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NARRATIVE REVIEW

What is the best diet to recommend when treating obesity? Part 2. The choice between high-carbohydrate, high-fat and high-protein options.

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Abstract

Background. The objective of this three-part narrative review is to examine empirical data on the best type of diet to recommend to clients with established obesity that are being treated by an exercise-centred weight reduction programme. The present section of the review considers the relative merits of high-carbohydrate, high-fat, and high-protein options. **Methods.** Information obtained from Ovid/Medline, PubMed and Google Scholar through to August 2019 was supplemented by a search of the author's extensive personal files. **Results.** Any proposed diet must meet basic needs for protein, essential fatty acids and micronutrients, but once such demands have been satisfied there is a vigorous competition between proponents of high-carbohydrate, high-fat, and high-protein dietary emphases. Discussion has focused on the respective abilities of these choices to prolong satiety and encourage adherence to the recommended regimen, to conserve lean tissue, to stimulate thermogenesis and to encourage the metabolism of fat. However, to date randomized controlled experiments have shown relatively little difference in the long-term weight reductions achieved with the three options. The main determinant of success in weight loss seems not the choice of diet but rather faithful adherence to whichever regimen is chosen. **Conclusions.** The optimal approach to weight loss comprises a moderate but consistent reduction of daily energy intake and faithful adherence to a programme of moderate physical activity. There seems little difference in the long-term weight-loss achieved by following a high-carbohydrate, a high-fat or a high-protein diet. The challenge for health professionals is to develop safe methods of reaching an effective dose of exercise, and to sustain the enthusiasm of programme participants for both dieting and increased physical activity until weight-reduction goals have been met. **Health & Fitness Journal of Canada 2019;13(1):3-37.**

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Introduction

In considering the best diet to recommend to clients who are following an exercise-centred weight reduction programme, the first section of this review explored optimal eating patterns and the influence of the sugar and salt content of foods (Shephard, 2020). We now consider the nutrient needs that must be satisfied, and empirical evidence concerning the relative merits of high-carbohydrate, high-fat and high-protein options, leaving to the final section of the review questions of water and fibre content, and other possible dietary modifications that may help the process of weight loss.

Minimum daily need of macro-nutrients

The 2010 Dietary Guidelines for Americans concluded that *"There is strong evidence that when caloric intake is controlled, the macronutrient proportion of the diet is not related to losing weight."* (http://www.cnpp.usda.gov/Publications/DietaryGuidelines/2010/DGAC/Report/D- 1-EnergyBalance.pdf). However, there are several important caveats to this apparent freedom of dietary choice (Table 1). The nature of the diet proposed for the person who is attempting to reduce body fat (the bulk of the food and its rate of gastric emptying) may influence a person's feelings of satiety and thus his or her acceptance of the proposed physical activity and dietary regimen. Food choices may also modify the relative metabolism of fat and protein; the goal is to maximize fat loss, and to minimize the metabolism of lean tissue. Finally, and perhaps most importantly, the foods that are chosen must meet minimum daily needs of essential proteins and fatty acids, and provide adequate daily quantities of vitamins and micro-nutrients.

Daily protein needs

The dietary reference protein intake is 0.8 g per kg of body mass per day, and it is widely accepted that sedentary adults should eat a minimum of between 0.7 and 1.0 g/kg of good quality protein each day. However, an athlete requires larger amounts; current recommendations are for 1.3-1.8 g/kg of proteins rich in leucine and other branch-chain amino acids, particularly if the individual is engaged in resistance training (Lemon, Tarnopolsky, MacDougall, & Atkinson, 1992; Phillips & Van Loon, 2011). Larger than standard daily amounts of protein are also needed by pregnant and lactating women, and by the elderly, where lean tissue mass is tending to decrease (Wolfe, 2012).

Protein supplements are particularly important if a negative energy balance is being instituted in order to reduce body mass. Protein intake should then be at least 1.8-2.0 g/kg per day in order to minimize the metabolism of lean tissue (Layman et al., 2005; Mettler, Mitchell, & Tipton, 2010).

Fatty acid needs

Fatty acids of particular dietary concern are the polyunsaturated fatty acids, since these are not synthesized in the body. The European Scientific Committee on Food has published recommendations on polyunsaturated fatty acids requirements for healthy (but presumably sedentary) adults (Scientific Committee on Food, 1993). These recommendations suggest that adults should eat 2% of their daily energy requirements in the form of omega-6 polyunsaturated fatty acids, and 0.5% as omega-3 polyunsaturated fatty acids. The Food and Nutrition Board of the U.S. Institute of Medicine (2002) expressed these needs as amounts of linoleic acid (17 g/day in men, 12 g/day in women) and alpha-linoleic acid (1.6 g/day in men, 1.1 g/day in women). The European Food Safety Authority (2009) proposed slightly differing

Table 1. Factors influencing the choice of foods during dieting.
• Influence of choice upon satiety and adherence to the recommended regimen
• Impact of choice upon the relative metabolism of fat and protein
• Provision of minimum daily protein requirements
• Provision of minimum daily requirement of essential fatty acids
• Ensuring adequate vitamin and micro-nutrient intake

figures: a combination of 10 g/day of linolenic acid, 2 g/day of alpha-linoleic acid, and 250 mg/day of eicosopentanoic acid and docosohexaenoic acid.

Optimal choice of diet for individuals seeking to lose weight

Different authors have proposed the use of high-carbohydrate, high-fat and high-protein diets to counter obesity, sometimes with their objectivity clouded by commercial interests in a particular approach. We will look here at the relative merits of each of these options, noting that in terms of bio-energetics, a Joule of energy has the same significance, whether it is ingested in the form of carbohydrate, fat or protein.

Despite their energy equivalence, some foods seem more effective than others in limiting and/or correcting body fat accumulation, possibly because of their impact upon factors such as palatability, blood sugar levels, appetite, and satiety, all of which can influence a client's success in adherence to a proposed dietary regimen.

High-carbohydrate/low-fat diets

For many years, the adoption of a high-carbohydrate, low-fat diet was advocated as the ideal means of preventing obesity, while at the same time maintaining cardiovascular health and reducing an individual's risk of cancer. Specific formulations of high-carbohydrate low-fat options have included, among others, the LEARN, Weight-Watchers and Ornish diets. Some programmes further have made the wise recommendation that the bulk of the ingested carbohydrates should be in the form of foods with a low glycaemic index.

LEARN diet. Kelly Brownell (2000) introduced the LEARN diet (based on the acronym lifestyle, exercise, attitudes, relationships and nutrition) to counter what he perceived as the growing popularity of low-carbohydrate regimens. The LEARN regimen allows 60% of energy intake in the form of carbohydrate, and reduces fat intake to less than 10%, although no foods are forbidden *per se*. Rather, the emphasis is upon portion control and the counting of calories. The programme also encourages exercise, behavioural modification and stress management.

Weight-Watchers programme. The Weight-Watchers programme (https://weightwatchers.com) is commercially based. It encourages an increase of exercise and eating "more healthily," usually through the organizing of group meetings that discuss weight control and encourage the creation of a negative energy balance. No food is off-limits to participants in the Weight-Watchers programme, but the total daily energy intake is monitored by a points scheme, with high point values being assigned to items rich in either sugar or fat, and lower point values being attributed to lean meat.

Ornish diet. The Ornish diet, devised by Dean Ornish (Ornish, 1990) has some ties to Seventh Day Adventist philosophy. It is generally similar to the Weight Watchers programme, but it also includes regular moderate structured exercise classes and it has a strong vegetarian emphasis. Ornish recommends the eating of beans, legumes, fruit and vegetables to provide satiety, with daily fat intake being kept to less than 10% of total energy intake through a moderate use of low or non-fat dairy products such as milk, cheese and yogurt. This menu is supplemented occasionally by fish oil and other selected animal products; any meat must be unprocessed, from animals raised without the use of hormones. Those adopting the Ornish programme must take care to avoid incurring a deficiency of vitamins and iron, and Ornish's comments on the dangers of meat-eating have been criticized by some as exaggerated and lacking in scientific proof (Moyer, 2015).

Changes of body weight seen with high-carbohydrate low-fat diets. Howard, Manson, Stefanik, Beresford, Frank, Jones et al., (2006) demonstrated by a randomized controlled trial on 48,385 post-menopausal women, that seven years of adherence to a low-fat diet, taking carbohydrates mainly in the form of vegetables, fruit and grain, did not increase the risk of obesity relative to a control sample. Indeed, over a 7.5-year follow-up, the body mass of these individuals remained marginally less than that of controls (a difference of 0.4 kg).

Saris et al. (2000) also compared a high-carbohydrate/low-fat diet with the normal US diet in 398 moderately obese adults. Over a 6-month period, they found that those persisting with their usual diet gained 0.8 kg, but those following a diet high in simple carbohydrates lost 0.8 kg, and those on a diet high in complex carbohydrates lost 1.8 kg.

Meta-analyses of randomized controlled trials have generally confirmed that the adoption of a high-carbohydrate low-fat *ad-libitum* diet reduces the body mass of obese individuals by 3-4 kg relative to comparison groups. Astrup, Ryan, and Grunwald (2000) evaluated 16 trials lasting from two to 12 months, and involving a total of 1728 individuals. Unfortunately, none of these reports involved obese subjects. The average weight-loss with an *ad-libitum* high-carbohydrate, high-protein diet relative to an unmodified diet was 2.55 kg, and by extrapolating their findings for those of normal weight to those with a BMI of 30 kg/m^2, they estimated that obese individuals would have lost around 4 kg. A further analysis of 19 trials involving 1910 individuals (Astrup, Grunwald, & Melanson, 2000) found that those following a high-carbohydrate regimen had on average had a weight loss of 3.2 kg relative to control subjects, the decrease in weight being larger in the heavier members of their sample.

Bray and Popkin (1998) examined the findings in 28 clinical trials. They concluded that a 10% reduction in energy intake from fat was associated with a progressive reduction in an individual's body mass that averaged 16 g/day. But against the positive conclusions associated with a deliberate experimental reduction of fat intake, the US population has seen a secular trend to a decrease in the average fat consumption, from 37% t0 35% of energy needs, over a couple of decades (Willett and Leibel, 2002; Melanson, Astrup & Donahue, 2009), and this secular trend has been associated with a rise rather than a fall in the prevalence of obesity (from 25% to 33% of the U.S. adult population between 1971-74 and 1988/9).

Opinions on the optimal proportions of dietary fat and carbohydrate thus remain divided, with some authors recommending a high-fat/low-carbohydrate rather than a high-carbohydrate/low-fat diet. Willett and Leibel (2002) published a seminal contribution to this debate. They rightly criticized the dietary conclusions that had previously been drawn from inter-regional comparisons in the "Seven-

Countries" study. They pointed out that populations who were living on a supposedly idyllic Mediterranean diet were also distinguished from North American populations by many particularities of personal lifestyle, including the overall availability of food and daily levels of physical activity. Thus, direct comparisons of the prevalence of obesity and cardiovascular health between those following Mediterranean and North American diets had little validity. Within regions of comparable economic development, there was no convincing evidence of a long-term relationship between daily fat intake and the prevalence of obesity. In the short-term, a low-fat diet sometimes induced a modest decrease in body mass, but in randomized controlled trials lasting one year or longer, fat intakes ranging from 18% to 40% of total energy intake apparently had little influence on a person's level of fatness (Willett & Leibel, 2002). Specific comparisons of high-carbohydrate versus high-fat diets are discussed further below. Several theoretical advantages have been suggested for a high-carbohydrate diet (Table 2), but not all of these supposed merits are strongly supported by empirical data.

Low energy density of carbohydrates. Carbohydrate foods usually have a low average energy density relative to fat (an average of 17 versus 37 kJ/g), thus making carbohydrates bulkier and potentially giving rise to a greater immediate sensation of gastric filling, but because of their rapid digestion, this advantage over fats is quickly lost in the post-prandial period. The energy density of protein is also about 17 kJ/g, while that of ethanol is about 29 kJ/g. However, not all carbohydrates have the same energy density; much depends on the associated fibre (Burton-Freeman, 2000), fat and water content (DiMaglio & Mattes, 2000). The energy yield of fibres depends on the ability of intestinal bacteria to break them down. In humans, a typical yield is about 8

Table 2. Suggested advantages and disadvantages of adopting a high-carbohydrate diet during periods of negative energy balance.
Suggested advantages • Low energy density of food facilitates lesser energy intake • High carbohydrate tends to conserve muscle glycogen, thus reducing fatigue during prolonged exercise and avoiding a diet-related reduction of daily physical activity? • High carbohydrate intake enhances muscle glycogen and conserves associated tissue reserves of water? • High carbohydrate intake tends to maintain blood glucose, thus reducing proteolysis and conserving lean tissue during dieting? • Decreased fat intake possibly reduces risk of cardiovascular disease and various cancers
Suggested disadvantages • Increase of blood glucose stimulates insulin secretion, thus increasing appetite • Simple carbohydrates have a low satiety value, thus leading to poor programme adherence • Prolonged reduction of fat intake reduces ability of tissues to metabolize fat • Low fat intake may lead to deficiencies of essential fatty acids, lipid soluble vitamins and trace elements

kJ/g.

People seem better able to compensate for an increased intake of solid carbohydrates than for an equal energy intake that is ingested in liquid form. Thus, DiMaglio and Mattes (2000) found that the intake of 1.89 MJ/day in the form of jelly-beans was closely matched by a subsequent reduction in the consumption of other food items. However, in this study there was no subsequent compensation for the daily intake of 1.89 MJ in the form of a soda drink.

Impact of high-carbohydrate intake on muscle glycogen content and thus on ability to undertake habitual physical activity. One might anticipate that a high-carbohydrate diet would help to boost muscle glycogen, thus minimizing the feelings of fatigue and weakness that could otherwise reduce bouts of sustained physical activity in a dieter (Bandini, Schoeller, & Dietz, 1994).

Certainly, a high-carbohydrate diet is a well-accepted means of boosting carbohydrate stores in an athlete, and a meta-analysis of 20 trials in endurance runners found that the time to exhaustion during a bout of endurance effort was on average 60% longer when a competitor was on a high-carbohydrate rather than a high-fat diet (Erlensbusch, Haub, Munoz, MacConnie, & Stillwell, 2005). However, it is less clear that any such advantage of a high-carbohydrate diet is relevant to individuals who are engaged in prolonged dieting, since they are unlikely to perform sufficiently long bouts of endurance exercise to seriously deplete their muscle glycogen stores.

Two studies of dieters yielded conflicting results concerning the impact of a high-carbohydrate regimen upon habitual physical activity. A cross-over comparison of 2 iso-energetic diets found that in the short-term (8-13 days), the total daily energy expenditure, as estimated by the ingestion of doubly labeled water, was 10.2 MJ/day with an 83% carbohydrate diet, as compared with only 8.6 MJ/day when consuming an 83% fat diet (Ebbeling et al., 2018). But against this, a longer-term study of 21 young adults who had recently achieved a 10-15% weight loss (Ebbeling, Swain, Feldman, Wong, Hochey, Garcia-Logos, et al., 2012) found a greater decrease in daily energy expenditure when following a high-carbohydrate/low-fat diet (-1.8 kJ/day) than with a high-fat/low-carbohydrate regimen (-0.4 kJ/day). Factors leading to differences of energy expenditure with the two types of diet may include differences in metabolic efficiency and the availability of metabolic fuels, as well as changes in hormone secretion and alterations in autonomic tone.

Impact of a high-carbohydrate intake on body water stores. To the extent that a high carbohydrate intake helps to conserve muscle glycogen stores, such a diet also maintains a reserve of up to 2 L of stored water that is available if a person must exercise in a hot environment while drinking little or no fluids. While this is sometimes a helpful resource for an athlete, it is unlikely to be of great benefit to a sedentary person who is engaged in the more limited periods of exercise associated with a weight-reduction programme.

A loss of the glycogen-associated water has been suggested as one reason why a high-fat diet sometimes achieves a greater immediate reduction of body mass than a high-carbohydrate diet. Thus, Yang and Van Itallie (1976) found that over a 10-day period, 61% of the weight loss on a ketogenic diet was due to a depletion of stored water, whereas on a normal mixed diet only 37% of the weight loss of dieters was attributable to water. Likewise, Werner (1955) compared 3-week responses to a high-fat diet and an iso-energetic high-carbohydrate diet in 6 patients. He attributed slightly greater weight losses in 4 of his 6 subjects when they were on the high-fat diet to a larger loss of stored water in this situation.

Another comparison of a high-carbohydrate versus a high-fat diet, both delivering 5.6 MJ of energy per day, was conducted in 21 obese adults. It also found a greater weight loss with a corn-oil based diet (a decrease of 12.5 kg) than with a high-carbohydrate regimen (a decrease of 9.5 kg) over the first 28 days, but in this study there were no significant inter-group differences of water balance between high-carbohydrate and high-fat options over the period of observation (Rabast, Vornberger, & Ehl, 1981).

Impact of a high-carbohydrate diet upon proteolysis. If blood glucose levels are allowed to drop below a critical level, there is a stimulation of gluconeogenesis, with an increased hepatic synthesis of glucose using amino acids that are obtained by a breakdown of lean tissue, particularly muscle protein. Thus, to the extent that a high glucose diet helps to maintain blood glucose levels in a dieter, it may help to conserve lean tissue.

In practice, the extent of benefit is debatable. In support of this idea, Noakes, Foster, Keogh, James, Mamo, & Clifton (2006) restricted the energy intake of their subjects by 30%, finding a greater weight loss (but no difference in fat loss) with a low-carbohydrate than with a low-fat diet. They argued that the greater decrease in overall body mass (2.6% versus 2.1% over a period of 8 weeks) reflected a greater loss of lean tissue with the low-carbohydrate than with the low-fat diet. Meckling, O'Sullivan, and Saari (2004) also found a smaller loss of lean tissue with a high-carbohydrate than with a high-fat diet (1.0 kg versus 1.9 kg) in a sample of 31 obese adults who were following a 10-week regimen that provided daily energy intakes of 5.0-6.7 MJ for the women and 5.9-9.2 MJ for the men. However, when healthy athletes who had adapted to a low-carbohydrate diet undertook a single 2-hour bout of endurance exercise, gluconeogenesis was no greater than that of their peers who had followed a normal mixed diet; rather, it appeared that the body had adapted to the dietary change by metabolizing less carbohydrate (Webster et al., 2016).

The extent of proteolysis over a weight-loss programme depends substantially on the amount of protein that is included in the diet. Some investigators have argued that the loss of lean tissue may actually be smaller with a high-fat/low-carbohydrate than with a high carbohydrate diet, provided that adequate amounts of protein or amino acids are provided at the same time. Moreover, with a high ingestion of fat, muscle and brain develop an ability to metabolize ketone bodies, offering a mechanism to spare tissue protein (Manninen, 2006b). Finally, a high fat intake stimulates hormonal changes that favour anabolic activity.

Possible ancillary health benefits of carbohydrates. A high-carbohydrate/low-fat diet has been held to reduce the risk of cardiovascular disease and of certain types of cancer. Nordmann et al. (2006) found that such a diet led to lower low density lipoproteins (LDL) cholesterol levels relative to a high-fat diet, although few differences in cardiovascular risk factors between the two options were found in healthy women over a 6-month comparison of the two dietary options (Brehm, Seeley, Daniels, & D'Alessio, 2003). Further, an 8.1 year randomized prospective study of 48,835 post-menopausal women did not observe any significant reduction in the risk of cardiac or cardiovascular disease in those trial participants who reduced their fat intake (Howard, Van Horn, Hsia, Manson, Stefanik, Wassertheil-Smoller et al., 2006). Prentice et al. (2006) examined the same sample of 48,835 women in regard to invasive breast cancer, and again they found no advantage among adherents to a low-fat diet over 8.1 year of observations. Finally, a third analysis of data for this population, demonstrated that a low-fat diet had no effect upon the risk of developing colonic cancer (Beresford et al., 2006).

Impact of carbohydrates upon insulin secretion. One major problem with adopting a low-fat diet is that it is commonly associated with a high intake of sugars and readily digested carbohydrates such as white bread, white rice and pasta. These particular nutrients have a high glycaemic index. They cause blood sugars to spike shortly after their ingestion, with an increased secretion of insulin. The appetite is stimulated (Abete, Astrup, & Martinez, 2010; Barclay, Petocz, & McMillan-Price, 2008; Mente, de Koning, Shannon, & Anand,2009), and thus the individual's tendency to over-eating and weight gain is increased (Mozaffarian, Hao, Rimm, Willett, & Hu, 2011). Glucose is the most hyperglycaemic of the sugars, and fructose is the least (Marks, 1989). Carbohydrate sources other than sugars, such as whole wheat, brown rice and barley are metabolized much more slowly and are much less prone to cause a spiking of blood sugar (Koh-Bannerjee, Franz, Sampson, Liu, Jacobs, Spiegelman, 2004; Ledoux, Hingle, & Baranowski, 2011; Liu, Willett, Manson, Hu, Rosner & Colditz, 2003).

A small-scale trial (Howard, Manson, Stefanik, Beresford, Frank, Jones, et al., 2006) allocated 24 obese but otherwise healthy premenopausal women between a high-carbohydrate and a high-protein diet. This trial demonstrated, among other metabolic differences, that after 6 months the insulin sensitivity of the high-carbohydrate group was 0.9 relative to a value of 4.0 in those following a high-protein diet. Other scores were for the homeostatic model of insulin resistance 2.3 versus 1.4, for the Matsuda index 3.5 versus 6.7, and for a measure of pancreatic beta-cell function 6.3 versus 11.8.

Satiety value of a high carbohydrate diet. Many high-carbohydrate foods are digested quickly. They thus tend to have a low satiety index, and feelings of hunger return rapidly after eating. Perhaps for this reason, long-term adherence tends to be poorer for high-carbohydrate than for high-fat or high-protein diets (Abete et al., 2010; Foreyt, Salas-Salvado, Caballero, Bullo, Gifford, Bautista et al., 2009; Sacks, Bray, & Carey, 2009).

Blundell, Green, and Burley (1994) argued it is possible to devise a high-carbohydrate diet that avoids problems of short-lived satiety. Simple sugars should be replaced by vegetables, fruits and grains, thus ensuring a combination of lasting satiety and a low glycaemic index. Blundell et al. (1994) cited one experiment that compared the responses of women to two-week periods of a diet with 15-20% fat/70% carbohydrate, 30-35% fat/55% carbohydrate, or 45-50% fat/42% carbohydrate, with the protein intake held constant in each of these options. Energy intakes for the three test periods (8.7, 9.8 and 11.4 MJ/day) were clearly lowest with meals that predominated in carbohydrate content (Lissner, Levitsky, Strupp, Kalkwarf, & Roe, 1987). Another report found a high-carbohydrate/low-fat meal yielded the greatest satiety over a period a long as 4 hours (Van Amelsvoort, Van Stratum, Kraal, Lussenburg, & Houtsmuller, 1989). A comparison of the effects of adding 1.67 MJ of either carbohydrate or fat to a breakfast found that the addition of carbohydrate reduced immediate feelings of hunger, while the addition of fat had no such effect (Smith, Burley, Westrate, & Blundell, 1991); however, in this study the beneficial effect of the carbohydrate was relatively short-lived, and neither supplement modified the individual's food intake at a lunch-time meal. Blundell et al. (1994) compared the effects of carbohydrate and fat on food intake during the ingestion of a dinner meal (the immediate satiation effect) and after the meal (the satiety effect). Values of ingested energy were 5.6 MJ and 1.3 MJ for a high-fat meal, as compared with 2.8 MJ and 1.6 MJ for a high-carbohydrate meal, underlining that carbohydrates typically induced a greater immediate satiation than fats, but that this advantage was rather short-lived.

If carbohydrate is taken in the form of starch rather than sugar, it can yield both short- and long-term satiety (Stubbs, Mazlan, & Whybrow, 2001). Westerterp-Plantegna, Rolland, Wilson, & Westerterp (1999) noted a close association between satiety and dietary thermogenesis, and in their experiments a high-protein high-carbohydrate diet yielded a greater 24-hour satiety than a high-fat diet.

Impact of a high-carbohydrate diet upon fat oxidation. A prolonged high intake of carbohydrates modifies enzyme activity in the muscles and elsewhere in the body, reducing their capacity to oxidize fat, limiting the contribution of fat to overall metabolic activity (Spriet, 2014). Thus Blaak (2004) observed that obese individuals had a reduced ability to oxidize fatty acids after following a high-carbohydrate dietary regimen.

Impact of a high-carbohydrate diet upon the intake of essential nutrients. If a high-carbohydrate/low-fat diet is adopted, it remains important to ensure that a client maintains an adequate intake of protein, together with lipid soluble vitamins and the essential fatty acids that the body is unable to synthesize. Moreover, it is important that the ingested protein and essential amino acids are used for the maintenance and synthesis of lean tissue rather than serving as an immediate substrate for gluconeogenesis. The anabolic utilization of ingested protein is best achieved by timing the intake of any specific supplements to the period immediately before until 3 hours following exercise sessions (Hartman, Tang, Wilkinson. Tarnopolsky, Lawrence, Fullerton & Phillips, 2007; Rasmussen, Tipton, Miller, Wolf & Wolfe, 2000; Tipton, Elliot, & Cree, 2007; Zderic, Davidson, Schenk, Byerly & Coyle, 2004).

A fat intake of at least 1.0-1.2 g/kg per day should meet the needs for essential fatty acids (7-10 g/day of linoleic and 1-2 g/day of alpha-linoleic acids), as well as providing adequate quantities of lipid soluble vitamins and trace elements. If the ingestion of fat falls below this threshold, a vitamin E deficiency may result in oxidative stress (Sachek, Decker, & Clarkson, 2000), with an increase of pro-inflammatory and a decrease of anti-inflammatory immune factors (Venkatraman, Leddy, & Pendergast, 2000). The intake of zinc and other minerals may also be compromised by a low fat intake, leading to fatigue, a decrease of endurance performance and a risk of osteoporosis (Micheletti, Rossi, & Rufini, 2001).

High-fat/low-carbohydrate diets

In considering the merits of high-fat diets, it should be acknowledged immediately that not all research on weight loss has encouraged a shift from high-carbohydrate to high-fat dietary regimens. In one study, a covert increase in the fat content of food increased fat storage by 50-100 g/day because of the high energy density of the meals, suggesting that fat did not enhance satiety or lead to auto-regulatory adjustments in total energy intake or fat utilization (Prentice, 1989). Indeed, if food has a high energy density because of its fat content, this may encourage over-eating (Rolls & Bell, 1999). In particular, a high intake of saturated or trans-fat can sometimes predispose to weight gain. Thus, one comparison of covertly modified low, moderate and high fat diets found respective total daily energy intakes of 9.1, 10.3 and 12.8 MJ/day (Stubbs, Ritz, Coward, & Prentice, 1995).

The supposed advantages of a high-fat/low-carbohydrate diet (Table 3) are generally the opposite of the benefits claimed for a high-carbohydrate/low-fat diet (Table 2). One of the main advantages of the high-fat diet is that it tends to remain in the stomach for longer than a carbohydrate meal, thus reducing appetite and hunger (Martin et al., 2011), and encouraging adherence to a dietary programme that demands a low total energy intake. A high-fat diet also modifies tissue enzyme activities, encouraging a greater contribution of fat to overall metabolism. Further, it reduces the post-prandial insulin surge that stimulates appetite shortly after eating a high-carbohydrate meal., and it is generally associated with a greater loss of body fat as weight is reduced (Abete et al., 2010; Foreyt et al., 2009; Krieger, Sitren, Daniels, & Langkamp-Henken, 2006). However, the possibly favourable impact of a high-fat diet upon the conservation of the dieter's lean tissue mass remains a controversial

Table 3. Suggested advantages and disadvantages of a high-fat diet.
Suggested advantages • Slow gastric emptying reduces appetite and hunger. thus encouraging adherence to a programme of dietary restriction • Increases percentage contribution of fat to total metabolism • Reduces post-prandial insulin surge • Conserves lean tissue in dieters by encouraging metabolism of ketones? • Tendency to greater long-term decrease of body mass than that seen with a high carbohydrate dietary regimen? • Increases intake of polyunsaturated fat content, reducing the risk of cardiac disease?
Suggested disadvantages • High energy density may encourage over-eating • High intake of saturated- and trans-fat appears to encourage weight gain • High intake of saturated fat possibly increases the risk of cardiovascular disease and cancers • Low carbohydrate intake potentially increases the metabolism of lean tissue

topic. Indeed, if carbohydrate intake is severely restricted, it might be anticipated that the body would be more likely to break down muscle protein in an attempt to maintain blood glucose, thus actually increasing the loss of lean tissue.

Manninen (2006) and Westman, Feinman, Mavropoulos, Vernon, and Wortman (2007) have argued that if a person follows a low-carbohydrate diet, the muscles and the brain develop an ability to metabolize ketones in place of glucose, thus reducing the tendency to protein catabolism. Finally, a high intake of polyunsaturated fats can reduce the risk of cardiac disease (Ander, Dupasquier, Prociuk, & Pierce, 2003). Nevertheless, claims that a high fat intake leads to an increased daily energy expenditure and a preferential loss of body fat remain largely unsubstantiated (Hall & Chung, 2018).

Against these suggested advantages of a high-fat diet, a high energy density may encourage an increased total ingestion of energy. There have been suggestions that the quantity of food that is eaten is regulated largely by its bulk rather than its energy content, so that a diet rich in high energy density saturated fat is likely to encourage weight gain. A low carbohydrate intake might also increase the risk of proteolysis if prolonged endurance exercise were to be undertaken, although a brief review by Manninen (2006) concluded that this was not usually a problem, provided that the diet contained adequate amounts of protein. The relative weight losses achieved by dieters following high- and low-fat diets are compared below (Table 4). Suggestions that the adoption of a high-fat diet increases the risks of cardiovascular disease and various types of cancer now seem largely disproven (Beresford et al., 2006; Howard, Van Horn, Hsia, Manson, Stefanik, Wassetheil-Smoller et al., 2006; Prentice et al., 2006).

Potential formulations of high-fat/low-carbohydrate diets include the Mediterranean diet and the Atkins diet.

Mediterranean diet. Observational data have long associated an intake of foods rich in unsaturated fat (as exemplified by the typical traditional "Mediterranean diet") with a low incidence of obesity in the population concerned (Buckland et al., 2008). However, a causal relationship cannot be inferred from these inter-regional comparisons, as there have also been important social and economic factors distinguishing populations who have followed a Mediterranean diet, including a high average level of daily physical activity and other aspects of personal lifestyle that are not commonly found among people living in North America (Buckland et al. 2008).

The composition of diets classified as "Mediterranean" has varied substantially between studies, although typically the menu has included large amounts of fruit, vegetables, nuts, legumes and seeds; fresh locally grown foods; olive oil as the main source of lipids; moderate quantities of wine; fresh fish and other seafood; moderate quantities of dairy products, poultry and eggs; and only limited amounts of red and processed meats.

In a systematic review, Buckland et al. (2008) found 7 cross-sectional, 3 cohort and 11 interventional studies of people following Mediterranean diets. Just over a half of these reports (13/21), including 8 of the 11 interventions, found that adherence to such a diet on a long-term basis was associated with a reduced risk of becoming overweight or obese relative to other populations consuming different diets. In the remaining 8 reports, no benefit was observed, but there were no studies where a Mediterranean diet actually increased the risk of obesity. In some instances, the apparent beneficial effect was quite marked- for instance, in one cohort study men who adhered to a Mediterranean diet had a 29% lower risk of obesity than their peers (Mendez, Popkin, Jakszyn,berenguer, Tormo, Sanchéz, et al., 2006; Sánchez-Villegas, Bes-Rastrollo, Martínez-González, & Serra-Majem, 2005), and in a cross-sectional comparison the risk of obesity was as much as 51% lower than in peer groups (Panagiotakos, Chrysohoou, Pitsavos, & Stefanadis, 2006).

Advantageous features of a typical Mediterranean diet include a high fibre content, a low energy density, a low content of saturated- and trans-fat, a low glycaemic load, and a high-water content. Typically, such a diet is also rich in micro-nutrients, particularly anti-oxidants. The high fibre content tends to increase both satiety and satiation. Finally, the usual format of a Mediterranean diet is highly palatable, and this encourages long-term compliance with the prescribed regimen.

Atkins diet. Another form of low carbohydrate diet that became very popular during the first decade of the present century was the Atkins diet. The main feature of this commercially-backed regimen is an extremely low intake of carbohydrates (20 g/day, increasing gradually to 50 g/day to control ketosis), with corresponding increases in the intake of both fat and protein to produce satiety. Since adherents rely mainly upon eating slowly digested fat, the onset of hunger following a meal occurs later than with an energy-restricted high carbohydrate diet, and the prolongation of satiation with the Atkins diet is claimed to address one of the main reasons for poor adherence to a low-fat, carbohydrate-based regimen (Atkins, 2004). Other supposed advantages of the Atkins programme, such as the greater energy cost of metabolizing fat rather than carbohydrate, are questionable, although thermogenesis may be increased by a high protein intake (Halton & Hu, 2004). Moreover, although a rapid initial weight loss is usually seen in those following the Atkins diet, a part of this loss seems due to a loss of body water (including glycogen-bound water) rather than the metabolism of fat (Freedman, King, & Kennedy, 2001).

A randomized controlled trial compared the Atkins diet with 3 other weight-loss systems (the Zone, Weight-Watchers and Ornish diets). The 4 approaches yielded similar and quite small decreases of body mass (Dansinger, Gleeson, & Griffith, 2005). After 1 year, weight losses and adherence rates were respectively 2.1 kg (53%), 3.2 kg (65%), 3.0 kg (65%), and 3.3 kg (50%). Likewise, all 4 options yielded only small reductions in cardiac risk factors.

A second randomized controlled trial (Gardner et al., 2007) compared the Atkins diet with the Zone, Ornish and Learn diets in 311 premenopausal women over a 12-month period. Respective weight losses were Atkins (4.7 kg), Learn (2.6 kg), Ornish (2.2 kg), and Zone (1.6 kg), with the difference between Atkins and the Zone being statistically significant. In this study, the Atkins diet also had a more favourable impact on the lipid profile than the other diets.

Empirical comparisons of high-carbohydrate versus. high-fat diets. A high-fat/low-carbohydrate diet sometimes produces a greater long-term decrease in body mass than a low-fat/high-carbohydrate diet (Tables 4, 5, and 6), but this is not always the case. The evidence from epidemiological studies is conflicting, due to such issues as an under-reporting of energy and fat intakes, and failure to allow for inter-individual differences in habitual physical activity and dietary behaviour (Seidell, 1998). Moreover, differences of outcomes between the two dietary approaches in many instances have been relatively small, and the apparent advantage of a high-fat diet has on occasion reflected mainly a greater loss of body water than that induced by a high-carbohydrate diet, rather than any greater success in ridding the body of excess fat.

Melanson, Astrup, and Donahoo (2009) reviewed a substantial range of cross-sectional, prospective and interventional trials, finding an almost equal number of reports that affirmed and denied relationships between body mass and the daily intake of fat or saturated fat. They attributed the lack of agreement among individual reports to short periods of observation, high drop-out rates, reliance upon notoriously unreliable dietary recall sheets to determine a person's fat intake, differences in the intake of other macro-nutrient characteristics such as fibre content and glycaemic index, and (perhaps the most important factor in cross-sectional analyses) a failure to control adequately for covariates (particularly inter-individual differences in the volume of habitual physical activity).

Meta-analyses. The findings from some meta-analyses involving relatively large numbers of subjects are summarized in Table 4. Note that there is a considerable overlap of study participants between the five analyses that are cited.

Hession et al. (2009) evaluated 13 comparisons of low-fat and low-carbohydrate diets of >6 months duration that had been conducted between 2000 and 2007. They involved a total of 1222 subjects. Subjects allocated to the low-carbohydrate diets had a lower attrition rate than those in the low-fat programmes, and in terms of weight loss the former were more effective at six months (a weight-loss advantage of 4.0 kg); they remained at least as effective as the alternative at one year (with a small and statistically insignificant persistent weight advantage of 1.1 kg for those pursuing a low-carbohydrate regimen).

Hu et al. (2012) analyzed changes of body mass in 23 studies that compared the response to low-fat (<40%) with that to low-carbohydrate (<45%) diets over periods of 6-24 months. Trials were conducted between 1966 and 2011, and included a total of 2788 subjects. Decreases in body mass and reductions in waist circumferences were similar for the 2 types of diet, although the low-carbohydrate diets tended to yield more favourable changes in serum lipids (LDL and total cholesterol).

Mansour et al. (2016) analyzed data from 11 trials with a total of 1369 participants, finding that weight loss was on average 2.2 kg greater with a low-carbohydrate than with a low-fat diet, but against this advantage they noted a greater increase in LDL cholesterol readings with the low-carbohydrate programmes.

Nordmann et al. (2006) focused on 5 trials that had adopted an "intention to treat" method of analysis; there were a total 447 participants in these studies. At 6 months, the low-carbohydrate diets achieved a 3.3 kg greater weight loss than that seen with the low-fat diets, but by 12 months this advantage was reduced to a non-significant 1 kg. They concluded that low-carbohydrate diets were at least as effective as low-fat diets in terms of one-year weight loss, but noted that any favourable changes in triglycerides and HDL cholesterol seen with the low-carbohydrate programmes should be weighed carefully against adverse changes in LDL cholesterol.

Sackner-Bernstein et al. (2015) evaluated 17 trials with a follow-up period varying from 8 weeks to two years. There were a total of 1797 participants in their analyses. Over this period, low-carbohydrate diets (<120 g/d) produced a greater weight loss than low-fat (<30%) diets, with an average 2 kg advantage that was accompanied by a lower risk of predicted future cardiovascular events.

Two other recent reviews (Hall & Chung, 2018; Hamdy et al., 2018) concluded that a high-carbohydrate diet appeared to be cardio-protective, whereas a high-fat diet had the advantage of decreasing post-prandial glucose levels. However, in their view, the optimal choice of macronutrients for a weight-loss programme still required further research.

In summary, most of the above meta-analyses have pointed to a greater short-term decrease of body mass with a low-carbohydrate than with a low-fat diet, although the contribution of body water to this advantage remains unclear, and in the longer-term there seems to be little difference in the weight loss achieved by the two approaches.

Cross-sectional data. Among cross-sectional analyses of data, a recent report analyzed 22 articles exploring links between a high carbohydrate intake and body mass. It concluded that there was no conclusive evidence that a high-carbohydrate intake increased the risk of obesity relative to other options (Sartorius, Sartorius, Madiba, & Stefan, 2018).

Some of the larger individual cross-sectional comparisons are summarized in Table 5. Howarth, Huamg, Roberts, and

Table 4. Meta-analyses comparing the effectiveness of high-carbohydrate and high-fat diets in terms of weight loss (Note: many of these analyses overlap in terms of the studies included).

Authors	Sample	Findings	Comments
Hession et al. (2009)	13 studies >6 months duration, 1222 subjects	Wt loss favoured low CHO at 6 months (-4.0 kg); advantage of low CHO only 1.1 kg at 1 yr	Attrition averaged 36% (greater for low-fat than low-CHO)
Hu et al.(2012)	23 trials of low fat (<40%) vs. low CHO (<45%); 2788 subjects followed 6-24 months	No significant inter-group difference of body mass, waist circumference or metabolic risk factors	High fat diets less reduction in LDL and total cholesterol
Mansour et al. (2016)	11 trials, 1369 participants	Wt loss 2.2 kg greater with low CHO	Low CHO diet increased low LDL cholesterol
Nordmann et al. (2006)	5 trials with intention to treat analysis (low fat vs. low CHO), 447 participants	At 6 months, low CHO had 3.3 kg greater wt loss, at 12 months only 1 kg advantage (ns)	High fat diet gave adverse changes in LDL cholesterol
Sackner-Bernstein et al. (2015)	17 trials lasting 8 wk-2yr, low fat (<30%) vs. low CHO (<120 g/d), 1797 participants	Low CHO gave 2 kg greater wt loss and lesser risk of CV events than low fat	

McCrory (2005) assessed multi-linear relationships between diet and BMI in 4539 US adults. In both sexes, the BMI was positively correlated with fat intake, and in women the greatest risk of obesity was seen in individuals with a low fibre intake (<1.5 g/MJ), and a fat intake that provided >35% of their daily energy needs.

Kromhout et al. (2001) examined correlates of subscapular skin-fold thickness among 12, 763 middle-aged male participants in the Seven Countries study. The reported fat intake varied widely between subjects from the different countries, with averages ranging from 33 to179 g/day. Subscapular skin-fold thicknesses were inversely correlated with the physical activity index and with the reported fibre intake, but showed little correlation with dietary fat intake.

Mirmiran et al. (2006) analyzed relationships between BMI and fat intake in 1290 Tehranians. After controlling for age, habitual physical activity, educational level and smoking habits, positive relationships were seen in both sexes at all ages except in young girls (aged 10-18 years). The effects of fat intake were strongest in those aged >51 years. However, no relationships were found between BMI and protein or carbohydrate intake.

An analysis of the effects of a high-carbohydrate diet was made in 4451 adults participating in the Canadian Community Health Survey cycle 2.2 (Merchant et al., 2009). This analysis found that after adjustment for a number of variables including leisure-time energy expenditures, the prevalence of overweight/obesity (BMI > 25 kg/m^2) was inversely related to the individual's reported carbohydrate intake, with an odds ratio of 0.56 on comparing the fourth to the first quartile of this measure. Obesity was least likely in those taking 47-64% of their energy in the form of carbohydrates.

A study of 2379 US girls aged 9-10 years (Obarzanek et al., 1994) found that the variance in body mass index and also the average thickness of three skin-folds was best explained by the subject's age, hours of television and video watching, the percentage of energy obtained from saturated fatty acids (in black girls) or total fat (in white girls), and a physical activity score. However, these variables explained only 2-5% of the total variance in BMI.

Panagiotakios, Chrysohoou, Pitsavos, et al. (2006) reported that the waist/hip ratio and the BMI were inversely related to the individual's adherence to a Mediterranean-type diet in a sample of 3034 adults aged 18-87 years, after controlling for age, sex, physical activity metabolism and other possible confounders.

Phillips et al. (2012) examined the genetic characteristics of 1753 French subjects. In those carrying the fat mass- and obesity-related gene FTO rs9939609, they noted that the inherent tendency to obesity was exacerbated by a diet high in saturated fat and low in poly-unsaturated fat.

Satia-Abouta et al. (2002) analyzed data from 15,266 men aged 55-79 years who were involved in a prostate cancer prevention trial. They noted a small difference of fat intake between those with a normal weight and those with an excessive body mass (31.4% versus 34.3%), and after allowing for age, ethnic background, education and physical activity, it was estimated that the BMI increased by 0.53 kg/m^2 for each additional 2.1 MJ of energy consumed as fat.

Table 5. Comparisons of the body mass between those following low carbohydrate and low fat diets, as seen in some of the larger cross-sectional studies.			
Author	**Sample**	**Findings**	**Comments**
Howarth et al. (2005)	4539 U.S. adults	Percent energy derived from fat associated with BMI in both sexes	In women, highest risk of obesity was with low fibre intake, fat >35% diet
Kromhout et al. (2001)	12,763 middle aged male participants in 7 Countries study	Subscapular skin-fold thickness associated with phys. activ. index & fibre intake, but not with fat intake.	Average fat intake ranged from 33 to179 g/day
Mirmiran et al. (2006)	1290 Tehranians	After control for covariates, BMI correlated with fat intake (except in females aged 10-18 yr)	Largest effects seen in subjects aged >51 yr
Merchant et al. (2009)	4451 Canadian adults	BMI> 25 kg/m^2 inversely related to fat intake; Odds ratio from lowest to highest quartile of fat intake 0.56	Obesity least likely with 47-64% CHO intake
Obarzanek et al. (1994)	2379 girls aged 9-10 yr	Variance in BMI and thickness of 3 skin-folds related to age, TV watching, energy from saturated or total fat and phys. activ.	Only 2-5% of variance in BMI explained by analysis
Panagiotakos et al. (2006)	3042 men and women aged 18-87 yr old	Waist/hip ratio and BMI inversely related to adherence to Mediterranean diet	Relationship persisted after controlling for age, sex, physical activity, metabolism & other possible confounders
Phillips et al. (2012)	1753 subjects; interaction of FTO rs9939609 gene with saturated fat intake	High saturated fat and low polyunsaturated fat exaggerated risk of obesity in this specific population	
Satia-Abouta et al. (2002)	15,266 men aged 55-79 yr	Obesity associated with energy derived from fat	BMI increased by 0.53 kg/m^2 for 2.1 MJ increase in fat intake
Stookey (2001)	5783 Chinese adults aged 20-59 yr	Fat and protein intake did not predict obesity	Water intake negatively associated with BMI

Stookey (2001) examined a large sample of 5783 free-living Chinese adults aged 20-59 years. In contrast to a number of other reports, obesity in this population was unrelated to either fat or protein intake, but BMI was negatively associated with water intake.

In summary, 6 of the 7 cross-sectional trials listed above have shown a positive association between the risk of obesity and the fat content of the diet.

Longitudinal data. Data from individual longitudinal studies are summarized in Table 6. Baron, Schori, Crow, Carter, and Mann (1986) made a 3-month trial of low-fat/low-fibre versus low-carbohydrate/high-fibre diets in a sample of 135 overweight subjects who were restricted to a total energy intake of 4 MJ/day. The weight loss was somewhat greater for the second dietary option (5.0 versus 3.7 kg), but no measures were made to assess how far this was attributable to inter-group differences in water loss. Complaints of hunger were comparable for the two types of diet, and at the end of the 3 months, there were only minor inter-group differences in serum lipo-proteins. However, the low-carbohydrate group made more complaints about both constipation and the cost of their diet than those who were following the low-fat regimen.

Bazzano et al. (2014) randomized 148 adults between a low-fat (<30% fat, <7% saturated fat) and a low-carbohydrate (<40 g/day) diet, finding respective weight losses of 2.0 and 5.5 kg over a one-year study. The average fat loss was also greater with the low-carbohydrate diet (1.8%) than with the low-fat regimen (0.1%).

Brehm et al. (2003) compared the effects of a low- fat diet with a very low-carbohydrate diet in 53 healthy obese women. At 6 months, decreases in both body mass (3.9 versus 8.5 kg) and body fat (2.0 versus 4.8 kg) were less for the low-fat (30%) than for the very low-carbohydrate regimen (20 g/day rising to 40-60 g/day if indicated by the development of ketosis).

Brinkworth et al. (2009) had 69 men and women with abdominal obesity (only 59% of their initial sample) complete a 12-month trial of a low-fat (30%) or an isocaloric but very low- (4%) carbohydrate diet. The total energy intake was limited to 2.5 MJ/day for the women and 2.9 MJ/day for the men. Both the average weight loss (11.5 versus 14.5 kg) and fat loss (9.4 versus 11.3 kg) were a little smaller with the low-fat diet than with the low-carbohydrate diet. However, the low-carbohydrate diet also tended to cause an undesirable increase of LDL cholesterol.

Cardillo et al. (2006) found that only 53 of 132 obese individuals completed a 3-year comparison of a low-fat versus a very low-carbohydrate diet. Initial changes of adipokines and weight loss data favoured the very low-carbohydrate group, but by the end of the 3 years, respective weight losses for the two groups were similar (4.2 and 4.0 kg).

Davis et al. (2009) compared two types of diet (an Atkins type regimen with 20-25g/day of carbohydrates, versus a low (25%) fat option) in 105 overweight adults aged >18 years with type 2 diabetes mellitus. Weight loss occurred faster with the low-carbohydrate diet, but by the end of one year both groups had reduced their body mass by a similar 3.4%. The low-carbohydrate diet also produced a greater increase in HDL cholesterol.

Ebbeling et al. (2007) compared a low-fat (20%) versus a low-glycaemic index (40% carbohydrate) diet in 73 obese young adults. Over a 6-month study and a 12-month follow-up period, the reduction of body fat in the group as a whole was similar for the two types of diet, but in those with a plasma insulin concentration greater than 57.5 pIU/mL at 30 minutes, the low-glycaemic index diet produced a greater reduction of fat than the low-fat diet.

A prospective study of 41,518 nurses initially aged 41-68 years found a weak positive association between weight gain over an 8-year period and the intake of saturated and trans- fats, with women apparently gaining around 1 kg in body weight for each 1% increase in the energy that they derived from trans-fats. In contrast, there was no relationship between weight gain and the intake of mono-unsaturated and polyunsaturated fats (Field et al., 2007).

Foster et al. (2003; 2010) followed 307 middle-aged adults for who were restricted to an energy intake of 4.8 to 7.2 MJ/day for 2 years. Low-fat and low-carbohydrate-based regimens were compared. After 3 and 6 months, the weight loss was greater with the low-carbohydrate than with the low-fat diet, but by 12 months any advantage of the low-carbohydrate regimen was small and no longer statistically significant. The trial was extended to 2 years. Programme adherence was poor for the second year of the study, but at the end of this time the continuing members of both groups had lost about 11 kg (11% of their initial body mass).

Golay et al. (1996) conducted a 6-week trial in 54 obese individuals. The weight loss (6.2-7.5 kg) on a 4.5 MJ/day diet did not differ between a low-fat, a low-carbohydrate, and a balanced diet over this period.

Meckling et al. (2004) followed a small group of 31 obese or overweight adults over a 10-week study. The weight loss was similar for low-fat (7.0 kg) and low-carbohydrate (6.8 kg) diets, but the low-carbohydrate group lost 1.9 kg of lean tissue, whereas the low-fat group did not.

Noakes et al. (2005) placed a group of 100 obese women on a 5.6 MJ/day diet, either high-carbohydrate (64%) low-protein (17%), or high-protein (34%) low-carbohydrate (46%) in type. Over a 12-week trial, both subject groups reduced their body mass by 7.6 kg, although the decrease in total body fat was somewhat greater with the low-carbohydrate high-protein diet than with the low-protein high carbohydrate regimen (5.7 versus 4.5 kg). In a further trial with 86 obese women who followed a 6 MJ/day diet, Noakes et al. (2006) compared low-fat, low-carbohydrate, and high-unsaturated fat programmes. Again, at 12 weeks decreases of body mass were similar for the three groups (4.0, 4.5, and 4.4 kg), but the respective losses of lean tissue (2.1%, 2.6%, and 1.4%) tended to favour the high-unsaturated fat intake diet.

Sacks et al. (2009) involved 811 individuals in a trial where they were assigned to diets with respective carbohydrate, fat and protein contents of 65/20/15%, 55/20/25%, 45/40/15% and 35/40/25%. The weight loss over 2 years was relatively similar with each of these formulations, and no inter-group differences of satiety, hunger or programme compliance were observed.

Samaha et al. (2003) carried out a 6-month trial with 132 severely obese adults. They found a substantially smaller decrease of body mass with a high-carbohydrate than with a high-fat diet (1.9 kg versus 5.8 kg), and the high-fat diet was accompanied by a greater improvement in triglyceride levels and insulin sensitivity.

Shai et al. (2008) studied a sample of 322 Israelis, 86% of whom were men. Subjects were distributed between a high-carbohydrate (<30% fat) diet, a Mediterranean diet and a low-carbohydrate diet (<20 g/day, rising to 120 g/day). The respective decreases in body mass over a 2-year trial were 2.7 kg (low-fat), 4.4 kg (Mediterranean) and 4.7 kg (low-carbohydrate). The low-carbohydrate group also showed the greatest improvement in serum lipids.

Westman et al. (2008) distributed 84 obese patients with type 2 diabetes mellitus between a low glycaemic index (55% carbohydrate, 2.1 MJ/day) diet and a low-carbohydrate (<20g/day) diet. Over 24 weeks, the decrease of body mass was greater for the low-carbohydrate than for the low glycaemic index diet (11.1 kg versus 6.9 kg), and the improvement of glycaemic control was also greater for the low-carbohydrate group.

Yancy et al. (2004) evaluated 120 obese and hyperlipidaemic adults over a 24-week study. Subjects engaged in an exercise programme, developing a total energy deficit of 2.1-4.2 MJ/day, and they were allocated between a low-fat diet

Table 6. Comparisons of decreases in body mass between those following low carbohydrate and low fat diets, as seen in longitudinal studies.					
Author	**Sample**	**Intervention**	**Findings**	**Study duration**	**Comments**
Golay et al. (1996)	54 obese	4.5 MJ/d diet; no difference in weight loss between low-carbohydrate, low-fat or balanced diets	Weight loss 6.2 kg to 7.5 kg	6 weeks	Similar weight & fat loss occurs with diet of iso-energetic foods
Meckling et al. (2004)	31 obese or overweight adults	Low- carbohydrate vs. low-fat diet	Weight loss 7.0 vs. 6.8 kg	10 wk	Low-fat group conserved more lean tissue
Noakes et al. (2005)	100 obese women aged ~ 49 yr	Diet 5.6 MJ/d (high-protein or high-CHO)	Weight loss 7.6 kg in both groups	12 wks	More fat lost with high-protein than with high-CHO diet
Noakes et al. (2006)	83 obese women	Low-fat vs. low-CHO vs. high-unsaturated fat diet	Weight loss 4.0 kg, 4.5kg, 4.4 kg	12 wks	Low CHO diet improved HDL-cholesterol levels & insulin resistance
Sacks et al. (2009)	811 overweight adults	4 diets varying in CHO, fat & protein content	4 kg wt loss, with little difference between diets	2 yr	
Samaha et al. (2003)	132 severely obese adults	Low-fat vs. low carbohydrate diet	Weight loss 1.9 kg vs. 5.8 kg	6 months	Attrition 33% low carb, 47% low fat
Shai et al. (Shai et al., 2008)	322 Israeli adults, 86% men	Low fat vs. Mediterranean vs. low-CHO diet	Wt loss low-fat 2.9 kg, Mediterranean 4.4 kg, low-CHO 4.7 kg	2 years	Low CHO also had greatest improvement in lipids
Westman et al. (2008)	84 obese diabetics	Low glycaemic index vs. low CHO diet	Wt loss 6.9 kg vs. 11.1kg	24 weeks	Low-CHO diet also improved glycaemic control

(<30% fat) and a low-carbohydrate regimen (<20 g/day). Weight loss was greater with the low-carbohydrate than with the low-fat diet, and the low-carbohydrate group also showed a greater decrease in body fat (9.4 kg versus 4.8 kg). Further, the low-carbohydrate regimen led to greater improvements in serum triglycerides and HDL cholesterol levels than the low-fat diet.

In summary, early responses favoured the low-carbohydrate diet in 12 of the 17 comparisons, and in the remaining 5 trials there was little inter-group difference of weight loss between low-carbohydrate and low-fat programmes. However, in at least three of the studies initially favouring a high-fat low-carbohydrate regimen, this advantage disappeared when observations were continued for a year or more.

Table 6 Continued.					
Author	**Sample**	**Intervention**	**Findings**	**Study duration**	**Comments**
Yancy et al. (2004)	120 hyperlipidaemic adults	Exercise & energy restriction, low- fat vs. low-CHO diet	Wt loss 2.4 vs. 3.3 kg	24 weeks	Low-CHO diet improved triglycerides and HDL cholesterol
Baron et al. (1986)	135 overweight adults	Low-fat/low fibre vs. high- fat/ high-fibre diet	Weight loss 3.7 vs. 5.0 kg	3 months	No measures of water loss
Bazzano et al. (2014)	148 adults	Low-fat vs. low-carbohydrate diet	Weight loss 2.0 vs. 5.5 kg	1 yr	Also greater loss of fat with low CHO diet
Bradley et al. (2009)	24 overweight /obese adults	20%fat, 60% CHO vs. 20% CHO, 80% fat	No inter-group difference in weight loss	8 wks	Similar changes of insulin secretion in both groups
Brehm et al. (2003)	53 healthy obese women	Low-fat vs. very low-carbohydrate diet	Wt. loss 3.9 vs. 8.5 kg, fat loss 2.0 vs. 4.8 kg	6 months	
Brinkworth et al. (2009)	69 men and women with abdominal obesity completed trial	Low-fat vs. very low-carbohydrate diet	Weight loss 11.5 vs. 14.5 kg, fat loss 9.4 vs. 11.3 kg	12 months	Low carbohydrate diet increased low HDL cholesterol
Cardillo et al. (2006)	53 of 132 obese adults completed study	Low -at vs. very low-CHO diet	Weight loss 4.2 vs. 4.0 kg	3 yr	Initial favourable changes of adipokines and body mass with low CHO diet not sustained at 3 yr
Davis et al. (2009)	105 overweight adults with type 2 diabetes mellitus	Low-fat vs. low- CHO diet	3.4% weight reduction in both groups	12 months	Weight loss initially faster with low-CHO
Ebbeling et al. (2007)	73 young adults	Low-fat vs. low glycaemic load diet	Body fat at 6 months -1.4, -1.3%, at 18 months -1.1, -1.5%	6 month intervention, 12 month follow-up	Low glycaemic diet reduced body fat in those with high insulin concentration
Field et al. (2007)	41,518 nurses initially aged 41-68 yr	Relationship of saturated and trans-fat to weight gain	1 kg increase of weight for each 1% increase of energy from trans fat	8 yr	
Foster et al. (2003; 2010)	307 obese adults, aged 45.5 yr	Low-fat vs. low-carbohydrate diet, 4.8-7.2 MJ/d	2.5% vs. 4.4% decrease of body mass at 1 yr, and 11 kg at 2 yr in both groups	2 yr	Attrition high by 2 yr

High protein diets

Since the Atkins diet places no restrictions on a client's protein intake, it could be classed not only as a high-fat, but also as a high-protein diet. Other high-protein options include the Zone, the Dukan diet, and the ketogenic diet.

The Zone diet. The Zone diet was developed by Barry Sears, an American biochemist. He recommended taking five meals per day, all with a low (40%) carbohydrate content, also opting for carbohydrates with a low glycaemic index, with the residue of nutrients coming from protein (30%) and fat (30%) (Cheuvront, 2003). This diet was claimed to balance the user's ratio of insulin to glucagon, purportedly affecting eicosanoid metabolism in a way that permanently regulated body mass, reduced the risk of chronic disease, enhanced immunity, maximized physical and mental performance, and increased longevity. However, there seems little research to back these extensive purported benefits.

The Dukan diet. The French general practitioner Pierre Dukan developed a regimen where patients were allowed to eat as much as they wished of 68 protein-rich foods (Dukan, 2018). He claimed as the main justification for his programme that such a diet matched that of our Paleolithic ancestors, and that humans were still genetically adapted to such a pattern of nutrition. There are several potential side-effects of the Dukan diet, including a deficiency of micro-nutrients, together with risks of severe ketosis, nephrolithiasis and chronic renal disease (Freeman, Willis, & Krywko, 2014; Zamora Navarro & Pérez-Llamas, 2013).

The ketogenic diet. Typical formulations of the ketogenic diet comprise an adequate intake of protein, a high intake of fat and a low intake of carbohydrate. Such a diet has been commended mainly as a means of countering various neurological conditions. In particular, reducing the number of attacks sustained by a person with epilepsy. However, it has also been proposed as a treatment for obesity.

The ketones that are formed during fat metabolism pass into the brain and (with persistent consumption of a ketogenic diet) they can become an alternative energy source to glucose in both the brain and the skeletal muscles. One major disadvantage of the ketogenic diet is that the associated acidosis can lead to a progressive bone demineralization, with the formation of urinary calculi. Other potential side effects include constipation, high cholesterol levels, and (in children) a stunting of growth.

Choice of proteins. In terms of long-term weight control, the preferred sources of protein include nuts, poultry and fish. Such sources have a substantial advantage over traditional sources of protein. One prospective study showed that those eating red and/or processed meat gained about 0.5 kg of weight every 4 years, but those focusing on nuts gained only 0.25 kg over 4 years (Mozaffarian et al., 2011).

Potential advantages of a high protein diet. Among the advantages of a high protein diet (Table 7), we may note greater satiety, a greater thermogenesis, and conservation of lean tissue in the face of a negative energy balance.

Table 7. Suggested advantages and disadvantages of a high-protein diet.

Suggested advantages • High-protein diets produce greater satiety than high-carbohydrate or high-fat diets • High-protein diets have a greater thermic effect than high-carbohydrate or high-fat diets • High-protein diets facilitate the conservation of lean tissue if total energy intake is restricted • The resulting ketosis suppresses appetite • High protein diets improve serum lipid profile • High protein diets Increase insulin sensitivity
Suggested disadvantages • Ingestion of glucogenic amino acids lowers blood pressure • Ingestion of acidifying amino acids raises blood pressure • A high protein intake may decrease nephron mass

Greater feelings of satiety. The sensation of satiety is greater following a high-protein diet (20-30% of energy needs) than that seen after either a high-carbohydrate or a high-fat meal (Halton & Hu, 2004; Smeets, Soenen, Luscombe-Marsh, Ueland & Westerterp-Plantegna, 2008; Westerterp-Plantenga, Nieuwenhuizen, Tome, Soenen, & Westerterp, 2009). The hierarchy of satiety for these 3 dietary options is consistently protein > carbohydrate > fat. Thus, in 11 of 14 reviewed trials, Halton and Hu (2004) noted that protein induced greater feelings of satiety than carbohydrate or fat.

A little surprisingly, the satiety effect seems greatest when ingesting proteins that lack some of the essential amino acids (Westerterp-Plantenga et al., 2009). Satiety may possibly arise when there is an increased blood level of amino acids that cannot be channeled into protein synthesis, or it may reflect the influence of individual amino-acids upon neurotransmitters (for instance, a histidine-induced production of the anorexic agent histamine).

Greater thermic effect of proteins. Protein has a greater thermic effect than carbohydrate or fat (i.e. it takes more energy to metabolize protein than other foods of equal energy content) (Halton & Hu, 2004; Westerterp-Plantenga et al., 2009). Reported thermic effects, expressed in relation to ingested energy, have ranged from 0-3% for fats, 5-10% for carbohydrates, and 20-30% for proteins.

A careful study in a metabolic chamber found a thermic effect of 1295 kJ/d for a high-protein diet, compared with 931 kJ/d for a high-fat diet (Westerterp-Plantenga et al., 2009). In consequence, 14.6% versus 10.5% of ingested energy was dissipated as metabolic heat. Johnston, Day, & Swan (2002) also noted that thermogenesis two hours after a meal was about twice as great with a high-protein as with a high-carbohydrate diet, and they concluded that this explained much of the greater weight loss seen in dieters pursuing a high-protein diet.

Luscombe, Clifton, Noakes, Parker, & Wittert (2002) found a rise in thermic effect of 28% on increasing dietary protein from 16% to 28% of the total energy intake in a group of patients with type 2 diabetes mellitus who were following a period of dietary restriction.

Conservation of lean tissue during dieting. Perhaps most importantly, a high protein intake has the potential to help in conserving lean tissue when a person is dieting (Westerterp-Plantenga et al., 2009), perhaps through a stimulation of muscle protein synthesis. Leucine intake seems a key factor in this process (Phillips, Tang, & Moore, 2009), facilitating a repartitioning of ingested protein from metabolic to anabolic pathways (Ha & Zemel, 2003).

One trial reported that if the protein content of the diet was increased from 0 to 50 g/day, the protein loss over a 28-day period of dieting decreased from 1202 to 91 g (Soenen & Westerterp-Plantegna, 2008). Likewise, Krieger et al. (2006) noted that a protein intake 40% higher than the minimum recommended allowance was associated with an 0.6 kg greater retention of lean tissue over the first 12 weeks of dieting, and the benefit increased to 1.2 kg over longer periods of dietary restriction. The sparing of lean tissue is particularly likely if an increased protein intake is combined with regular resistance exercise (Krieger et al., 2006; Mettler, Mitchell, & Tipton, 2010).

Appetite suppression by ketosis. The ketosis associated with a high protein/low carbohydrate diet may have an appetite suppressing effect (Astrup, Larsen, & Harper, 2004).

Improved serum lipid profile. Some studies have shown a high protein diet to increase HDL cholesterol levels and to reduce serum triglycerides (Astrup et al., 2004).

Increased insulin sensitivity. Improved indices of insulin sensitivity have been reported for those following a high protein diet (Astrup et al., 2004).

Possible adverse effects. A diet rich in glucogenic amino acids has a blood pressure lowering effect, whereas a diet with a high content of acidifying amino acids raises blood pressure. An excessive production and excretion of ammonia may also lead to a decrease in nephron mass (Frassetto, Morris, & Sebastian, 2006; Praga, 2005).

Comparison between protein and carbohydrate or fat diets.

A number of randomized controlled studies have compared responses to high-protein versus high-carbohydrate diets, although some of these investigations have had too short a duration to evaluate either the effect of long-term readjustments of body water stores or their impact upon programme adherence (Table 8).

The subjects of Baba et al. (1999) were 13 obese and hyperinsulinaemic men. They were assigned to a diet that met 80% of their resting energy expenditures, with either a high-protein (45%) or a high-carbohydrate (58%) basis. After 4 weeks, the high-protein diet had yielded a greater weight loss than the high-carbohydrate regimen (8.3 versus 6.0 kg), but much of this apparent advantage was due to a greater water loss; the fat loss was essentially similar for the two treatments (7.1 and 6.3 kg).

Dumesnil, Turgeon, Tremblay, Poirier, Gilbert, Gagnon et al. (2001) exposed 12 overweight men to a high-protein Mediterranean-type diet and the AHA Stage 1 diet, each for periods of 6 days. The high-protein diet led to a weight loss of 2.2 kg, with associated decreases in waist and hip circumferences, but no such changes were seen when following the AHA diet.

Larsen, Mann, Maclean, & Shaw (2011) compared a high-protein (30% protein) with a high-carbohydrate (55% carbohydrate) diet in 99 overweight/obese individuals. Over a period of 12 months, the weight loss of 2.2

kg was almost identical for the two programmes, and there was no evidence that the high-protein diet was better than the high-carbohydrate programme in terms of any parameter relating to the course of diabetes mellitus, such as HbA_{1c} or serum lipids. In a larger study of 548 obese adults who had reduced their body weight by at least 8%, a modest increase of protein intake and reduction of glycaemic index were each associated with increased continuing adherence to a weight-loss programme (Larsen et al., 2010). The weight regained over a 26-week follow-up period averaged 1 kg less in those receiving a high-protein low-glycaemic index diet than in those following the high-carbohydrate programme.

Layman, Boileau, Erickson, Painter, and Shiue (2002) compared the effects of a high-carbohydrate diet (3.5 times the protein intake of 68 g/day) with a lower carbohydrate intake (1.4 times a protein intake of 125 g/day) in a sample of 24 women aged 45-56 years. The weight loss over 10 weeks was marginally greater with the higher protein intake (7.5 versus 7.0 kg), and there was no disadvantage in terms of an increased lean tissue loss (0.9 versus 1.2 kg).

Luscombe et al. (2002) tested 26 obese subjects with type 2 diabetes mellitus. Over an 8-week study, they were restricted to a 6.7 MJ/day diet, with a composition of either 28% protein and 42% carbohydrate, or 16% protein and 55% carbohydrate. Both groups lost 4.6 kg of body mass, of which 4.5 kg was fat. There were no inter-group differences in resting energy expenditures or the thermal effect of the two options.

McAuley et al. (2005) divided a group of 96 normoglycaemic but insulin resistant women between 3 treatments- a high protein (Atkins-type) diet (carbohydrate 20 g/day rising to 50 g/day), a high-carbohydrate diet, and a high-fat (Zone) diet (30% fat, predominantly mono-unsaturated lipids, and 40% low glycaemic index carbohydrates). At 24 weeks, the respective weight losses (6.9, 4.7, 7.1 kg) and decreases in waist circumference (8.8, 6.9. 9.8 cm) were slightly smaller for the high-carbohydrate option), but the decrease in lean tissue mass was also a little smaller for the high-carbohydrate regimen than for the other two options (2.8, 2.1, 2.5 kg).

Miller and Mumford (1967) evaluated the effects of two dietary alternatives on 6 weeks of deliberate over-feeding in a small sample of healthy young adults. Neither group gained the 5.0-5.4 kg in body mass predicted from the excess food, but the weight gain was greater for a high protein (14-17%) than for a low-protein (2-3%) diet (3.7 versus 1.1 kg).

Noakes et al. (2005) recruited 100 obese women aged ~49 years to a 12-week programme. Food intake was restricted to 5.6 MJ/day, and a high-protein was compared with a high-carbohydrate diet. Both subject groups lost ~7.3 kg of body mass over the 12-week intervention, with the two dietary options yielding similar losses of fat (5.7, 4.5 kg) and of lean tissue (1.5, 1.8 kg).

Parker et al. (2002) assigned 54 obese men and women with type 2 diabetes mellitus to a dietary programme (energy intake limited to 5.2-5.3 MJ/day for 8 weeks, then 4 weeks of energy balance); this regimen was combined with either a high-protein (31% protein, 44% carbohydrate) or high-carbohydrate (18% protein, 61% carbohydrate) diet. Over the 12-week trial, both groups reduced their

Table 8. Comparison of weight losses achieved by high-protein and other types of diet.			
Author	**Sample**	**Protocol**	**Findings**
Baba et al. (1999)	13 obese hyperinsulinaemic men	Dieting + high-protein or high-CHO diet for 4 weeks	Weight loss 8.3 vs. 6.0 kg, body fat loss 7.1 vs. 6.3 kg over 4 wks
Dumesnil et al. (2001)	12 overweight men, tested on both diets for 6 days	High protein Mediterranean vs. AHA stage 1 diet	2.3 kg weight loss vs. no change in wt
Larsen et al. (2011)	99 overweight/obese type 2 diabetics	High-CHO vs. high-protein diet; 12 month	No advantage from high- protein diet- wt loss 2.2, 2.2 kg
Larsen et al. (2010)	548 obese adults who had recently lost 8% weight	High or low glycaemic, high- or low-protein diets vs. control	Wt. regain ~1 kg less with high-protein low glycaemic diet. Adherence also better with high protein/low glycaemic diet.
Layman et al. (2002)	24 women aged 45-56 yr	High-protein vs. high-CHO diet	At 10 wk, wt loss 7.5 vs. 7.0 kg, more lean tissue loss with high- protein diet
Luscombe et al. (2002)	26 obese subjects with type 2 diabetes mellitus	Diet plus high-protein vs. high-CHO	At 8 wk, wt. loss of 4.6 kg (4.5 kg fat) in both groups
McAuley et al. (2005)	96 normoglycaemic insulin resistant women	High-protein (Atkins) vs. high-CHO vs. high-fat (Zone) diets	Wt loss at 24 wk 6.9, 4.7, 7.1 kg, waist circ. loss 8.8, 6.9, 9.8 cm, fat free mass loss 2.8, 2.1, 2.5 kg
Miller & Mumford (1967)	10 healthy adults	Deliberate over-eating low- vs. high-protein diet for 6 wk	Low-protein gained 1.1 kg. high-protein gained 3.7 kg
Noakes et al. (2005)	100 obese women aged `49 yr	5.6 MJ/d diet, high-protein vs. high-CHO diet	7.3 kg wt. loss both groups over 12 wks
Parker et al. (2002)	54 obese men and women with type 2 diabetes mellitus	Diet, high-protein vs. high-CHO	Over 8 wk, both groups lost5 5.2 kg, but in women more fat loss with high protein diet (5.3 vs. 2.8 kg)
Platti et al. (1994)	25 women	High-protein vs. high-CHO, 3.3 MJ/d diet	Fat loss 3.3 vs. 3.2 kg, lean tissue loss 1.9 kg less with high-protein than high-CHO diet
Skov et al. (1999)	65 healthy but overweight adults aged 18-55 yr	High-protein vs. high-CHO vs. control diet	Wt. loss 8.9 vs. 5.1 kg, fat loss 7.6 vs. 4.3 kg

body mass by 5.2 kg, but in the women the fat loss was greater with the high-protein than with the high-carbohydrate diet (5.3 versus 2.8 kg).

Platti et al. (1994) evaluated 25 normoglycaemic women who were following a 3.3 MJ/day diet. Half of the sample followed a 45% protein diet, the others a 60% carbohydrate diet. Both options induced a similar decrease of body fat (3.3 versus 3.2 kg) over a period of 21 days, but the high-carbohydrate diet was associated with a 3.0 kg loss of lean tissue, as compared with only a 1.4 kg loss in those following the high-protein diet.

Skov et al. (1999) enrolled 65 healthy but overweight adults aged 18-55 years in a trial that compared high-protein (25%), high-carbohydrate (12% protein) and control diets. The weight (8.9 versus 5.1 kg) and fat (7.6 versus 4,3 kg) losses were greater for the high-protein than for the high-carbohydrate diet, with no changes seen in the control group.

In summary, of the 12 studies cited, seven showed a similar weight loss with a high-protein and a high-carbohydrate diet, four showed a small advantage to the high-protein approach, and in one (a study of over-eating) the high-protein group gained more weight than the high-carbohydrate group.

Discussion and conclusions

Various diets have been vigorously advocated both for the prevention of obesity and for its treatment, with attempts to reach conclusions about their respective merits complicated by a reliance upon the resulting changes in body weight, while ignoring potential changes in stored water (due to the metabolism of stored glycogen) and the metabolism of lean tissue. Although much of the weight loss that is achieved by a dieter does reflects a decrease in body fat, several other factors influence the change in body mass observed over a period of dietary restriction, including the thermogenic properties of the foodstuffs that are chosen, the extent to which the body's glycogen reserves are depleted and the resulting release of associated bound water, the extent to which lean tissue is broken down to maintain blood glucose levels, and differences in the mineral content of foods with resulting changes in body water content.

The success of a given diet in achieving rapidly a desired reduction in body weight is certainly an important consideration, but the choice between the various dietary options is also influenced by other factors such as the influence of various foods upon feelings of hunger and satiety, and consequent differences in long-term adherence to the prescribed programme, the ability of the proposed dietary emphasis to satisfy the body's basic nutrient requirements in terms of amino acids, essential fatty acids, vitamins and micronutrients, and any side-effects of dietary extremes upon serum lipids, cardiac risk factors, glucose regulation, and the risks of neoplasia.

The proposed regimens have included high-carbohydrate, high-fat, and high-protein options. Each of these choices has some theoretical advantages, but in terms of the long-term weight losses achieved by dieters, outcomes seem rather similar for each of these options. One argument for a high protein intake is that it may help to conserve lean tissue during a period of negative energy balance, particularly if it is combined with a well-timed regular programme of resistance exercises; however, this same objective can probably be met if other types of stringent diet are balanced by small and appropriately-timed protein supplements.

Areas meriting further research in terms of carbohydrates include the possible adverse effect of a prolonged high-carbohydrate intake upon the ability of the tissues to metabolize stored fat, the extent to which an appropriate choice of complex carbohydrates can limiting the spiking of blood sugars and thus an increase in the risk of diabetes mellitus, and gastric emptying rate for various types of carbohydrate, with resulting implications for long-term satiety. In terms of a high fat consumption, more information is needed on the possible health impact of an ability of various tissues to metabolize ketones in place of sugars, and a possible adverse influence of saturated and trans-fats on the risks of cardiovascular disease, Further, does the minimizing of carbohydrate intake significantly increase the risk of metabolizing lean tissue when dieting? And for the protein-based diets, questions remain regarding adverse effects upon blood pressure and the health of the nephrons.

However, based upon present knowledge, the conclusion seems that provided care is taken to avoid hyperglycaemic sugars and saturated or trans fats, there is little reason to advocate strongly for a diet containing any preponderance of carbohydrate, fat or protein. If a dietary restriction has been imposed, the most important factor is to choose a menu that the client enjoys and to encourage him or her in faithful adherence to continued exercise and a restriction of energy intake.

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Author's Qualifications

The author's qualifications are as follows: Roy J. Shephard, C.M., Ph.D., M.B.B.S., M.D. [Lond.], D.P.E., LL.D., D.Sc., FACSM, FCSEP, FFIMS, FAAPE.

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