy during fasting days and less energy during the feast days [56]. Similarly with weight loss, intermittent fasting diets produced similar changes with control diets in body composition [53,56,57] and cardiovascular risk factors or insulin sensitivity [57], while the most prolonged study reported an increase in LDL-cholesterol at completion of the trial in the intermittent fasting group [56].

Given the lack of a benefit of intermittent fasting schemes on weight loss and the lack of evidence on long-term safety of such protocols, intermittent fasting should be advised only in cases where other options of weight management have failed.

2.2.2. Meal Replacement Formulas for Weight Loss

Another approach for weight loss that has been tested in several clinical trials is substitution of one or more meals daily with formula food products. A total meal replacement intervention providing 800 kcal daily in obese individuals for 6.5 months led to a greater weight loss, compared to a prescribed low fat dietary plan with an energy restriction of 500–750 kcal [58]. Another clinical trial tested a 6-month program that included total meal replacements by formulas providing 810 kcal daily for 2 months and gradual reintroduction of regular meals, in combination with behavioral support [59]. Greater weight loss was observed in the intervention group, compared to usual care (a diet program with modest energy restriction and behavioral support by a practice nurse), along with beneficial changes in waist circumference, insulin resistance and serum triglycerides. It should be noted that in the trials mentioned above observed changes in weight loss could be attributed to the intensity of the intervention as well as to the fact that the control group did not consume an isocaloric diet (in fact, the intervention group received a very low calorie diet, whereas the control group a moderate energy restriction diet).

Some other studies have compared less intensive meal replacement interventions with an isocaloric control diet. Replacement of two meals daily with a high protein formula in obese individuals for 3 months resulted in greater weight loss, compared to an isocaloric diet [60]. Replacement of one meal per day by a formula product for 6 months led to a greater weight loss and glycated hemoglobin reduction, compared to an isocaloric food-based dietary plan in diabetic individuals [61]. Similarly, a clinical trial in patients with the metabolic syndrome concluded that lifestyle education for weight loss, coupled with replacement of one meal by formula resulted also in slightly but significantly greater weight loss, compared with lifestyle education alone [62].

In light of the similar attrition rates for meal replacement strategies and conventional dieting observed in the above-mentioned studies [58–60,62], it might be concluded that meal replacement products may provide favorable results in a weight management intervention and could be considered as a treatment option.

2.3. Food Groups in Weight Management Programs

Moving a step forward from specific nutrients, studies have examined the effect of food groups on weight loss. Fruits and vegetables, as non-energy dense foods with a high content of fiber and anti-inflammatory constituents, have been investigated for their potential impact on weight loss. In the BeWEL study, an intervention targeting a 7% reduction in body weight through diet, physical activity and behavior change, participants with a weight loss >7% of initial body weight ate more portions of fruits and vegetables/day compared to those who achieved lower weight loss (<2%) [63]. Similar results were obtained in a 24-month behavioral intervention that included physical activity support and eating behavior change: a positive association was found between increases in fruits and vegetables consumption and weight loss, an effect that was mediated by increased self-regulation [64]. Moreover, it was observed that higher consumption of fruits and vegetables was associated with reduced consumption of other foods, namely dairy products, meat, bread products and sweets. On the other hand, in a clinical trial where participants were instructed to consume double portions of vegetables, weight loss did not differ significantly compared to the control weight loss diet [65]. Adding 500 mL of orange juice daily in a weight loss program did not produce differences in weight loss or body composition changes over 3 months relative to control group, but this intervention had beneficial effects on cardiovascular risk factors and insulin sensitivity [66]. A meta-analysis of clinical trials of duration of >2 months and with weight loss as outcome concluded that either recommendations to increase fruits and vegetables intake or provision of fruits and vegetables do not result in weight loss [67]. On the contrary, a meta-analysis of studies without a weight loss goal revealed

that increased vegetable and fruit consumption produced a small reduction in body weight or reduced gain, relative to controls [68].

Carbohydrate staples have been consistently blamed for the rising prevalence of overweight/obesity due to their increasing consumption along the rise of obesity [69]. However, a meta-analysis, including 32 clinical trials, found that pasta in the context of low-glycemic index dietary patterns significantly reduced body weight by −0.63 kg, compared with higher-glycemic index dietary patterns [70]. Thus, one may speculate that it is not the specific food group to blame but the context in which it is consumed. The fiber content of high carbohydrate foods has been also investigated in relation to weight loss. A clinical trial of 3 months duration compared a weight loss diet containing either whole-grain or refined-grain products [71]. Weight loss was similar in the two groups; however greater decreases in waist circumference, blood glucose and diastolic pressure were observed in the whole-grain products arm. A single blind randomized clinical trial tested whether an online weight loss program from a fully interactive website with breakfast cereals, given to the participants in a prescribed amount, versus a website giving standard advice on weight loss, was more effective regarding weight loss [72]: weight lost was greater in the first group compared with the second one and the same was true for the percent of body fat; however one could argue that the greater weight loss achieved was due to the more intensive intervention and to the cereals intake per se [72].

In relation to legumes, substitution of 30 g of animal protein with soy protein during a weight loss diet for 3 months also produced similar weight loss with the control group, but soy consumption was associated with greater reductions in total and LDL-cholesterol blood concentrations [73]. However, a meta-analysis of 21 randomized trials comparing the effects of diets containing whole pulses with comparator diets without pulses dietary intervention concluded that diets containing pulses resulted in a small but significant weight reduction of 0.34 kg over a median duration of 6 weeks [74].

Sweetened beverages and juices have gathered great scientific interest regarding their impact on weight loss [75]. A clinical trial in 78 obese individuals that were randomly allocated to an energy restricted diet or an energy restricted diet plus 500 mL/day of orange juice, observed that both groups had similar weight loss [66]. An alternative for the caloric beverages could be the beverages with non-nutritive sweeteners: a 1-year randomized clinical trial provided evidence that non-nutritive sweeteners beverages may be an effective tool to aid in weight loss and maintenance, among regular users of these beverages, when used as part of a behavioral weight loss treatment program [76]. However, another clinical trial of similar design, i.e. weight loss program with either substituting diet beverages for water or continue drinking diet beverages for 5 times/week after lunch in frequent diet beverages consumers, came to different results. The group that substituted diet beverages for water had greater decrease in weight and greater improvements in insulin sensitivity [77]. Of note, in the follow-up period of 12 months, the water group had greater additional weight loss and enhanced insulin sensitivity [78]. Similarly, Vazquez-Duran et al. found that a reduction in the consumption of sweetened beverages (caloric and non-caloric) and replacing it with plain water and tea/coffee without sugar, in addition to an isocaloric diet, could contribute to a better body mass index at 6 months, compared with subjects who did not change their consumption of sweetened beverages [79]. Nevertheless, a meta-analysis of clinical trials that provided low-calorie sweeteners in the context of a weight loss diet and trials that provided low-calorie versus sugar-based sweeteners in the context of habitual diet concluded that substituting low-calorie sweeteners options for their regular-calorie versions results in a modest, but significant, weight, fat mass and waist circumference loss [80]. It should be noted that substituting of full-calorie sweeteners with low-calorie ones and incorporating the latter in a person's diet are different behaviors that may have different implications on weight loss management, as in the first instance a dietary compensation is expected to occur, i.e. change in consumption of other food groups. Indeed, in a secondary analysis of a clinical trial, substitution of sugar-based beverages in frequent consumers by low-calorie beverages or water for 6 months led to a greater decrease in dessert consumption in the low-calorie beverages group, while substitution with water led to a greater increase in fruits and vegetables consumption. In a more recent trial, habituation with low calorie beverages (660 mL daily) for 5 weeks did not result in significant changes in energy, macronutrient intakes or selection of sweet foods under controlled of free-living conditions, compared to a control group receiving 660 mL water daily [81].

Nuts may also have the potential to beneficially affect weight loss attempts, due to their favorable effects on satiety which may result in reduced energy intake [82]. Clinical trials that have tested the hypothesis that a nut enriched reduced energy diet may favorably impact weight loss have produced controversial results. Supplementation with walnuts for 6 months [83] or with almonds for 3 months [84] at a level equal to 15% of total energy intake did not result to a significant difference in weight loss compared to the control groups. On the contrary, two trials that included supplementation with 30 g walnuts daily for 12 months [85] or with 50 g almonds daily for 3 months [86] reported greater weight loss compared to the standard diet. Regarding cardiovascular risk factors changes, a study found a greater decrease in LDL- and total cholesterol with walnuts consumption at 6 months [83], while another one found a greater decrease in LDL-cholesterol and a higher increase in HDL-cholesterol in the control group at 3 months, compared to the almond supplemented group [86].

There are some studies opting to investigate the impact on weight loss by adding or excluding from the diet various food groups. For example, an open-arm study in obese men examined the effects on weight loss when excluding highly refined foods, such as butter, vegetable oil, margarine, processed meat and sugary products, with no other restrictions concerning the diet [87]. After two years, participants had a modest weight loss of ~6% of their initial body weight.

In summary, dietary schemes that are focused on specific food groups have statistically significant, but minimal effects on weight loss. However, even if these interventions do not achieve a substantial weight loss they may provide benefits for cardiovascular and metabolic health and hence should be encouraged when weight loss strategies are not an option. Such interventions should be always examined in the context of total dietary intake, as promoting increased or decreased consumption of a food group may affect consumption of other food groups.

2.4. Dietary Patterns for Weight Management

Isolating specific nutrients or food groups has been criticized for providing a possibly misleading view towards real-life food and nutrients interactions and synergies in diet [88]. Hence, emphasis on dietary patterns and how they could potentiate weight loss brings additional insight towards obesity management. Popular dietary patterns are plant-based diets (i.e. vegetarian or vegan diets), traditional or population derived diets i.e. Mediterranean Diet, Nordic Diet or patterns that may be extracted from a posteriori analyses.

In a cluster analysis of 2 weight loss clinical trials, individuals adhering a non-healthy pattern and seeking weight loss, had greater chances of reducing energy intake and their body weight at 3 months, compared to those endorsing a pattern of higher quality [89]. On the contrary, in a web-based weight reduction program, allocation to a healthful eating pattern at baseline resulted in higher chances of >5% weight loss, over a 3-month period [90]. This pattern was characterized by increased consumption of vegetables, mushrooms, soya and herbs, cereals, dairy products and salads. Participants who changed to or remained in the healthful eating pattern had greater chances of being successful, highlighting the importance of overall diet quality for weight loss.

The Mediterranean dietary pattern is the most extensively studied pattern for various health outcomes, including obesity and weight management. It is a pattern characterized by high consumption of fruits, vegetables, whole grains and olive oil and everyday consumption of

fermentable dairy, nuts and seeds, giving emphasis on plant protein (legumes) and seafood instead of red meat, but also including wine consumption in moderation. The larger study completed so far including Mediterranean Diet is the PREDIMED study, with two Mediterranean Diet interventions arms, one supplemented with olive oil, the other supplemented with nuts; and advice for a low-fat diet as a control group. All diets were provided without a caloric restriction. Analysis of the results of this trial regarding weight changes during 5 years did not reveal a substantial difference between the tree arms, while waist circumference increased less in the Mediterranean Diet plus nuts group, compared to the control group [91]. Similar results between the three groups regarding weight change and glycemic control were obtained in diabetic individuals of the same study during one-year follow-up [92]. Changes in body weight, visceral fat, waist circumference and cardiovascular risk factors were also comparable in a 4-month energy restricted Mediterranean Diet and an isocaloric diet low in fat, moderate in carbohydrates and high in dietary fibers [93]. On the contrary, a non-randomized 3-month intervention in 116 Mediterranean obese adults at high cardiovascular risk, based on the principles of the Mediterranean diet along with health education, resulted in a significantly different weight loss compared with the control group [94]. However the observed differences in this trial could be merely attributed to differences in the intensity of the intervention, as the control group received only one educational meeting and monthly reinforcement messages. In a meta-analysis of 9 clinical trials in diabetic individuals studying the effects of Mediterranean Diet on weight loss, cardiovascular risk factors and glycemic control concluded that this plant-based dietary pattern had a favorable effect on all outcomes [95]. Discrepancies between the two meta-analyses may be attributed to the sample population (overweight or obese, versus diabetics) or the different definitions used for the Mediterranean diet in every single study and may indicate that the Mediterranean diet has more profound effects in patients with already established high cardiovascular risk.

Other dietary patterns have been examined to a lesser extend in the context of weight management. In a clinical trial in centrally obese participants, the New Nordic Diet (a dietary pattern high in fruits, vegetables, whole grains and fish), provided ad libitum, resulted in ~3.5 kg larger weight loss compared to a group receiving a diet that was similar to the average Danish diet [96].

Vegetarian diets have gained attention in recent years, mainly due to their cardio-protective effects [97,98]. In a meta-analysis of 12 randomized controlled trials with 1151 participants and median duration of 3.5 months, participants assigned to non-vegetarian diets lost 2 kg less compared to those assigned to vegetarian diet interventions [99]. This effect was more pronounced in vegan participants, and applied to a lesser extent in lacto-ovo-vegetarians [99]. Similarly, a clinical trial that compared five different diets on weight loss over 6 months concluded that weight loss was greater in the vegan diet, compared to pesco- and semi-vegetarian or omnivore diet, but not different compared to the vegetarian diet [100]. These results appear promising for overweight individuals that favor a more restrictive diet; however, their general application may be non-feasible for omnivore populations.

Based on the available information, there is no convincing evidence that a specific healthy dietary pattern is superior for weight loss, compared to another isocaloric healthy diet. Yet, specific dietary patterns may have health-enhancing effects beyond weight loss. Their applicability in weight management programs should be examined taking into account adherence and cultural issues, as dietary patterns derived from a specific population may not be feasible to other populations. This issue is essential in weight loss programs, where life-long changes in dietary habits are required for successful weigh loss maintenance.

2.5. Timing of Eating: The Chronobiology of Diet and Weight Loss

A growing body of evidence suggests that there may be variations in the efficiency of dietary energy utilization throughout the day. These variations may result from behavioral adaptations or circadian driven variations in physiology and energy metabolism [101] and may have implications in weight management. Some studies have provided post hoc analyses of the effect of distribution of energy during the day on weight loss during energy restriction interventions. In a study of a 3-month weight loss program, weight loss in those individuals that decreased breakfast eating frequency during the intervention was lower compared to those that did not change or increased breakfast eating frequency [102]. In a 5-month program, individuals were categorized into early eaters and late eaters, according to the timing of the main meal (lunch or dinner). Late eaters lost less weight during the intervention and skipped breakfast more frequently [103]. Similarly, excess weight loss after 6 years of bariatric surgery was 67% in morning types, relative to 58% in evening types [104]. Interestingly, in this study assessment of energy intake at the time of lowest weight achieved and at the end of the follow up was not different between the two groups.

Other studies have examined by design the effect of different energy intake distribution throughout the day on weight loss, in the context of a hypocaloric diet. Distribution of a higher amount of energy at the first half of the day, compared to an almost equal distribution during the day was associated with a greater decrease in body weight (~2 kg difference in weight change between groups), waist circumference, serum triglycerides and insulin resistance during 3 months [105]. Similar results were obtained in a study that included a high-energy breakfast and a low-energy dinner, compared to a low-energy breakfast and a high-energy dinner [106]. On the contrary, a 4-month trial came to different findings. This study included three intervention groups: a group that was advised to consume breakfast before 10:00 a.m., a group that was advised not to consume any food before 11:00 a.m. and a control group, all of them receiving dietary advice at the beginning of the study [107]. No difference in body weight change was observed among groups. It should be noted that the opposing results in this trial could be credited to the low intensity of the intervention and the accompanying small weight loss in all groups. Finally, in a study that compared the effect of high energy intake at lunch with high energy intake at dinner over 3 months, weight loss was greater in individuals assigned to the high energy lunch [108].

The macronutrient content of breakfast in relation to weight management has been poorly studied, despite the fact that a high protein breakfast has been found to produce acute satiety responses [109]. The only relevant study identified was conducted in diabetic individuals [110]. This trial included three energy restricted intervention groups with different breakfast: one with a high protein, high soy protein breakfast, one with a breakfast high in protein of various sources and one with a high carbohydrate breakfast. Weight loss after three months was 7.6%, 6.1% and 3.5% of initial body weight in the three groups respectively. These results highlight the potential importance of protein content of breakfast on weight management; however the evidence is still not conclusive.

It may be concluded that an early day chronotype in energy intake and especially allocation of a significant amount of daily energy intake at breakfast may beneficially impact weight loss, as also suggested in a recent review [109]. However, the lack of evidence from more prolonged clinical trials should be acknowledged, as there is the possibility of adaptations in the long-term that would eliminate the observed effect of chronotype on weight loss.

3. Dietary Modifications During Weight Loss Maintenance

Apart from observational research, discussed in the introduction section, recent evidence investigating dietary interventions for weight loss maintenance is scarce. Although most of the studies refer to rates of weight loss maintenance following specific dietary interventions for weight loss, there are also few clinical trials investigating the potential effect of different weight maintenance interventions following a

standard weight loss approach. Both types of studies will be presented below.

Intermittent energy restriction was described in a relevant section above as an energy intake manipulation, weight loss method. In relation to weight loss maintenance, Keogh et al. found that intermittent dieting using a week-on/week-off pattern was equally effective to continuous dieting in promoting weight loss maintenance after 1 year [111]. Similarly, the rate of weight loss does not affect the proportion of weight regained within 144 weeks in contrast to the widely-held belief that rapidly-lost weight is more quickly regained [112]. As far as the method used during the weight loss period is concerned, recent evidence indicates that the all meals provision approach is at least as effective or may have greater efficacy in weight loss maintenance compared to self-directed weight management programs [113].

A small number of studies have attempted to investigate the potential effect of specifically-designed weight loss maintenance programs. Despite the disappointing results by Pekkarinen et al., that found no success of an 1-year maintenance program in preventing or delaying weight regain in severely obese patients (the program was based on a series of behavioral techniques along with nutrition education) [114], there are few reports of better weight maintenance rates seen in patients receiving extended care. A maintenance intervention that focused on the cognitive and behavioral processes involved in weight loss maintenance and delivered primarily by telephone with decreasing frequency of contact managed to slow the rate of weight regain in obese adults at week 54 after the initial weight loss period [115]. Furthermore, continuation of meal replacements during the weight maintenance period has shown to have no benefit for weight regain, in a study that meal replacements were given free of charge during the 9-month maintenance phase of the intervention [116]. However, Christensen et al. found that meal replacements (used on a daily basis for replacing 1–2 meals) along with counselling every 3 weeks for 3 years were equally effective in maintaining a 10% body weight loss in the long term in obese patients with knee osteoarthritis compared to a maintenance program comprising intermittent treatment (3 annual intensive 5-week periods of low energy diets and counselling for 3 years) [117].

Manipulations regarding the macronutrient composition of the diet during maintenance period have also been tested. Participants on a high protein diet regained less weight than subjects on the low protein diets: in specific an increase in dietary protein content (+7% of total energy intake) in the context of an ad libitum diet reduces weight regain over 12 months after weight loss induced by an energy-restricted diet [118]. During the first 6 months, adherence to dietary compositions was optimized by providing >80% of all relevant foods for each of the different diet groups at no cost through a lab-based shop system, whereas during the whole 12-month period, subjects received guidance by a dietitian. On the other hand, Due et al. [119] recorded that either a high fat (40% of energy)–rich in monounsaturated fatty acids diet, a moderate fat–rich in fibers or a Western diet, were equally ineffective for weight loss maintenance, as all resulted in similar weight regain and body fat accumulation. Of note, protein intake was equal in all schemes, and attrition rate was highest in the high fat diet. Nevertheless, dieters with impaired fasting plasma glucose regained more weight on a Western diet, than on a moderate fat–high fiber diet [120]. Finally, replacing diet beverages with water, in female overweight or obese regular consumers of diet beverages was found to be an effective means for achieving not only weight loss but also weight loss maintenance [78].

4. Conclusions and Directions for Future Research and Clinical Practice

Scientific literature on diet and weight management published after the 2013 guidelines is still plentiful. In agreement with these guidelines, we conclude that a variety of dietary approaches may produce significant weight loss, if energy reduction is achieved. Summary findings of the studies on dietary modifications for weight loss in overweight and obese adults, published in the last 5 years are summarized in Table 2. A balanced hypo-caloric diet, containing at least the recommended protein intake was found adequate for weight loss. In relation to carbohydrate contribution, existing evidence indicates that a low carbohydrate diet produces equal weight loss compared to an isocaloric diet with higher carbohydrate content. There are also reports on the beneficial effects of a very low carbohydrate diet; however, recent evidence suggests that the safety of such an approach in the long term is questionable. Food-focused dietary regimes or specific dietary patterns may also produce weight loss as long as they induce changes in food intake and thus decreases in total energy and/or negative energy balance, besides the other beneficial effects they may have on health. Finally, well beyond weight loss per se, the maintenance of the lost weight remains the major challenge in weight management and in this area we do not have solid evidence to recommend specific dietary regimens.

More research is definitely needed in this area. As numerous biological and environmental factors may explain the inter-individual variability in response to a specific intervention, relevant studies should explore these factors and report on potential predictive models. Existing interventional approaches should be tested with long-term follow-up periods, aiming at maximizing adherence to a weight maintenance promoting lifestyle. The chronobiology of energy and nutrient distribution throughout the day has been poorly investigated so far and it is a promising area of research. Finally, weight loss and obesity management should be further explored under the sustainable diets/decreased carbon print paradigm.

Waiting for research advancements, and given that a wide range of dietary regimens provide comparable weight loss, Health professionals treating obese individuals should advocate a dietary plan that fits to individual preferences. Cultural context and potentiality for long-term adherence has to be considered. Clinicians should also advise patients that the adoption of certain dietary approaches, e.g. a pattern close to the Mediterranean diet, will produce significant health benefits beyond weight reduction. Last but to not least, weight loss maintenance should be an integral part of any weight loss intervention. This extended care should be evidence-based and again tailored to individual needs and personal burdens.

Table 2
Summary findings of the studies on dietary modifications for weight loss in overweight and obese adults, published beyond the 2013 AHA/ACC/TOC guidelines

Dietary intervention	Summary of findings
Very low carbohydrate diets	• Greater weight loss compared to a moderately energy restricted, and/or a low fat diet.
Low carbohydrate diets	• Equal weight loss compared to an isocaloric diet with higher carbohydrate content.
High protein diets	• No consistent evidence for a beneficial effect for weight loss and body composition of a high protein intake.
Intermittent fasting/severe energy restriction	• No additional benefit on weight loss, compared to the continuous energy restriction.
Meal replacements	• Greater weight loss, compared to conventional dietary plans.
Diets promoting specific food groups	• Without a definite energy restriction, only minimal weight loss. • Evidence for improvements in the quality of the diet and other health-enhancing benefits.
Diets close to the Mediterranean dietary pattern	• Benefits for weight reductiononly in the context of a hypo-caloric diet • Evidence for other health-enhancing benefits.
Diets with varying energy distribution throughout the day	• Greater weight loss when an early eating pattern is used.
Weight loss maintenance diets	• Lack of solid evidence on the most appropriate dietary approach for weight loss maintenance.

Conflicts of Interest

Mary Yannakoulia is the PI of the MedWeight, a study that was initially funded by the Coca Cola Foundation (2012–2015, KA 221).

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