CHAPTER 11

Energy balance, food intake and obesity

Paul McCrory, Boyd Strauss and Mark L. Wahlqvist

Introduction

It has been suggested that the development and maintenance of obesity has a strong genetic basis. The impact of environmental and psychological factors must also play a significant additional role in this process. The means by which the body achieves the regulation of energy balance may be the critical factor in the process of weight maintenance which remains poorly understood. The implications of energy balance for the individual may be profound in terms of health and longevity.

Components of daily energy expenditure

Total daily energy expenditure (DEE) is made up of a number of individual components (see Fig. 1). These include the resting metabolic rate (RMR), the thermic effect of exercise (TEE) and the thermic effect of food (TEF).

Resting metabolic rate

When considering the total DEE, approximately 60% to 70% of this is due to the resting metabolic rate, which represents the basal requirements for the maintenance of the homeostasis of the body. The RMR is measured when the subject is resting quietly in a supine position in a thermo-neutral environment, approximately 8–12 hours after the last meal. Although a small genetic component has been suggested, the major single determinant of the RMR is the fat-free mass. Most of the variation in RMR between subjects can be accounted for by the variation in the fat-free mass. The RMR can be sub-divided into the sleeping metabolic rate and the additional energy expenditure of wakefulness that occurs without physical activity (see Fig. 1).

Thermic effect of exercise

The second largest component of the daily energy expenditure is the thermic effect of exercise (TEE), which is defined as the energy expenditure of useful muscular work. The efficiency of converting energy to muscle work is approximately 30% and does not appear to vary much between individuals. Therefore the energy expended may be related to the duration and intensity of the exercise performed.

It is now appreciated that there is another common form of energy expenditure in which no apparent useful work is accomplished. This is the energy expended ‘fidgeting’ while the subject is at rest. The variability accounted for by this process is estimated to be between 100 and 800 kcal per day. The authors suggest that familial traits may account, at least in part, for this variation.

Exercise and obesity.
As has been noted by several authors, the potential increase in energy expenditure due to exercise is greater than can be accounted for merely by the thermic effect of the exercise alone. One long-term effect of exercise is to increase the fat-free mass and since this accounts for greater than 85% of the variance in resting metabolic rate between individuals, this has the potential to have a significant impact on daily energy expenditure over time.

Recently, a study has shown tremendous individual variation in response to exercise training with high and low ‘responders’. This may reflect a genetic difference between the two groups. In addition, a single bout of exercise may also acutely affect the resting metabolic rate. This ‘carry over’ effect on daily energy expenditure usually occurs when strenuous exercise is undertaken. Bielanski found that the resting metabolic rate was increased 50% even as much as 18 hours following a 3-hour bout of exercise at 50% of the maximum aerobic capacity. Similarly, Devlin found an increase in the resting metabolic rate 12 hours after more strenuous exercise at 85% of maximal aerobic capacity.

In addition to the increase in metabolic rate which accompanies exercise, there are metabolic changes such as improvement in lipid oxidation, glycogen storage and a reduced glucose oxidation (see later). This prolonged increase in RMR following exercise may have practical implications in the timing of meals in relation to exercise in both the obese and the non-obese. It has been proposed that there is a synergistic relationship between the effects of exercise immediately after a meal on the thermic effect of food. This relationship may be altered in obese patients and enhanced in strength trained athletes, a finding that is not fully explained.

The thermic effect of food
The thermic effect of food (TEF) is defined as the energy expenditure above resting metabolic rate that follows the meal ingestion. The duration of this effect is unknown.
Despite the fact that the TEF accounts for only 10% to 15% of the daily energy expenditure, it is of great interest because it varies enormously between individuals. One study\textsuperscript{11} has shown that the thermic effect of food is reduced with age, obesity, and in patients with diabetes mellitus. The thermic effect of food also varies with the composition of the diet, being greater after carbohydrate and protein consumption than after fat. Additionally, spicy foods have a greater effect in not only enhancing, but in prolonging this effect. An interesting study\textsuperscript{12} indicates that certain foods may alter energy utilisation. The authors showed that meals with added chilli and mustard in healthy subjects, increased the basal metabolic rate significantly more than unspiced meals and that this effect was sustained for more than three hours (see Fig. 2). It has been suggested that capsaicin may be the responsible factor in causing this effect, and that it may act through the vasculature.

Figure 2. The effects of spicing on metabolic rate.\textsuperscript{12}

The TEF can be partitioned into the obligatory and the facultative components

The obligatory component accounts for approximately 60% of the TEF and represents the energy expended in digesting, absorbing, transporting and storing the ingested substrates. The exact amount of the obligatory component varies depending on what is eaten as well as the metabolic state of the individual. It has been reported\textsuperscript{13} that 23% of the energy value of carbohydrates are utilised for obligatory thermogenesis if carbohydrate is converted to triglyceride and stored as fat. However this may seldom occur under normal circumstances. In humans, fat that is stored generally is derived from dietary fat. Carbohydrate can also be stored as glycogen at an energy cost of 87% or maybe immediately utilised as glucose at an energy cost of 5%. Fat can be stored as triglyceride or adipose tissue with an obligatory energy cost of only 3\textsuperscript{13}.

The facultative component accounts for 32% of the TEF or approximately 5% of the daily energy expenditure. This expenditure is felt to be accounted for by the metabolic inefficiency of the system.
The effect of exercise on the thermic effect of food has been extensively studied. Conflicting studies have been reported in humans. For example, Davis\textsuperscript{6} and Lundholm\textsuperscript{7} found that the thermic effect of food was significantly increased in relation to the VO\textsubscript{2,max} in trained subjects. Others have found that the thermic effect of food was acutely reduced in trained subjects.\textsuperscript{8,9} It is likely that methodological differences in training intensity, meal composition and meal timing make explain some of the differences between the published studies.

The potential for influence on each of these separate factors in weight reduction is enormous. Resting metabolic rate can be increased through increases in lean body mass mediated by exercise, The thermic effect of food maybe altered by the timing and nature of meals and the thermic effect of exercise represents the most variable and easily influenced component via increases in energy expenditure. The implications in the development and maintenance of obesity make these effects clinically important.

**Techniques of measurement of energy balance**

There are a variety of methods, both direct and indirect, which can be used to assess the energy expenditure of an individual. This has been recently reviewed in detail.\textsuperscript{14}

**Direct calorimetry**

The amount of heat produced by the body reflects the energy utilisation and production. This can be measured by the use of whole body calorimetry. In essence, this is a large insulated box that is able to measure the rate at which body heat is produced. Such instruments are accurate but necessarily large and expensive and are consequently available in few centres world-wide.

**Indirect calorimetry**

Indirect calorimetry is a more versatile method of determining metabolic rate and energy expenditure by the measurement of oxygen utilisation. The basic energy producing process of the body is the oxidation of carbohydrate and fat with the consequent release of energy. The rate of energy production is proportional to the rate of oxygen use. W.O. Attwater was the first to demonstrate this relationship between energy production and oxygen uptake. The precise value of the oxygen utilisation will vary slightly depending on the predominant metabolic substrate.

Indirect calorimetry is performed using a closed or open loop system and portable units can be used as ‘backpacks’ or hoods in an attempt to replicate and measure energy expenditure in a free-living environment.

More recent utilisation of metabolic carts whereby minute to minute variation in energy expenditure can be determined make this a particularly useful technique in determining energy expenditure during a given activity (e.g. running). Such devices are also useful in the acute hospital setting where a precise knowledge of energy utilisation is useful in determining nutritional support.

**Double-labelled water**

Double-labelled water (D\textsubscript{2}\textsuperscript{18}O) may be used and the consequent elimination of water (as hydrogen and oxygen) is measured by utilising stable non-radioactive isotopes. The deuterium equilibrates with the total body water and the labelled oxygen equilibrates with total body water and carbon dioxide. The elimination of deuterium provides a measure of oxygen utilisation and hence energy expenditure. This technique ‘averages’ the daily energy expenditure over days to weeks.
At the present time, a world-wide shortage of doubly labelled water makes this technique expensive.

The effect of ageing on energy balance

Ageing is characterised physiologically by the loss of skeletal muscle and bone tissue. This is the reverse of the chances seen in growth and development. There is also a linear reduction in basal metabolic rate consequent on this age-induced reduction in fat-free mass.

In the 1930s, McCay and his colleagues\textsuperscript{15} addressed the role of underfeeding and the consequent improved longevity in rats. Whilst many groups have confirmed the original findings, some concerns have been raised as to whether these can be extrapolated to humans. Both Widdowson\textsuperscript{16} and Harper\textsuperscript{17} suggest that underfeeding during the growth phase would lead to increased morbidity and mortality due to infection. Studies from famines in the third world\textsuperscript{61} and from starvation studies during the Second World War\textsuperscript{62} suggest that infective disease such as tuberculosis is dramatically increased.

No conclusive evidence has been put forward to suggest that a restrictive diet in late life would reduce the likelihood of degenerative disease and thus lead to increased life expectancy. As an anecdotal point, Widdowson\textsuperscript{16} notes that the extreme elderly of today were ‘survivors’ in times of inadequate food supply, increased infections, reduced medical and public health standards and poor hygiene. The potential for the well-nourished children of today remains unknown.

Other changes in diet and nutrition in the lifetimes of the elderly means that the longevity and health are a reflection of a composite position of nutrition and energy balance. The occurrence of two world wars, civil wars, depressions, times of famine and plenty result in a huge variation of energy throughput over a lifetime. Public health intervention in terms of dietary change such as a decreased intake of saturated fats and the effect of mass migration skews the traditional dietary sources and ultimately results in changes in the food culture. Further, there may be a genetic influence or tolerance of high energy throughput during life resulting in an improved longevity. The ‘hunter-gatherer’ cultures have been suggested to have a more energy ‘economic’ daily energy expenditure so as to be able to sustain themselves in times of famine and shortages in the food supply.

Life expectancy and energy balance

As has been already noted, there is a great deal of interest in the manipulation of energy intakes as a means of influencing health outcomes, in particular longevity.

Obesity reflects periods of positive energy balance during life. In obese individuals where energy intake is high, strategies designed to counter this may be effective in weight reduction. However, there is evidence that increasing energy intake through dietary carbohydrate, rather than fat, actually reduces the risk of coronary disease in a dose-dependent fashion.\textsuperscript{18}

The influence of energy expenditure in achieving a steady energy balance has been examined in several long-term studies\textsuperscript{18,19,20,21}. At least two of these\textsuperscript{19,20} indicate that the level of increase in energy expenditure required to achieve increased life expectancy is in the order of 300 to 500 kcal per day (1300–2100 kJ/day). The energy cost of activities such as walking depend on factors such as body mass and mechanical
Table 1. Energy cost of exercise (for 70 kg male).

<table>
<thead>
<tr>
<th>Activity</th>
<th>Duration (mins)</th>
<th>Energy Expenditure (kcal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walking</td>
<td>60</td>
<td>350</td>
</tr>
<tr>
<td>Jogging</td>
<td>45</td>
<td>450</td>
</tr>
<tr>
<td>Running</td>
<td>30</td>
<td>550</td>
</tr>
<tr>
<td>Tennis</td>
<td>60</td>
<td>450</td>
</tr>
<tr>
<td>Swimming</td>
<td>30</td>
<td>300</td>
</tr>
<tr>
<td>Golf</td>
<td>120</td>
<td>700</td>
</tr>
<tr>
<td>Aerobics</td>
<td>45</td>
<td>450</td>
</tr>
<tr>
<td>Cycling</td>
<td>45</td>
<td>300</td>
</tr>
</tbody>
</table>

Figure 3. The London Busmen Study – Coronary Heart Disease (CHD) relative risk and exercise (from Morris et al.61).

Figure 4. Physical activity and all cause mortality and longevity in college alumni in the Harvard alumni study (from Pfaffenbarger et al.19).
efficiency. For a 73 kg individual this level of energy expenditure would be achieved by walking on flat ground for 30 to 40 minutes at a brisk pace (see Table 1).

These studies are important as they represent a direct vehicle through which behaviour at an individual level may influence morbidity and mortality directly (see Figs 3, 4 & 5).

Response of the obese to energy restriction

There has been concern expressed, that following attempts at loss of weight in the obese, the reduction in the resting metabolic rate may be exaggerated beyond that expected from the reduction in the fat-free mass alone. In one study, the authors estimated the requirements for weight maintenance in twenty-six obese women after weight reduction and they found a 25% reduction in the energy requirements necessary for maintenance, however physical activity was not measured. De Boer when investigating the response to energy restriction in obese women found a 15% reduction in the level of daily energy expenditure. This was not explained by simple changes in body composition alone. Garrow has reported that the resting metabolic rate of women shows considerable individual variation and did not find significant differences when compared to lean women. Whether these changes are primary or secondary is not clear and perhaps obese people may have to compensate for the reduced resting metabolic rate following weight loss. Given this limitation, the maintenance program of diet and exercise must therefore be individualised to ensure success in maintaining weight loss.

Do obese people eat more?

Several investigators have reported that obese people eat less than their lean counterparts and still maintain their weight. Since the obese have an increased fat-free mass and hence an increased basal metabolic rate, the ability to maintain weight with a
lower food intake is surprising. Various studies\textsuperscript{20,27,28} have reported that, in men followed between the ages of 50 and 60, body weight increased by 3.5 kg, whereas average energy intake decreased by 450 kcal. This study utilised reported dietary intake which may well be less reliable in the obese than in the non-obese\textsuperscript{29,30}. Without a free-living technique to measure daily energy expenditure in non-steady state conditions, accurate measurement is difficult.

The survival value of fat stores as a form of ‘insurance’ against famine was recognised long ago. During periods of abundant food availability, two mechanisms tend to ensure adequate storage. First, a ‘taste’ factor to encourage consumption and second, the fact that the energy cost for storing fat is relatively low.

Contrary to the general impression, excess dietary carbohydrate is not directly deposited as fat, at least not in the short-term. Acheson\textsuperscript{31} demonstrated that high-carbohydrate meals actually resulted in a negative fat balance. Facultative thermogenesis was stimulated to only a small extent. Presumably, the insulin response to a carbohydrate load would have an anti-lipolytic effect and thus should curtail the release of fat.

Several short-term studies\textsuperscript{32,33,34} suggest that the relative proportion of fat in the diet may contribute to the aetiology of obesity. Thus dietary manipulation is critical in the reduction of body weight and as will be seen in a later section, in longevity.

\textbf{Food intake and energy balance}

There are several inherent characteristics of food that appear to encourage intakes.\textsuperscript{35} These include variety, palatability and novelty. Schiffman\textsuperscript{36} has further suggested that the amount of food eaten is determined by the ‘quest’ for flavour. Satiety may also depend upon the physical bulk of the food.

With exercise, energy intake may be reduced below energy expenditure so as to result in a negative energy balance.\textsuperscript{37} The mechanism of this is unclear. Changes in body image at the time of exercise may function as a feed-back signal. A similar concept was investigated by Simpson and others\textsuperscript{38} who used a waist cord in previously obese individuals to maintain weight loss.

Sustained improvement in energy balance requires behavioural lifestyle change.\textsuperscript{39} The motivation to effect and maintain an exercise and dietary program in the face of social, psychological and peer-group pressure requires a behavioural approach in the management between the patient and therapist.

\textbf{Energy expenditure and physical activity}

Many authors suggest that obese subjects have a lower level of energy expenditure because of lower levels of physical activity. However, an obese person must expend more energy for a given activity when compared to a lean counterpart, and therefore the total energy expenditure of the obese is potentially greater. A more difficult question is whether an obese person expends less energy than would a non-obese person of comparable lean body mass. Several studies\textsuperscript{2,40,41} have found that patterns of daily energy expenditure differ between lean and obese and that an increased energy intake is maintained at a given level of obesity.

\textbf{The benefits of exercise}

It is theoretically more effective for an obese person to refrain from unnecessary eating than to try and burn off energy by episodes of exercise unless he or she enjoys physical activity. There are other benefits of exercise involving the concept of ‘metabolic fitness’
with an improvement in plasma insulin levels, insulin sensitivity, improved glucose tolerance, free fatty acid flux and LPL activity as well as improved well-being, which may facilitate adherence to such weight loss programs (see chapters by Després and Bouchard).

Exercise by obese individuals would be expected to stimulate appetite so that loss of weight may be retarded. When lean women exercise, they adjust their energy intake to match the increase in energy expenditure\(^\text{42}\). However, in at least one study,\(^\text{42}\) in which energy expenditure was increased for prolonged periods and food intake was covertly monitored, obese women did not produce a full compensatory increase in food intake. Weight was lost, most of which was fat mass. Thus to be regularly physically active may allow a more correct set of appetite in order to achieve energy balance.

Wood et al.\(^\text{21}\) during a long-term study of physical exercise without dietary modification found that there was an overall net negative energy balance and that body fat decreased and lean body mass increased slightly. Further studies by Wood et al.\(^\text{43,44}\) showed that whether fat loss occurred through dieting or exercise, comparable and favourable changes in plasma lipoproteins occurred. Exercise tended to enhance the improvement in lipoprotein profile seen with diet alone. It may be said that some of the men involved were 'metabolically' obese\(^\text{45}\). It is this group that stands to benefit most from a program of increased activity and dietary modification. The mere presence of obesity and insulin-glucose ratios during fasting or in response to a glucose load may help identify such subgroups. There is a need for a clinically applicable method of evaluating insulin resistance. The 'minimal model' of Yang et al.\(^\text{46}\) holds promise of being such a useful clinical measure.

A meta-analysis of 13 studies\(^\text{47}\) in humans evaluating the effect of aerobic exercise in body weight found a small but significant decrease in total body weight in the groups studied. This is deceiving because profound positive changes in body composition may occur without necessarily changes in body weight. These are not measured in detail in most studies. The reduction in body fat in obese individuals undertaking exercise differs from the non-obese. Several attempts have been made to sub-classify obese people. One such method is to classify obesity in terms of the number and size of the fat cells. Unfortunately, these measures vary significantly between individuals and do not seem to be applicable as a universal concept.

Other studies have investigated the effects of different forms of exercise on both weight control and metabolic parameters. One study from the Cooper Institute for Aerobics Research (see \(^\text{48}\)) compared high and low intensity walking exercise on fitness, weight control and lipid profiles in young women. Compared with sedentary controls, the level of aerobic fitness increased in a dose response manner in all the walkers. HDL levels increased in all groups and total body fat declined.\(^\text{48}\) Similarly, a study on cardiovascular fitness and golf\(^\text{49}\) found a significant loss of weight over one golfing season. A reduction in total cholesterol levels was also seen in conjunction with a favourable improvement in the overall lipid profile (see Table 2).

Several classic studies\(^\text{18,19,20,27,28,30,31,52}\) in the field of diet, nutrition and longevity demonstrate quite clearly the fact that a higher energy intake predicts a reduced mortality rate. The beneficial interplay between these factors has been addressed in a prospective fashion (see Tables 1 and 2, Fig. 6).

Recent studies have shown that the distribution of fat may be more important than the absolute amount of fat. Moderately obese subjects with central obesity not only have a greater number of medical complications but respond better with exercise training.\(^\text{53}\) Other variables may also play a prominent role in determining the body fat response to exercise training. These include intensity, duration, frequency and starting
Table 2. Benefits of exercise in obesity.

Reduction in body weight
  Increase in RMR
  Decrease in total fat mass
  Reduction of appetite
  Increased energy expenditure

Reduction in cardiovascular risk
  Alteration of fat distribution
  Improvement in metabolic profile
  Reduction in cholesterol
  Increase in HDL-Cholesterol
  Decrease in cardiac workload
  Increased lipoprotein lipase activity
  Decreased blood pressure

Psychological
  Sense of well-being
  Increase in self-esteem
  Improvement in body image

Figure 6. Age standardised incidence (%) of myocardial infarction over 12 years by quintiles of energy intake in Swedish women.18

weight. A review of exercise studies54 found that significant loss of weight required a frequency of at least three times per week and furthermore, that loss of weight was directly proportional to the amount of energy expended during exercise. An exercise duration of more than thirty minutes is more likely to be associated with significant loss of weight. Low-intensity and long-duration exercise would be expected to be favourable for fat loss because it would increase the ratio of fatty acid to glucose utilised as fuel. However, no studies have fully addressed this point as yet.
Table 3. The health effects of obesity.

Increased mortality
Cardiovascular Disease
Diabetes Mellitus
Neoplastic Disease
Gall bladder Disease
Accidents
Suicide

Increased morbidity
Social problems
Psychological
Physical disability
Joint disease
Cardiorespiratory
Mechanical problems
Medical disease
Cardiovascular
Diabetes
Neoplasia
Gall bladder disease

Effect of exercise on dietary ‘loss of weight’ programs
One of the well-described consequences of dietary loss of weight is the reduction in
resting metabolic rate. Possible reasons for this include a decrease in the concentration
of tri-iodothyronine, a decrease in the activity of the sympathetic nervous system, a
decrease in the thermic effect of food and the loss of fat-free mass. Of these factors,
Garrow considers loss of lean mass to be the most important. The observed reduc-
tion in energy requirements in the reduced obese patient, maybe of critical importance
in explaining the high recidivism rate in dietary loss of weight programs.

A possible untoward consequence of very low-energy diet (VLED) is the negative
impact on exercise capacity. Exercise time to exhaustion is significantly reduced es-
specially in glycogen limited high-intensity exercise. The clinical experience of using
VLED is that patients will often complain of excessive tiredness when attempting to
regularly exercise on such a restricted energy intake.

Recent studies have compared the effect of dietary intervention plus exercise versus
diet alone on loss of weight and body composition. In one study, three groups of
overweight middle-aged women were compared. The first group on a 500 kcal per day
diet restriction, the second group had a 500 kcal per day increase in energy expendi-
ture and the third group had a 250 kcal per day dietary restriction plus a 250 kcal per
day increase in energy expenditure. After 16 weeks total weight loss was no different
but the two groups that included exercise had lost less relative fat-free mass. Thus,
significantly more of the lost weight was fat. Other studies had found similar re-
results. The overall fat distribution is altered with loss of central or abdominal fat
predominantly. This may account for improvements in insulin sensitivity and an
overall improvement in ‘metabolic fitness’.

Yet again, exercise induces an increased sense of well-being and its effect on eating
behaviour and the feedback that movement provides for a sense of body size and
shape may be improved.
Other beneficial metabolic effects of exercise
In addition to reduction in overall adiposity and fat distribution, there are a number of other potentially beneficial metabolic effects in the obese. Improvements in insulin sensitivity, reduced plasma insulin and improvement in glucose tolerance are evident. Abnormalities in the plasma lipid profile commonly seen in obese patients may be reversed eg: elevation in VLDL, triglycerides, LDL and a reduction in HDL with a resulting increase in the LDL:HDL ratio. These are independent risk factors in the development of atherosclerotic disease.

Aerobic exercise is associated with reduced triglyceride levels. This is due to the increase in lipoprotein-lipase mediated removal of the LDL particles. There have been variable reductions in total cholesterol levels reported although overall profiles may be improved. Both cross sectional and prospective studies have demonstrated an increase in the HDLC fraction following exercise training particularly after aerobic exercise.

The effect of exercise on energy intake
In 1954, Mayer published the first studies, investigating the influence of exercise on energy intake in rats. Over a wide range of added daily exercise, the increment in the daily exercise expenditure was closely matched by an increase in the energy intake and there was no overall change in body weight. At the extremes of added daily exercise, intake did not increase proportionally and loss of weight occurred. In human studies, spontaneous food intake is much harder to study. More recently Woo studied the relationship between exercise and food intake in exercising obese women under strict metabolic ward condition. They showed a small but non-significant increase in the energy intake as activity level increased. However, the subjects went into a negative energy balance and follow-up studies detected an energy catch-up phase after the extended period of exercise training had failed to demonstrate any significant change. Parallel studies in normal non-obese patients show a tight correlation between energy expenditure and energy intake.

Activity in energy expenditure

There are several lines of reasoning when reaching the conclusion that decreased levels of energy expenditure may be important in the pathophysiology of obesity. Epidemiological surveys agree that energy intake in the obese is not greater than in the non-obese and that obese adults are less active. Evidence that obese individuals adopt a more sedentary lifestyle with regard to television viewing habits, lifestyle and occupational practices tends to reinforce this concept. Although studies have shown that obese are less active, it cannot be inferred however that they expend less energy, since energy expenditure to complete a given task is greater in the obese.

Daily total energy expenditure in a free-living environment has not been fully explored to show whether there is a difference between the obese and the non-obese that may account for the occurrence of the obesity.

Practical principles

Combined loss of weight programs need to ascertain both a patients desire to lose weight as well as a realistic program of negative energy balance with defined short- and long-term goals of success.
Dietary programs remain the mainstay of treatment, they must have three characteristics:

- They must provide less energy than is required to maintain the body weight of the obese patient.
- They should be nutritionally adequate.
- They should be acceptable to the patient.

In practice, the energy deficit required to produce weight loss is estimated (usually in the range of 800 to 1500 kcal per day) and the loss of weight observed at regular intervals. Restriction of saturated fats in the diet is especially important both for loss of weight as well as the prevention of coronary heart disease.

Other methods to assist weight loss include.\textsuperscript{26,64}

- Physical exercise.
- Pharmacological measures. These include drugs to inhibit the absorption of nutrients, increase energy expenditure and/or reduce hunger.
- Jaw wiring and/or gastric stapling.
- Waist cord.\textsuperscript{38,64}
- Behaviour modification.

Public health and clinical implications

Several important implications flow from the control of energy balance in the development, maintenance and prevention of obesity and in improvements in overall health.

(1) Longevity and coronary mortality can be beneficially influenced by high energy intakes, particularly of high-carbohydrate foods (eg: cereals, fruits and vegetables). There is evidence that a high fish intake reduces the risk of atherosclerotic complications.

(2) Longevity can also be improved by increasing energy expenditure. An increase of 1500–2100 kJ per day can result in a significant reduction in mortality. This is equivalent to walking briskly for 30 to 40 minutes per day. Long-term prospective studies have repeatedly demonstrated the dose relation effect of increasing energy expenditure on reductions in mortality.

(3) Measures to control energy balance must consider other factors aside from weight as the sole end point in decision analysis. Changes in body composition, intra-abdominal fat and in the distribution of adiposity have profound health effects over and above the metabolic improvements seen with exercise. These factors may well be more important than the absolute value of weight change.

(4) Success in achieving and maintaining weight loss requires behavioural change to effect long-term solutions to the required negative energy balance and the consequent improvement in health outcomes.

References


