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Diet and Exercise for Weight Loss
A Review of Current Issues

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Abstract

Obesity is a fast growing epidemic that is primarily due to environmental influences. Nutrition and exercise represent modifiable factors with a major impact on energy balance. Despite considerable research, there remains continued debate regarding the energy content and the optimal macronutrient distribution for promoting healthy and effective weight loss. Low-fat diets have been advised for many years to reduce obesity. However, their effectiveness has been recently challenged, partly because the prevalence of obesity continues to rise despite reductions in fat intake. There are also concerns regarding the methodology of clinical trials showing benefits of fat reduction on weight loss. Although often viewed as a fad diet, very low-carbohydrate (ketogenic) diets are very popular and several recent clinical trials indicate they are more effective at promoting short-term weight loss and improving characteristics of the metabolic syndrome than low-fat diets. However, there is a need to obtain long-term safety and efficacy data. Clearly, weight loss can be achieved with a variety of diet interventions but the effects on other health-related aspects also need to be considered and studied in more detail. Exercise can have positive effects on weight loss, weight control and overall general health, although debate exists concerning the most effective mode, duration and intensity of exercise required to achieve these effects. Importantly, any effective weight control treatment must consider a life-long plan or there will likely be weight regain. Perhaps the most challenging, but rewarding, question that faces researchers is how to predict individual responses to diet and exercise interventions.

There has been a rapid increase in obesity in the US, which cannot be totally explained by genetic factors,[1] highlighting the importance of environment or lifestyle choices as causative factors. Increased energy intake and a sedentary lifestyle represent the major targets for interventions aimed at combating this epidemic. A large body of literature exists on the effects of diet and exercise with no clear agreement among researchers on their short- or long-term efficacy. Many combinations of diet and exercise can produce weight loss, but if treatment is stopped, weight is regained. In this sense, overweight is not curable, but it is manageable if permanent lifestyle changes are made. Weight loss should not be the sole endpoint by which the effectiveness of a particular treatment is assessed. Effective interventions should also consider the impact on the composition of weight loss (e.g. ratio of lean and fat tissue), regional location of the weight loss (e.g. peripheral vs central), measures of physical performance (e.g. muscular strength, power and endurance, cardiorespiratory fitness), activities of daily living, how a particular intervention affects mental health and most importantly risk for disease (e.g. diabetes mellitus, coronary artery disease, hypertension). In this paper, we briefly discuss the role of

energy content and then overview the controversial, but pertinent, issue of fat restriction versus carbohydrate restriction on weight loss and weight control. The role of exercise is also summarised. We will not discuss dietary supplements, pharmacological or surgical treatments of obesity for which the reader is encouraged to consult other excellent reviews.[2]

1. Diet and Weight Loss

Weight reduction requires that energy expenditure exceed dietary energy intake. Despite a considerable amount of research dedicated to understanding the role of diet in mediating weight control, there remains disagreement regarding basic issues including the appropriate energy content, and perhaps more controversial, the ideal macronutrient distribution.

1.1 Energy Content

Manipulation of the energy content will impact the rate of weight loss. Very low-calorie diets will result in larger, more rapid reductions in weight loss, whereas a small to moderate reduction in energy intake will result in a small, steady rate of weight loss. The pertinent question becomes: does the rate of weight loss affect long-term weight maintenance or other health-related outcomes?

Although it is commonly recommended to achieve a slow, steady rate of weight loss to enhance long-term weight maintenance, this notion is not supported by all research.[3] Analyses of several weight-loss intervention studies have indicated that greater rate of initial weight loss is positively associated with sustained weight loss up to 5 years later.[4-9] A cause and effect relationship cannot be made from these types of studies but it does provide relevant information that could have important implications on prescription of energy content. In a randomised clinical trial, subjects who were prescribed a very low-energy diet for 8 weeks lost the same amount of weight as a group prescribed a moderate energy diet for 17 weeks. Data obtained after 1- and 2-year follow-up testing indicated that subjects consuming the very low-energy diet who lost the weight faster maintained the weight loss slightly better than the group who lost weight at a slower rate.[9]

Importantly, long-term retention of weight loss following an increased rate of initial weight loss must be accompanied by continued treatment that may consist of regular exercise, diet education and behavioural therapy, otherwise, significant weight regain is likely.[10] Although the concept of inducing a greater initial rate of weight loss to enhance long-term weight maintenance challenges conventional wisdom, some evidence exists to support this hypothesis. Hypothetically, a greater rate of initial weight loss could have psychological benefits by enhancing initial motivation, but this has not been adequately evaluated. The health effects of this approach have also not been adequately addressed, in particular, how the rate of weight loss affects body composition or regional fat loss.

1.2 Macronutrient Composition

Research is far from clear in determining the ideal macronutrient distribution for weight loss and weight maintenance and the safety/efficacy and advantages/disadvantages of the diverse approaches to weight control promoted in the lay press. Commercial weight-loss diets vary from ultra low low-fat (Ornish; Pritikin) to ultra low-carbohydrate (Atkins) and everything in between. Among researchers, the area given the most attention is restriction of dietary fat and currently this approach has been challenged with the resurgence of very low-carbohydrate diets. Here we discuss the diametrically opposed low-fat and very low-carbohydrate diets.

1.2.1 Dietary Fat

This question is a widely debated topic among weight-loss researchers.[11-13] Those who argue against a role of fat restriction in obesity management often site that the percentage fat intake in the US has decreased at the same time the prevalence of obesity has dramatically increased,[14,15] yet this cannot be used as a sole argument because other factors may explain this trend such as greater physical inactivity. Those in favour of targeting fat restriction point to the greater caloric density of fat and argue high-fat diets favour passive and active over consumption of energy.[16] In support of fat restriction as being important for weight maintenance, observational data from the National Weight Control Registry has shown that individuals who maintained an

average weight loss of ~13.6kg for an average of 5.5 years are consuming a low-fat diet (~24% of energy from fat) and expending approximately 11830 kJ/week through physical activity.[17] Despite the importance of this issue, surprisingly few randomised clinical trials have examined the impact of diets differing in macronutrient composition on weight loss and maintenance.

Two recent meta-analyses both concluded that a reduction in dietary fat in an *ad libitum* diet facilitates weight loss.[3,18] In their review of 28 clinical trials mainly of short duration, it is estimated that a reduction of 10% in the proportion of dietary fat results in a reduction in weight of 16 g/day or a 5.8kg advantage if carried out to 1 year.[18] Willett[13] has criticised the interpretation of these meta-analyses arguing that serious flaws exists in many of the included studies because the control groups did not receive comparable treatment (diet advice and motivation), thus biasing a favourable outcome for fat reduction. Based primarily on results of four studies that included an adequate control group that received an intervention,[19-22] Willett[13] concludes that fat restriction *per se* does not enhance long-term (1 year or longer) weight loss or prevent regain of weight.

To complicate the issue even further, the effectiveness of fat reduction must be considered along with the effect on other health-related outcomes and body composition. There is overwhelming evidence that low-fat diets are effective in reducing total cholesterol and low-density lipoprotein-cholesterol (LDL-C).[23] There is concern, however, that low-fat/high-carbohydrate diets may increase risk for heart disease by increasing triglyceride and reducing high-density lipoprotein-cholesterol (HDL-C) levels,[24-26] a problem particularly relevant for people with the metabolic syndrome. Well controlled feeding studies indicate that low-fat/high-carbohydrate diets exacerbate these lipid responses when not associated with significant weight loss or increased physical activity.[23,27] Low-fat/high-carbohydrate diets have unfavourable effects on fasting triglycerides,[28,29] postprandial lipaemia,[30-32] HDL-C,[33-35] and size and composition of LDL-C.[36,37] Thus, in individuals with characteristics of the metabolic syndrome, restricting fat to very low levels could be counterproductive and, therefore, current dietary recommendations for these people may need to be modified.[38,39]

Another issue not adequately addressed in previous research is whether fat restriction affects the composition of weight loss. In a meta-analysis, Garrow and Summerbell[40] predict from regression analysis that for a weight loss of 10kg by dieting alone the expected loss of fat mass is 71% and when a similar weight loss is achieved by both diet and endurance exercise the expected loss from fat mass is increased to 83%. Whether fat restriction *per se* affects the composition of weight loss was not specifically addressed in the meta-analysis, but there is some indication that composition of weight loss might be more favourable with a diet higher in protein or lower in carbohydrate. Layman et al.[41] showed similar weight loss after 10 weeks of dieting in overweight women who consumed a diet of 30% protein, 41% carbohydrate and 19% fat versus an isoenergetic diet 16% protein, 58% carbohydrate, and 26% fat. However, the higher protein and lower carbohydrate diet resulted in significantly greater loss of fat and retention of lean body mass. In support of higher protein intake, fat loss was greater after 6 months of a high-protein versus a high-carbohydrate diet (both diets were equal in fat).[42] Higher protein intake has also been shown to result in better weight maintenance after weight loss. There is a need to perform more studies that directly compare diets of different macronutrient distribution; however, the limited data indicate that diets lower in carbohydrate and higher in protein may offer some benefit. Since accumulation of fat in the abdominal area is associated with insulin resistance, diabetes, dyslipidaemias and atherosclerosis,[43] diet studies should measure fat loss in this region.

The public has been advised to restrict fat intake for over 30 years with the primary justification to reduce obesity. Yet, it has been argued whether these recommendations were based on 'hard' science,[44] so the debate continues. Clearly, further comparative research with appropriate control groups that consider the associated health-related outcomes is needed to answer the question whether fat reduction is beneficial for weight control.

1.2.2 Low-Carbohydrate Diets

At the opposite end of the macronutrient distribution spectrum are very low-carbohydrate diets, which by nature tend to be very high in fat. There has been a resurgence of diets promoting a low-carbohydrate intake, perhaps due to the allure of fad diets or more likely their greater weight reducing potential. Regardless of the reason for their popularity, the recent findings of several randomised clinical trials comparing very low-carbohydrate and low-fat diets from independent laboratories requires that this 'non-conventional' diet approach be considered as a viable treatment for weight loss.

There were several studies performed in the 1960s and 1970s that showed greater weight loss with a very low-carbohydrate compared with a low-fat diet, even when diets contained the same energy content,[45] suggesting "a calorie is not a calorie" and, therefore, indicative of metabolic advantage. Metabolic advantage in this sense is defined as a greater weight loss with a very low-carbohydrate diet compared with a low-fat diet of equal energy content. Very little follow-up work was done until recently as evidenced by several recent randomised clinical trials again showing greater weight loss with very low-carbohydrate diets ranging from 3 to 12 months in duration.[46-49] Weight loss in these studies was on average 2-fold greater in subjects following the very low-carbohydrate compared with low-fat diet. Since food was not provided in these studies, it is possible less energy was consumed during the very low-carbohydrate diet, but energy intakes were similar between diets according to analysis of reported intakes.

Metabolic advantage is proclaimed to be a violation of the first law of thermodynamics and mistakenly used to support the notion "a calorie is a calorie" or that the macronutrient distribution does not influence weight loss independent of energy content. However, diets very low in carbohydrate utilise different chemical pathways that vary in efficiency, thus weight loss can indeed vary compared with an isoenergetic low-fat diet without violating the first law of thermodynamics. In other words, there can be and are differences in energy expenditure associated with the metabolism of different macronutrients, which could explain some of the differences in weight loss on diets of different macronutrient distribution with the same energy content. Very low-carbohydrate diets result in powerful metabolic adaptations to enhance mobilisation and utilisation of lipids while sparing carbohydrate fuel sources.[50,51] A metabolic advantage driven by increased protein turnover to fuel gluconeogenesis[52] is a plausible hypothesis to explain greater weight loss on very low-carbohydrate diet compared with a low-fat diet.[53] Very-low carbohydrate diets suppress appetite and *ad libitum* energy intake,[54] which may be partially due to the fewer food choices available on the diet, but a more likely explanation is the inhibitory effects of the primary circulating ketone body, 3-hydroxybutyric acid,[55] on appetite.

Some early reports show that very low-carbohydrate diets resulted in preferential loss of fat and preservation of lean body mass.[56-60] In agreement, we recently reported that a free-living 6-week very low-carbohydrate diet resulted in significant decreases in fat mass and increases in lean body mass in normal-weight men.[60] In a follow-up study, we showed that a very low-carbohydrate diet resulted in 2-fold greater whole body fat loss and 3-fold greater fat loss in the trunk region compared with a low-fat diet.[61] Although the mechanisms by which very low-carbohydrate diets increase fat loss have not been elucidated, a reduction in insulin is probably important in explaining a portion of the greater fat loss.[60] Inhibition of lipolysis occurs at relatively low concentrations of insulin with a half-maximal effect occurring at a concentration of 12 pmol/L and a maximal effect at a concentration of about 200–300 pmol/L.[62] Thus, even small reductions in insulin may be permissive to mobilisation of body fat on a very low-carbohydrate diet.

Much of the concern regarding very low-carbohydrate diets is related to potential adverse effects on heart disease. Studies have repeatedly shown that short-term very low-carbohydrate diets up to 1 year do not adversely affect risk factors for cardiovascular disease.[46-49,57] Studies consistently show that very low-carbohydrate diets reduce fasting triacylglycerols and postprandial lipaemia by 30–55%, which is associated with significant increases in HDL-C, decreases in total cholesterol/HDL-C ratio and a shift to a larger LDL particle distribution.[63-67] Insulin levels are also decreased and glucose is normalised. These beneficial effects are independent

of weight loss and tend to be more pronounced in individuals with the metabolic syndrome.

The metabolic syndrome is a highly prevalent multifaceted clustering of cardiovascular disease risk factors with key features of central obesity, insulin resistance, dyslipidaemia and hypertension, as well as chronic inflammation, procoagulation and impaired fibrinolysis.[68-70] Although the precise definition varies, it is estimated that almost 25% of adults aged >20 years and 40% of adults aged >40 years have metabolic syndrome in the US[71] and, therefore, it has been described as a healthcare crisis of epidemic proportions.[72] The basis of therapies at this time are interventions promoting weight loss and physical activity,[73] but diet represents another behavioural aspect that could have an important impact on the risk factors associated with metabolic syndrome. The dyslipidaemia of metabolic syndrome includes increased fasting and postprandial triacylglycerols, low HDL-C and a predominance of small LDL particles. As overviewed in the paragraph above, these lipid disorders are all improved on a very low-carbohydrate diet in addition to glucose and insulin, even without weight loss. Thus, carbohydrate restriction should be looked at as a viable treatment approach for metabolic syndrome.

Although the benefits of following a very low-carbohydrate, moderate protein and fat diet on fat loss look promising, they remain controversial[74,75] and long-term (>1 year) data on their safety and efficacy are not available at this time. Decreased appetite may work in concert with a metabolic advantage to facilitate weight loss on a very low-carbohydrate diet. Although adverse effects have not been observed in clinical trials, very low-carbohydrate diets may not be advisable for individuals with a history of gout and there is concern the diet may increase the renal acid load and, therefore, exacerbate the risk of kidney stones and osteoporosis.[76] Further long-term work examining these issues is of high priority as a large percentage of the public continue to follow a low-carbohydrate approach.

2. Exercise and Weight Loss

Section 1 focused on the use of dietary interventions in weight reduction or weight management. The other half of the energy balance equation (Δ energy stores = energy intake − energy expenditure) is also important in the process of weight reduction and/or weight maintenance. Organised physical activity is one component of energy expenditure that can be altered significantly. It is important to consider several factors when prescribing physical activity as a weight loss technique such as: (i) type or mode of activity; (ii) duration of the activity; and (iii) intensity of the exercise. Each of these components can be altered independently with different overall responses by the individual.

The mode of activity can range from lifestyle activities (e.g. gardening or mowing the lawn) to specific exercises (e.g. running, swimming or weightlifting). Lifestyle activities appear to be useful for weight loss when coupled with dietary intervention.[77,78] These activities must be carefully examined in light of the intensity demands of the activity, with more physically demanding activities providing the greatest results.

Resistance training is gaining acceptance as a useful tool in weight reduction interventions. This form of training has been thought to increase fat-free mass resulting in improved resting energy expenditure.[79,80] Although various intervention studies have been completed, the data do not suggest the use of resistance training either alone or an adjunct to endurance training and dietary intervention for enhanced weight loss.[79,80] However, other factors must be considered regarding resistance training. Enhanced strength gains should increase the ability of the overweight individual to perform other tasks (i.e. daily living tasks or physical activity), thereby increasing the likelihood of success in overall weight reduction strategies.

The effect of exercise intensity on weight loss has been studied recently in large-scale interventions. Various methods have been employed to assess or to prescribe exercise intensity such as a percentage of maximal heart rate or a percentage of maximal oxygen consumption ($\dot{V}O_{2max}$). The exercise habits of individuals in the US National Weight Loss Registry were assessed. The individuals spent at least one-quarter of their exercise time in vigorous physical activity.[17] A more recent study by Jakicic and colleagues[81] evaluated various combinations of intensity and duration on weight loss in overweight women. Females were placed into one of four

groups: (i) vigorous intensity and high duration; (ii) moderate intensity and high duration; (iii) vigorous intensity and moderate duration; or (iv) moderate intensity and moderate duration. All combinations of intensity and duration caused significant weight loss; however, no differences were reported between the types of intervention.[81] One reason for the findings was that the potential for total energy expenditure between the groups was smaller than proposed resulting in an inability to differentiate between the exercise stimulus in this study. Generally, the data supports the need for sufficient duration of moderate intensity exercise (55–70% maximal heart rate) for weight loss.

An additional aspect of intensity is often overlooked when prescribing weight loss interventions – substrate oxidation. The intensity of the activity should relate to the fuel sources utilised during the exercise with higher intensity exercise using primarily carbohydrates as a fuel and lower intensity using primarily fats as a fuel. However, Melanson et al.[82] reported no difference in 24-hour substrate oxidation following either a bout of exercise at 40% or 70% $\dot{V}O_{2max}$. In addition, there were sex differences in substrate oxidation in response to the exercise interventions with females oxidising a higher proportion of fat compared with their male counterparts. Melanson et al.[82] refute the notion that low-intensity exercise facilitates enhanced fat utilisation following exercise, although the low-intensity exercise is higher in fat oxidation during the exercise bout than the higher intensity exercise. Current understanding of the impact of exercise intensity on substrate oxidation remains unclear. During bouts of equivalent total energy expenditure, the intensity of the exercise does not directly relate to the absolute volume of fat oxidised. Further research is necessary in this area to more clearly delineate the influence of exercise intensity, in the context of total caloric expenditure associated with activity.

Current guideline recommendations suggest 30 minutes of physical activity, 5 days per week.[83,84] This recommendation has been effective in reducing the risks for health-related problems such as diabetes or cardiovascular disease. The 150-minute weekly dose of activity has not been supported in the weight-loss literature. Studies investigating varied durations found that ~150 minutes per week was less effective than >150 minutes per week at causing weight loss.[85] Based solely on the energy balance equation, increased duration of exercise should result in greater weight loss (assuming energy intake remains fixed). The literature on weight loss and weight management supports this claim. Although the literature remains controversial regarding the benefits of exercise on bodyweight loss, physical activity is the primary factor impacting bodyweight maintenance. It is important to utilise the guidelines described above to maintain weight loss over extended periods of time.

Public health recommendations and the current findings from intervention studies support the use of longer (200–300 minutes per day or greater) durations of activity.[84] The ability of individuals to develop habitual exercise behaviours is critical in long-term weight maintenance. It is important to provide exercise recommendations that are reasonable from a behavioural perspective. Recent epidemiological studies report a 1.8–2.0kg average annual weight gain for US adults.[86] Hill and colleagues[86] suggest small weekly increases in physical activities such as walking 1.6km (1 mile) per day. Walking 1.6km is approximately 2000 steps and would result in a caloric expenditure of 100–150 kcals. The addition of walking to small changes in dietary intake (~100 kcal/day) would result in weight maintenance for the average person. An additional 2000 steps per day (or 1.6km of walking) is a very mild intervention strategy that is easily obtainable and could be effective from a behavioural standpoint.

3. Conclusions

As the prevalence of overweight and obesity continues to rise in adolescents and adults, there is an urgent need to enhance our understanding of how modifiable treatments including diet and exercise affect short- and long-term weight loss and other health-related outcomes. Collectively, research supports the concept that a diet of any macronutrient composition can lead to short-term weight loss; so the more pertinent question becomes is there a specific dietary approach that is more effective at maintaining weight loss long-term, or perhaps more importantly, is there a diet that results in improved risk status for disease? Low-carbohydrate and low-fat diets each have advantages and disadvantages in

terms of their impact on risk for disease and there is a great deal of variation in the individual response to these diets. There is also evidence that diets higher in protein have some metabolic advantages over lower protein diets. Based on the lack of systematic studies comparing diets with different macronutrient distributions, it is difficult to make a standard recommendation. In fact, a single diet recommendation for the public is an unrealistic expectation given the variability among individuals in their response to the same diet. Future work focusing on methods to predict how individuals will respond to diet will be critical in moving the field of nutrition forward. The importance of exercise is less controversial, but few studies have examined the interaction of exercise with different diets. With respect to exercise alone, one important issue pertains to the question of what is the minimum effective dose to achieve health benefits. From a public health perspective, it seems prudent to conclude that that any exercise is better than none and more is probably better (using caution against excessive exercise). Strength training is encouraged to specifically enhance lean body mass and force production capabilities. Individual preevaluation is important so the effectiveness of any weight-loss treatment can be adequately evaluated in terms of any number of potential outcome measures. The treatment programme must include a permanent maintenance plan to be successful.

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