PART III

Understanding how overweight and obesity develop

7. Factors influencing the development of overweight and obesity

7.1 Introduction

In simple terms, obesity is a consequence of an energy imbalance — energy intake exceeds energy expenditure over a considerable period. Many complex and diverse factors can give rise to a positive energy balance, but it is the interaction between a number of these factors, rather than the influence of any single factor, that is thought to be responsible. In contrast to the widely held perception among the public and parts of the scientific and medical communities, it is clear that obesity is not simply a result of overindulgence in highly palatable foods, or of a lack of physical activity.

The various influences on energy intake and expenditure that are considered to be important in weight gain and the development of obesity are considered below. Section 7.2 gives an overview of the fundamental principles of energy balance, the physiological regulation of body weight and the dynamics of weight gain. Section 7.3 examines the role of dietary factors and physical activity patterns in weight gain. Section 7.4 discusses the multitude of environmental and societal forces that adversely affect food intake and physical activity patterns, and may thus overwhelm the normal regulatory processes that control the long-term energy balance. Finally, section 7.5 reviews the various genetic, physiological or medical factors that can determine an individual's susceptibility to those forces and that put that person at higher risk of weight gain and obesity.

The following should be noted:

- Obesity can result from a minor energy imbalance that leads to a gradual but persistent weight gain over a considerable period. Once the obese state is established, physiological processes tend to maintain the new weight.
- Body weight is primarily regulated by a series of physiological processes but is also influenced by external societal and cognitive factors.
- Recent epidemiological trends in obesity indicate that the primary cause of the global obesity problem lies in environmental and behavioural changes. The rapid increase in obesity rates has occurred in too short a time for there to have been significant genetic changes within populations.
- The increasing proportion of fat and the increased energy density of the diet, together with reductions in the level of physical activity

and the rise in that of sedentary behaviour, are thought to be major contributing factors to the rise in the average body weight of populations. Dealing with these issues would appear to be the most effective means of combating rises in the level of overweight and obesity in the community.

- The global obesity problem can be viewed as a consequence of the massive social, economic and cultural problems now facing developing and newly industrialized countries, as well as ethnic minorities and the disadvantaged in developed countries. Escalating rates of obesity, NIDDM, hypertension, dyslipidaemia and CVD, coupled with cigarette smoking and alcohol abuse, are frequent outcomes of the modernization/acculturation process.
- Epidemiological, genetic and molecular studies in many populations of the world suggest that there are people who are more susceptible to weight gain and the development of obesity than others. Genetic, biological and other personal factors such as smoking cessation, sex and age interact to determine an individual's susceptibility to weight gain.
- Certain ethnic groups appear to be especially liable to the development of obesity when exposed to an affluent lifestyle, although susceptibilities to obesity comorbidities are not uniform across these groups.

7.2 Energy balance and the physiological regulation of body weight

The major influences on energy balance and weight gain are shown in Fig. 7.1.

7.2.1 *Fundamental principles of energy balance*

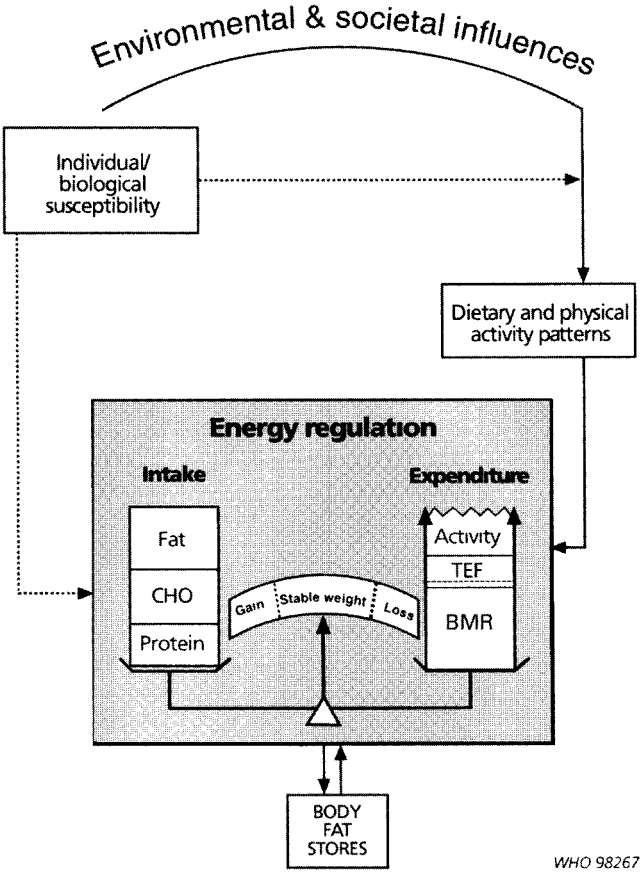
The fundamental principle of energy balance is:

changes in energy stores = energy intake – energy expenditure

A positive energy balance occurs when energy intake is greater than energy expenditure; it promotes an increase in energy stores and body weight. Conversely, a negative energy balance occurs when intake is less than expenditure, promoting a decrease in energy stores and body weight.

Under normal circumstances, the energy balance oscillates from meal to meal, day to day and week to week without any lasting change in body stores or weight. Multiple physiological mechanisms act within each individual to equate overall energy intake with overall energy expenditure and to keep body weight stable in the long term. Thus, if

Figure 7.1
Influences on energy balance and weight gain (energy regulation)



The diagram shows the fundamental principles of energy balance and regulation. A positive energy balance occurs when energy intake is greater than energy expenditure, and promotes weight gain. Conversely, a negative energy balance promotes a decrease in body fat stores and weight loss. Body weight is regulated by a series of physiological processes that have the capacity to maintain weight within a relatively narrow range (stable weight). It is thought that the body exerts a stronger defence against undernutrition and weight loss than it does against overconsumption and weight gain. However, powerful societal and environmental forces influence energy intake and expenditure, and may overwhelm the above-mentioned physiological processes. The susceptibility of individuals to these forces is affected by genetic and other biological factors, such as sex, age and hormonal activities, over which they have little or no control. Dietary factors and physical activity patterns are considered to be the modifiable intermediate factors through which the forces that promote weight gain act.

TEF = thermic effect of food; BMR = basal metabolic rate; CHO = carbohydrate.

Table 7.1
Energy content of macronutrients

Macronutrient	Energy contribution	
	($kcal_{th}$/g)	(kJ/g)
Fat	9	37
Alcohol	7	29
Protein	4	17
Carbohydrate	4	16

is only when there has been a positive energy balance for a considerable period that obesity is likely to develop.

Energy intake

Total energy intake refers to all energy consumed as food and drink that can be metabolized inside the body. Table 7.1 shows the energy content of the constituent macronutrients present in food and drink. Fat provides the most energy per unit weight, and carbohydrate and protein the least. Fibre undergoes bacterial degradation in the large intestine to produce volatile fatty acids that are then absorbed and used as energy. The size of the energy contribution from fibre is thought to be 6.3 kJ/g (1.5 $kcal_{th}$/g) (*1*).

Energy expenditure

The second element of the energy balance equation, total energy expenditure, has the following three main components:

— the basal metabolic rate (BMR);
— dietary thermogenesis (meal-induced heat production);
— physical activity.

The proportion that each component contributes to the total energy expenditure varies according to the regularity and intensity of physical activity. In sedentary adults, the BMR accounts for nearly 60% of total energy output, the dietary thermogenic response for around 10%, and physical activity for the remaining 30%. In those engaged in heavy manual work, total energy expenditure increases and the proportion of energy expenditure accounted for by physical activity may rise to about 50%. Dietary thermogenesis appears to remain constant at 10%, leaving the BMR to account for 40% of the total energy expenditure. Although the BMR may vary intrinsically between individuals of similar weight by ±25%, within each individual it is tightly controlled (*2*). The key variable of energy output in an individual is the degree of physical activity.

7.2.2 *Physiological regulation of body weight*

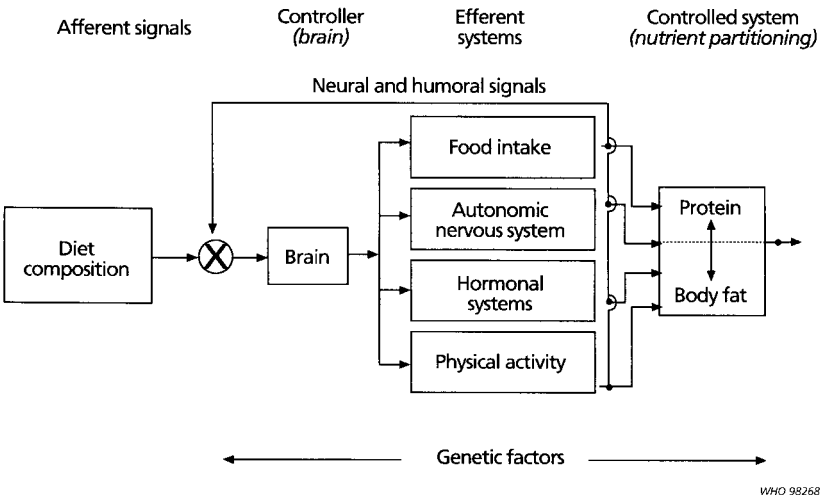
Societal and cognitive factors can influence the control of body weight to a certain extent, but it is a series of physiological processes that are primarily responsible for body weight regulation. In traditional societies, where people tend to be more physically active, and provided that food supplies are not limited, few adults are either underweight or overweight despite the interaction of seasonal cycles of work, festivities, individual susceptibilities to obesity for physiological or genetic reasons, and the wide range of varying physical demands within a society. Such physiological mechanisms constitute a fundamentally important biological process that can be observed throughout the animal kingdom. It is thought that the body exerts a stronger defence against undernutrition and weight loss than it does against overconsumption and weight gain (*3*).

The physiological mechanisms responsible for body weight regulation are incompletely understood. However, there is increasing evidence of a range of signalling mechanisms within the intestine, the adipose tissue and brain, and perhaps within other tissues, that sense the inflow of dietary nutrients, their distribution and metabolism and/or storage. These mechanisms are coordinated within the brain and lead to changes in eating, in physical activity and in body metabolism so that body energy stores are maintained. The recent discovery of the hormone leptin, which is secreted by adipocytes in proportion to their triglyceride stores and binds with receptors in the hypothalamus, provides interesting insights into possible regulatory signal systems that act to maintain the energy balance. However, much remains to be elucidated about such systems, some of which are illustrated in Fig. 7.2.

7.2.3 *Dynamics of weight gain*

Despite the extensive physiological regulation of body weight outlined above, a positive energy balance can lead to weight gain if it persists in the long term. The initiation of a chronic positive energy balance is due to an increase in energy intake relative to requirements, either as a result of an increase in total energy intake, a decrease in total energy expenditure, or a combination of the two. Currently there is little information about the fluctuations in energy balance that lead to weight gain and obesity. It is possible that large deviations from energy balance at regular intervals may contribute to weight gain, but it is believed that a small consistent deviation over a long period is also capable of producing large increases in body weight.

Figure 7.2
Physiological processes involved in body weight regulation



The diagram shows the interaction between the different mechanisms that affect energy and body weight regulation within individuals. The brain integrates an array of afferent signals (nutrient, metabolic, hormonal and neuronal) and responds by inducing changes in food intake, autonomic nervous system activity, hormonal responses or spontaneous physical activity. The different components then directly or indirectly determine the proportion of dietary energy deposited as protein rather than fat.

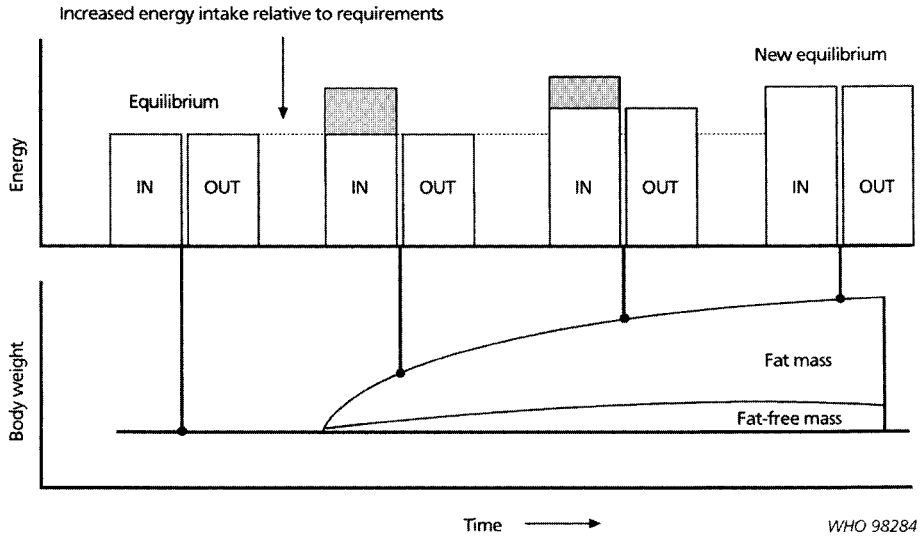
Fig. 7.3 shows that the process of gaining weight can be divided into the following three phases:

- The *preobese static phase*, when the individual is in long-term energy balance and weight remains constant.
- The *dynamic phase*, during which the individual gains weight as a result of energy intake exceeding energy expenditure over a prolonged period.
- The *obese static phase*, when energy balance is regained but weight is now higher than during the preobese static phase.

The dynamic phase can last for several years and often involves considerable fluctuations in weight (weight cycling) as a result of conscious efforts by the individual to return to a lower weight. However, in the absence of intervention, the difference between energy intake and energy expenditure progressively diminishes. This is due to an increase in BMR as a result of the larger fat-free mass (including that in the expanded adipose tissue) as well as to an additional energy

Figure 7.3

Effect on energy expenditure, energy balance and body weight of an increase in energy intake relative to requirements[a]



A persistent increase in energy intake above requirements will lead to a gradual gain in body weight. However, the size of the energy imbalance progressively diminishes as weight is gained, because of an increase in metabolism associated with the larger fat-free mass and the expanded adipose tissue. A new higher equilibrium weight is eventually established that is again defended by physiological mechanisms. Thus, it is harder to lose the weight gained than it is to experience a second cycle of increasing body weight should, for example, a fall in physical activity occur at the same time as a further period of prolonged positive energy balance.

[a] Adapted, with permission, from: Schutz Y. Macronutrients and energy balance in obesity. *Metabolism*, 1995, 4(9 Suppl. 3):7–11 (reference *4*).

cost of activity imposed by the extra weight (*5*). There may also be an increase in resting metabolic rate (RMR) with overfeeding (*6*).

Once the obese static phase is established, the new weight appears to be defended. This can best be shown by the response of obese individuals to underfeeding; they show a fall in metabolic rate as the body recognizes the loss of energy (*7*) and an unconscious physiologically driven increase in energy intake (*8*).

7.2.4 *Implications for public health*

Given the global epidemic of obesity, the aim should be:

— to identify the environmental factors, including societal changes, that have overwhelmed the physiological regulatory processes outlined above;

— to determine whether some individuals are more susceptible to those influences for medical, behavioural or genetic reasons.

7.3 Dietary factors and physical activity patterns

Dietary factors and physical activity patterns strongly influence the energy balance equation and can be considered to be the major modifiable factors through which many of the external forces promoting weight gain act (Fig. 7.1). In particular, high-fat, energy-dense diets and sedentary lifestyles are the two characteristics most strongly associated with the increased prevalence of obesity worldwide.

7.3.1 *Dietary factors*

Macronutrient composition

Laboratory experiments in animals and clinical studies in humans have repeatedly shown that dietary factors, particularly the level of fat and energy intake, are strongly and positively associated with excess body weight. By contrast, population-based studies of diet and obesity have reported inconsistent results. Such inconsistencies have been attributed to a number of factors, including weaknesses in study design, methodological flaws, confounders, and random and/or systematic measurement error in the data, especially the dietary data (*9*). Thus, in population studies that pay careful attention to the determinants of obesity, a positive association is observed between dietary factors and obesity identical with those found in animal models and human clinical studies (*10*).

Energy intake. Dietary fat has a higher energy density than other macronutrients (see Table 7.1, p. 104 and Table 7.2, p. 111). This is thought to be largely responsible for the overeating effect, or *passive overconsumption* as it is often called, experienced by many subjects exposed to high-fat foods (*3*). The stimulatory effect of fatty foods on energy intake may also be due to the pleasant mouth-feel of fat when eaten (*11*).

The body does compensate for the overconsumption of energy from high-fat foods to some extent, but the fat-induced appetite control signals are thought to be too weak, or too delayed, to prevent the rapid intake of the energy from a fatty meal. Episodic intakes of high-fat foods are therefore particularly likely to overwhelm these signals, and the control of food intake thus depends on long-term regulatory processes that seem much less able to respond to overfeeding than to underfeeding with weight loss. Fibre, by contrast, limits energy intake by lowering a food's density and allowing time for appetite-control signals to occur before large amounts of energy have been consumed (*3*).

There is no clear evidence to suggest that high intakes of sugar overwhelm the appetite-control signals in the same manner as fat. However, there is some indication from short-term feeding trials that *ad libitum* low-fat high-complex-carbohydrate diets of low energy density induce weight loss. This does not occur on energy-dense diets, regardless of whether the energy density has been increased by modifying the fat content or the sugar content of the diet (*12*). Further studies are required before any conclusions can be drawn from this work.

Energy storage and macronutrient balance. The macronutrient composition of the diet also influences the extent to which excess energy is stored, depending on the storage capacity within the body of the macronutrients concerned, those macronutrients with a low storage capacity within the body being preferentially oxidized when intakes exceed requirements:

- *Alcohol*: no storage capacity within the body and so all ingested alcohol is oxidized immediately. This response dominates oxidative pathways and reduces the rates at which other fuels are oxidized.
- *Protein*: limited storage capacity as body protein, which is accessible only through loss of lean body mass. Amino-acid metabolism is tightly regulated to ensure the oxidation of any excess.
- *Carbohydrate*: small capacity for storage as glycogen. The intake and oxidation of carbohydrate are very tightly "autoregulated", rapid and substantial changes in carbohydrate oxidation taking place in response to alterations in carbohydrate intake. Excess carbohydrate can also be converted into fat, but this metabolic pathway is not used by humans to any appreciable extent unless a large excess of a low-fat, high-carbohydrate diet is consumed. When carbohydrate is oxidized, however, less fatty-acid oxidation is required so that dietary fat is stored and endogenous fat retained. About 60–80% of the excess energy may be stored on carbohydrate overfeeding (*13*).
- *Fat*: the capacity for fat storage in the body is virtually unlimited and excess dietary fat does not markedly increase fat oxidation. Excess dietary fat is readily stored in adipose tissue depots with a very high efficiency (about 96%).

Thus, the bulk of the evidence suggests that carbohydrate and protein balances, but not fat balance, are well regulated. It is becoming clear that weight changes following challenges to body weight are due primarily to disruptions in fat balance, as these account for most of the imbalance produced in total energy (*13–19*).

In the long term, however, fat balance has to be regulated in order to achieve energy and macronutrient balance. Achieving fat balance again following a perturbation in energy balance is thought to require a change in the body fat mass. This may be because fat oxidation varies directly with body fat mass (*20*), but the way in which fat mass and total fat oxidation are linked is not clear. As an example, an increase in dietary fat without a rapid change in fat oxidation will produce a positive fat balance and hence lead to increases in body fat mass. As body fat mass increases, fat oxidation also increases. Fat mass will increase to the point at which fat oxidation matches fat intake, and the body fat mass will then stabilize at the new, higher, level.

Food palatability and pleasure. The palatability of food has an important influence on behaviour (*3*). Food palatability tends to promote consumption and is one of the most powerful influences in inducing a positive rather than a negative energy balance. It increases both the rate of eating and the sense of hunger during and between meals. The presence of fat in food is particularly enjoyable, and is associated with a pleasurable mouth-feel. The food industry has capitalized on this phenomenon by developing foods of increasing palatability. Moreover, the pleasurable sensations provided by foods can be viewed as a reward by those consuming them and can condition behaviour that favours overconsumption.

Sweetness is one of the most powerful, easily recognized and pleasurable tastes, so that many foods are sweetened in order to increase their palatability and consumption. The consumption of sugars does, however, lead to a subsequent suppression of energy intake by an amount roughly equivalent to the amount provided by the sugars (*21*). Nevertheless, sweetened foods of high fat content are expected to be conducive to excess energy consumption since palatability is enhanced both by sweetness and mouth-feel, and fat has only a small suppressive effect on appetite and intake. A preference for sweet–fat mixtures has been observed in obese women and may be a factor in promoting excess energy consumption (*22*).

Overview of macronutrient influence on body weight regulation. Table 7.2 summarizes the main characteristics of the macronutrients. Fat appears to be the key macronutrient that undermines the body's weight regulatory systems since it is very poorly regulated at the level of both consumption and oxidation. There is currently no consensus regarding the role of sugar intake on body weight regulation but there is some concern that the overconsumption of sweet–fat foods may be a

Table 7.2
Characteristics of macronutrients

Characteristic	Protein	Carbohydrate	Fat
Ability to bring eating to an end	High	Intermediate	Low
Ability to suppress hunger	High	High	Low
Contribution to daily energy intake	Low	High	High
Energy density	Low	Low	High
Storage capacity in body	Low	Low	High
Metabolic pathway to transfer excess intake to another compartment	Yes	Yes	No
Autoregulation (ability to stimulate own oxidation on intake)	Excellent	Excellent	Poor

problem, at least in certain subgroups of the population. Finally, although high protein intakes may appear to be advantageous in controlling energy intake and contributing to good body weight regulation, such intakes (especially of animal protein) have been associated with a number of adverse health consequences.

Dietary patterns

Daily eating pattern. Research on eating patterns and health has focused mainly on fluctuations in blood glucose and blood lipid concentrations throughout the day, particularly in the context of the control of NIDDM. There does appear to be some advantage in nibbling versus gorging under isocaloric conditions from the point of view of glycaemic control and hypertriglyceridaemia (*23*). However, in at least one controlled study, there was no effect of meal patterns on energy metabolism and energy balance (*24*).

Under free-living conditions, meal patterns vary widely across populations and cultures. Regular (high-fat) snacking has been associated with increased overall dietary intake in affluent societies, but this conclusion remains controversial (*25*). Other evidence from affluent societies suggests that dietary restraint and slimming leads to skipping breakfast and that this may result in overconsumption later in the day (*26*). Some people exhibit additional eating during the night, possibly as part of a night-eating syndrome (*27*) that is associated with obesity, although the mechanism underlying this association is not known. Recently, in a study in obese people trying to lose weight, it was found that the prognosis of weight loss was better in women who ate more and smaller meals than in those who ate fewer but larger meals.[1]

[1] Astrup A. ed. *Food and eating habits*, 1996. Background paper prepared by the Food and Eating Habits subgroup of the International Obesity Task Force.

Eating disorders. Eating disorders, particularly those that result in excess energy intake relative to requirements, have been implicated in the development of obesity. However, it is uncertain whether obesity is a direct result or an underlying cause of such disorders. For a more detailed discussion of eating disorders, including binge-eating disorder and night-eating disorder, see section 4.10.4.

7.3.2 *Physical activity patterns*

Cross-sectional data often reveal an inverse relationship between BMI and physical activity (*28–31*), indicating that obese and overweight subjects are less active than their lean counterparts. However, such correlations do not demonstrate cause and effect relationships, and it is difficult to be certain whether obese individuals are less active because of their obesity or whether a low level of activity caused the obesity. Results of other types of study, however, suggest that low and decreasing levels of activity are primarily responsible; for instance, obesity is absent among elite athletes while those athletes who give up sports frequently experience an increase in body weight and fatness (*32–35*). Furthermore, the secular trend in the increased prevalence of obesity seems to parallel a reduction in physical activity and a rise in sedentary behaviour. One of the best examples of this is provided by Prentice & Jebb (*36*), who used crude proxies for inactivity, such as the amount of time spent viewing television or the number of cars per household. These studies all suggest that decreased physical activity and/or increased sedentary behaviour plays an important role in weight gain and the development of obesity. This conclusion is further supported by prospective data. Dietz & Gortmaker (*37*), for example, have shown that the amount of television watching by young children is predictive of BMI some years later, while Rissanen et al. (*34*) have shown that a low level of physical activity during periods of leisure in adults is predictive of substantial weight gain (≥5 kg) in 5 years' time. More prospective data will help to clarify this relationship, but it seems reasonable to link physical inactivity with future weight gain.

Physical activity patterns have an important influence on the physiological regulation of body weight. In particular, they affect total energy expenditure, fat balance and food intakes. Box 7.1 outlines the different components of "physical activity" and defines "physical inactivity". Box 7.2 introduces the concept of physical activity levels (PALs).

Contribution of physical activity to total energy expenditure

Increased energy expenditure is an intrinsic feature of physical activity and exercise. Energy requirements increase from basal levels

Box 7.1
Physical activity

Physical activity is a global term referring to "any bodily movement produced by skeletal muscle that results in a substantial increase over the resting energy expenditure". It has three main components (*38*):

- *Occupational work*: activities undertaken during the course of work.
- *Household and other chores*: activities undertaken as part of day-to-day living.
- *Leisure-time physical activity*: activities undertaken in the individual's discretionary free time. Activity is selected on the basis of personal needs and interests. It includes exercise and sport:
  - — *Exercise*: a planned and structured subset of leisure-time physical activity that is usually undertaken for the purpose of improving or maintaining physical fitness.
  - — *Sport*: defined differently around the world but usually implies a form of physical activity that involves competition. It may also embrace general exercise and a specific occupation.

The time allocated to each of the three components varies considerably between individuals and populations.

Physical inactivity (sedentary behaviour)

Physical inactivity, or sedentary behaviour, can be defined as "a state when body movement is minimal and energy expenditure approximates RMR" (*39*). However:

- Physical inactivity represents more than an absence of activity; it also includes participation in physically passive behaviours such as television viewing, reading, working at a computer, talking with friends on the telephone, driving a car, meditating or eating (*40*).
- Physical inactivity may contribute to weight gain through means other than a reduction in energy expenditure. For example, recent studies in adolescents (*41*) and adults (*42*) have demonstrated significant relationships between inactivity and other adverse health practices, such as the consumption of less healthy foods and an increased fat intake.

immediately after the initiation of physical activity, and the increase persists for the duration of the activity. The total amount of energy expended depends on the characteristics of the physical activity (mode, intensity, duration and frequency) and of the individual performing the exercise (body size, level of habituation and fitness). These relationships have been extensively reviewed in the literature (*43*), and tables providing approximate values of the energy costs of various physical activities are widely available.

Box 7.2
Physical activity levels

Physical activity level (PAL) values express daily energy expenditure as a multiple of BMR, thereby allowing approximate adjustment for individuals of different sizes. PALs are a universally accepted way of expressing energy expenditure and help to convey an easily understandable concept.

Individuals whose occupation involves regular physical exercise are likely to have PAL values of 1.75 or more. Those whose lifestyle involves only light occupational and leisure-time activity will probably have PAL values of 1.55–1.60. People who engage in no activity whatsoever will have PAL values around 1.4.

In order to avoid obesity, populations should remain physically active throughout life, at a PAL value of 1.75 or more. Thus:

Lifestyle	*PAL*
Sedentary	1.4
Limited activity	1.55–1.60
Physically active	≥1.75

Some ways in which PAL can be increased from 1.55–1.60 to 1.75 or more by an extra hour of moderate activity each day are shown below. More strenuous activities require less than 1 hour each day to bring the overall average PAL up to 1.75.

Duration	*Activity ratio*[a]	*Activity*
1 hour	4–5	Brisk walk (6 km/h), canoeing (5 km/h); cycling (12 km/h), gardening; baseball; volleyball
45 minutes	6–7	Cross-country hiking; cycling (15 km/h); skating (14 km/h); water skiing; dancing; snow-shoeing
30 minutes	10–12	Any vigorous activity, e.g. football; hockey; running (13 km/h); rugby; handball; basketball (competition)

[a] Activity ratio = multiple of BMR.

If exercise is vigorous, oxygen consumption remains elevated above resting levels for some time after exercise ceases. This metabolic response is called the "excess post-exercise oxygen consumption" (EPOC) and is due to the need to restore energy reserves, especially glycogen levels in liver and muscles. Compared with the energy cost of exercise itself, however, the contribution of EPOC is likely to be modest. In a recent study, it was estimated that, after 2 hours' exercising at a moderate intensity, it accounted for an extra 200 kJ/day

(48 $kcal_{th}$/day) when averaged over 24 hours (*44*). Although this is quite small in terms of total daily energy expenditure, it has the potential to help maintain energy balance if exercise is undertaken regularly.

In addition to the immediate energy costs of increased physical activity and of the recovery period (i.e. EPOC), habitual exercise may influence several other components of energy expenditure including RMR. Although this area of research is still the subject of controversy, several recent studies have provided evidence for a positive association between activity levels and RMR (*45*). As the increase in the RMR is lost after several days of inactivity, this highlights the benefit of regular and sustained exercise patterns (*46*). Moreover, resistance exercise such as weight training may contribute to the maintenance of, or to an increase in, muscle mass, thereby favouring an elevation of the RMR or preventing a decrease in metabolic rate in the presence of weight loss (*47*).

Energy expenditure across the world

There is a widespread belief that daily life in less developed countries demands a much greater physical effort; for instance, a woman in a developing country spends 30–150 minutes every day of her life simply fetching water (*48*), and walks while attending to her daily chores for up to 1.5 hours. However, it is difficult to get accurate assessments of energy expenditure in free-living conditions; where developed and developing countries have been compared, few differences have been found (*49*). One explanation offered for this apparent discrepancy is that adults in less developed countries compensate by being inactive whenever possible; in Ethiopia, for example, energy expended on physical activity decreases in the post-harvest season (*50*). Secondly, the curtailment of physical activity in order to save energy represents the first line of defence against energy stress caused by insufficient dietary energy. Such a behavioural response can be illustrated by poorly nourished Rwandan women, who spend more time in low-cost activities than their better nourished counterparts (*51*). Overall, however, it is reasonable to conclude that people in less developed countries who spend a considerable portion of their time in finding food for their next meal and on personal chores are expending more energy in work and physical activity for a given body size than those in more developed countries.

Effect of physical activity on fat and substrate balance

Regular physical activity and substrate balance. One of the most important adaptations to regular exercise is the increased capacity to use fat

rather than carbohydrate during moderate physical activity. These differences become considerable when the exercise is maintained over a longer period; physically trained individuals metabolize more fat at given levels of energy expenditure than the untrained. It has been shown, for example, that the rate of fat oxidation in a group of unfit individuals increased by approximately 20% after a 12-week fitness training programme (*52*).

Of particular relevance is the observation that regular moderate physical exertion allows free-living volunteers to consume *ad libitum* a 40% fat diet without storing excess fat, whereas the same individuals, when sedentary, are in positive fat and energy balance and thus have a greater risk of becoming overweight and obese with time. If, however, they are offered a 20% fat diet, they remain in balance even when sedentary (*53*). Although these physiological studies should be interpreted with caution, they are of profound significance because they suggest a fundamental interaction between the level of physical activity and the proportion of dietary fat in determining whether energy balance can be sustained. The precise level of dietary fat that overwhelms the body's capacity to increase fat oxidation in response to increases in exercise and the extent to which this dietary fat level varies between individuals are unknown. However, it is thought that people who sustain moderate or high levels of physical activity throughout life can tolerate diets with a high fat content (e.g. 35–40% of energy) whereas lower fat intakes (20–25% of energy) may be needed to minimize energy imbalance and weight gain in sedentary individuals and societies. Thus, since most people in developed countries are sedentary, it is reasonable to assume that fat balance is achieved at a level of fat intake of 30% or less. In developing countries, the level of dietary fat compatible with fat balance may be higher as a result of the amount of energy expended on work and personal chores.

Exercise intensity and substrate balance. The metabolic responses to low- and high-intensity physical activity are very different. The extent to which fat and carbohydrate contribute to energy metabolism depends on the intensity level of the activity; fat is preferentially oxidized during low-intensity activity whereas carbohydrate is the dominant fuel at high intensity. In theory, the highest relative level of fat oxidation occurs when adults are moderately active at around 50–60% of maximum. In addition, theoretical calculations suggest that multiple bouts of intense exertion are better stimuli for fat oxidation than the equivalent energy use through more prolonged low-activity levels (*54*). The important point to remember is that the number of grams of fat oxidized during activity increases with the intensity and

the duration of the activity, despite the fact that the proportion of fat in the mixture of fuel oxidized for muscular contraction may decrease at higher intensities. It should also be kept in mind that fat is oxidized not only during the activity but also in the recovery period.

Impact of physical activity on food intake and preference

Food intake. There is a common perception that exercise stimulates appetite, leading to an increased food intake that even exceeds the energy cost of the preceding activities. In fact, there is little supporting evidence for this from human studies; if a compensatory rise in intake does occur, this tends to be accurately matched to expenditure in lean subjects so that energy balance is re-established in the long term (*54*, *55*). However, Woo et al. (*56*) showed that obese women did not compensate for the higher energy expenditure induced by exercise by increased intake, and thereby obtained a significant negative energy balance on exercise. This suggests that those who have stored an excess amount of energy may particularly benefit from exercise.

In the short term, hunger can be suppressed by intense exercise, and possibly by low-intensity exercise of long duration (*54*). The effect is short-lived, however, so that the temporal aspects of exercise-induced anorexia may best be measured by the delay in eating rather than the amount of food consumed (*57*).

Food preference. Whether exercise influences the type of food and the mix of macronutrients chosen by free-living subjects remains uncertain. In a small number of longitudinal studies, a higher intake of carbohydrate-rich foods has been observed with an increase in PAL (*58*), and a significant positive relation was recently found between the level of PAL and carbohydrate intake in a diet intervention study (*59*). However, it is not known whether dietary advice on optimum sport nutrition or physiological needs helps to initiate such dietary changes (*54*).

More information is needed in order to assess the value of a higher intake of carbohydrate-rich foods in the general population in whom changes in the level of physical activity are relatively small.

Physical activity levels for prevention of excessive weight gain

Analyses of over 40 national physical activity studies worldwide show that there is a significant relationship between the average BMI of adult men and their PAL, the likelihood of becoming overweight being substantially reduced at PALs of 1.8 or above (see Box 7.2, p. 114, for information on PALs). The relationship for women, though not statistically significant, is similar, but their physical activity tends to be lower

(mean PAL 1.6) (*49*). It has been suggested, therefore, that people should remain physically active throughout life and sustain a PAL of 1.75 or more in order to avoid excessive weight gain. Sedentary people living or working in cities typically have a PAL of only 1.55–1.60, and PALs in industrialized societies are drifting downwards.

People who make extensive and increasing use of motorized transport, automated work and sedentary leisure pursuits, may find it difficult to attain PAL levels at or above 1.75 simply by increasing activity during "leisure time". This is illustrated by the calculations of Ferro-Luzzi & Martino (*49*), who showed that, for an average 70-kg adult male, increasing a PAL of 1.58 to one of about 1.70 involves an average of 20 minutes a day of vigorous exercise, such as running or circuit training at an activity ratio of 11 (a level of activity achievable only by a physically fit person), or else 1 hour of extra walking every day. Increasing a PAL of 1.58 to one of 1.76 requires approximately 1 hour and 40 minutes of extra walking (at 4 km/h) per day (Fig. 7.4). As these activity requirements are *additional* to a 24-minute period of "active leisure" (12 minutes of sports and 12 minutes of walking) already required for a PAL of 1.58, it follows that urban sedentary populations are likely to attain a PAL of 1.75 or more only if supported by vigorous national policies that encourage physical activity. For example, these should encourage children to be active at play and school, and should create environments in which walking and cycling become the most common means of travel to work and for short journeys.

7.4 Environmental and societal influences

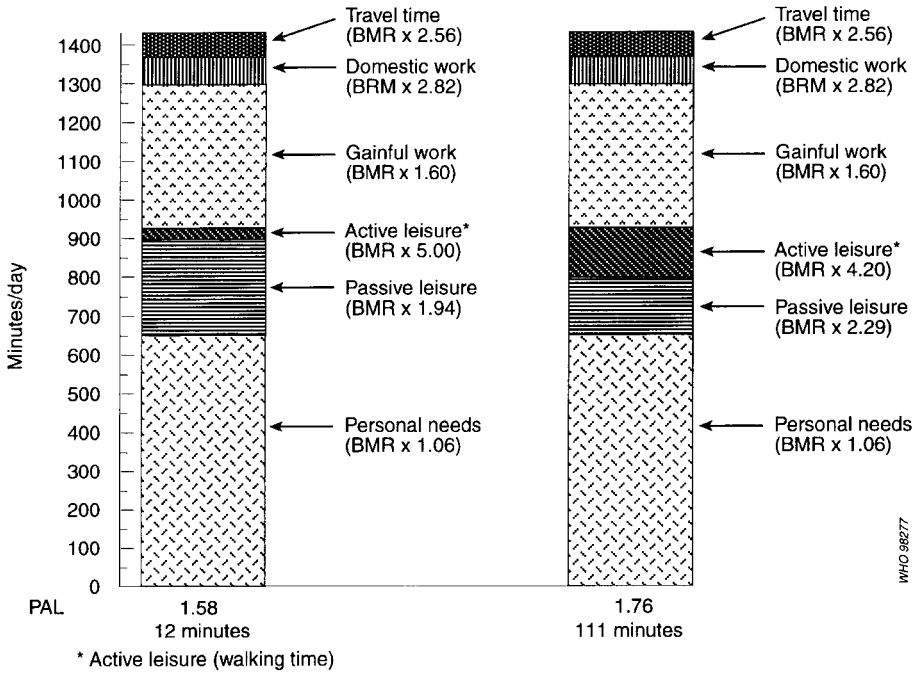
As previously mentioned, the rapid increase in obesity rates in recent years has occurred in too short a time for there to have been any significant genetic changes within populations. This suggests that the primary cause of this increase must be sought in the environmental and societal changes now affecting a large proportion of the world's population.

This section discusses the environmental and societal factors that, through their effects on food intake and physical activity patterns, have overwhelmed the physiological regulatory processes that operate to keep weight stable in the long term. The societal changes that influence food intake and physical activity are also briefly considered.

7.4.1 *Changing societal structures*

The trend towards industrialization and an economy based on trade within a global market in most of the developing countries has

Figure 7.4
Active leisure required to achieve an overall mean PAL of 1.76[a]



This model of the nature, duration and timing of active leisure required to achieve an overall mean PAL of 1.76 is based on the activity profile of the average Italian adult male, aged 30–60 years (*60*). He is assumed to weigh 70 kg and to have a predicted BMR of 1690 $kcal_{th}$/day. He is sedentary, being employed in a light-activity job (BMR factor = 1.60 (*61*)), and he spends only 24 minutes per day in active leisure (made up of 12 minutes' sports and 12 minutes' walking) at an overall BMR factor of 5.0. The other 252 minutes are spent in passive leisure (BMR factor 1.94). Increasing his daily walking time (speed 4 km/h, BMR factor 4.0) to 111 minutes raises his daily PAL to 1.76. The extra 99 minutes of walking time have been taken from the 252 minutes of passive leisure time; more specifically, it has been assumed that he would replace all the time spent watching television (90 minutes) and 9 minutes spent reading by walking.

[a] Adapted from reference *49* with the permission of the publisher. Copyright John Wiley & Sons Ltd.

brought about a number of improvements in the standard of living and in the services available to the population. However, it has also had various negative consequences; these have led, directly and indirectly, to deleterious nutritional and physical activity patterns that contribute to the development of obesity. Changing societal structures resulting from this economic transition have given rise to new problems associated with unemployment, overcrowding, and family and community breakdown. Social dislocation has often followed the loss by indigenous populations of traditional lands that are then used for production for the export market (*62*).

The food system that has emerged today is based on an industrial approach to agriculture and food production, makes most foods available regardless of season, and supplies highly processed outputs. While this may have contributed to improved food availability, it has not necessarily solved the problem of undernutrition in many of the poorer countries, nor has it improved the nutritional quality of the diets of the affluent (*63*). Indeed, some aspects of the industrialization of food production have contributed to the consumption of a diet higher in protein and fat (particularly saturated fat) and lower in complex carbohydrate.

The decline in energy expenditure seen with modernization and other societal changes is associated with a more sedentary lifestyle in which motorized transport, mechanized equipment, and labour-saving devices both in the home and at work have freed people from physically arduous tasks (Table 7.3). Work-related activity has declined over recent decades in industrialized countries, while leisure time dominated by television viewing and other physically inactive pastimes has increased (*49*). In the United Kingdom, for instance, the average distance walked by English children aged 14 years and younger fell by 20% between 1985 and 1992, and the average distance cycled fell by 26%, while the average distance travelled by car increased by 40% (*64*). The dangers of traffic and fears for personal safety have also influenced the decline of play in public areas.

Some of the key changes in societal structures that are thought to underlie the observed adverse changes in dietary and physical activity patterns implicated in the rapid global rise in obesity are considered below.

Modernization

Most adults who still have a "traditional" lifestyle appear to gain little or no weight with age. Anthropometric studies have reported an absence of obesity in the few remaining hunter–gatherer populations of the world, since energy expenditure is generally high and food supplies are scarce in certain periods of the year (*70*). For the majority of the world's population, however, the process of "modernization" has had a profound effect on the environment and on lifestyles over the last 50–60 years.

Food is now more abundant and the overall energy demand of modern life has dropped appreciably. These changes have subsequently been associated with dramatic increases in obesity rates. Indeed, Trowell & Burkitt, who carried out 15 case-studies of epidemiological

Table 7.3
Examples of energy-saving activity patterns in modern societies

Transport	Dramatic increases in car ownership mean that many people now travel short distances by car rather than walking or cycling to their destination.
In the home	Easily available fuel supplies obviate the need to collect and prepare fuels for lighting and heating; central heating has reduced the need to expend energy on thermoregulation. Energy expenditure is also reduced through the use of cooking equipment and ready-prepared foods/ingredients in meal preparation. Use of washing machines and vacuum cleaners makes for easier and quicker cleaning.
In the workplace	Mechanization, robotics, computerization and control systems have markedly reduced the need for even moderate activity, and only a very small proportion of the population now engages in physically demanding manual work.
Public places	Lifts, escalators and automatic doors are all designed to save substantial amounts of time and energy.
Sedentary pursuits	Television viewing is a major cause of inactivity, especially in the obese (*65*). Data from the USA show that it was strongly related to the incidence of new cases of obesity and to the failure of obese children to lose weight (*37*). These results are consistent with those of recent research showing that there were notable reductions in obesity when reductions in television viewing time were included in a dietary and activity intervention (*66*). The average person now watches over 26 hours of television a week in the United Kingdom, compared with 13 hours in the 1960s (*67*); children in the USA can spend more time watching television than attending school (*68*). Data are needed from other countries and for other sedentary pursuits such as computer use.
Urban residence	In urban areas of more affluent countries, children, women and older people are reluctant to go out alone or at night because of fears for their personal safety. Children also have difficulty in playing on streets in residential areas because of traffic trying to bypass congested main roads (*69*). For active leisure pursuits, children and adults therefore usually travel by car to sports facilities or to the open country as "special" outings rather than taking exercise routinely as a part of their daily lives. Further research is needed in this area to determine the relative importance of such factors, and whether or not they have an impact on obesity.

change in modernizing societies, report that obesity is the first of the so-called "diseases of civilization" to emerge (*71*). While early studies concluded that obesity usually emerged first in middle-aged women and then in middle-aged men, particularly among the more affluent

groups, in the last decade it has become clear that obesity is increasingly being seen in much younger age groups, e.g. in children and adolescents. Trend or longitudinal data generally indicate that steady increases in the rates of obesity are greater in urban areas (*72*). However, a recent report from Samoa noted a dramatic increase in obesity prevalence of 297% in men and 115% in women in a rural community (*73*). This was clearly apparent even in the 25–34-year age group in both sexes.

New World syndrome. Obesity can be seen as the first wave of a defined cluster of NCDs now observed in both developed and developing countries. This has been called the "New World syndrome" (*74*) and is already creating an enormous socioeconomic and public health burden in poorer countries. High rates of obesity, NIDDM, hypertension, dyslipidaemia and CVD, coupled with cigarette smoking and alcohol abuse, are closely associated with the modernization/acculturation process and increasing affluence. The New World syndrome is responsible for disproportionately high levels of morbidity and mortality in newly industrialized countries, including eastern Europe, as well as among the ethnic minorities and the disadvantaged in developed countries (*74*). Thus, while obesity is viewed by health professionals from a medical perspective, it also needs to be recognized as a symptom of a much larger global social problem.

Economic restructuring and transition to market economies

The world is going through a period of rapid economic transition. Economies based on a few primary commodities are no longer viable, and a great deal of investment is often required to modernize existing industries and infrastructures in order to compete in a global market.

For many countries, the economic transition has meant huge loans from international banks as well as investments by large multinational companies on terms more favourable to them than to the host country. Interest payments on these loans coupled with rising interest rates have crippled health, education and social services, and local economies have been restructured to rely on industries based on cheap labour (*63*). Thus, many developing countries are becoming increasingly reliant on imported non-traditional foods, have very high rates of unemployment, and are also faced with the large-scale migration of people from rural to urban areas in search of work that is becoming increasingly sedentary in nature (*75*, *76*).

Increasing urbanization

In less developed countries, urban residents are generally taller, heavier, and have a higher BMI than those who live in rural areas (*72*). This association between urban residence and obesity is of particular concern given the increasing numbers of people living in urban areas. Europe and North America are no longer the only major urban regions of the globe. Since the Second World War, the proportion of people living in the urban areas of less developed countries has increased from 16.7% in 1950 to 37% in 1994, and is predicted to grow to 57% in 2025 (*77*). Furthermore, there has been a shift towards the concentration of population growth in a few large cities of population greater than 5 million, often called urban agglomerations, and a shift in poverty to the urban areas, particularly into squatter and slum zones.

Urban residence is associated with a wide range of factors that in turn affect diet, physical activity and body composition. These include changes in transportation, access to and use of modern educational and health facilities, communications, marketing and availability of food, and large differences in occupational profiles, among others. In most countries, urban residents consume smaller proportions of carbohydrates and greater proportions of protein and fat, particularly saturated fat (*78*).

Changes in the role of women

In industrialized societies, an increasing number of women are entering the job market or are returning to full- or part-time paid employment within a few years of childbirth. They still tend to take responsibility for the health and well-being of the family but less and less for the more time- and energy-consuming domestic chores concerned with cleaning and the preparation and serving of food.

Going out to work has given women greater economic influence, especially over domestic purchases, and has contributed to the demand for convenience foods and labour-saving devices such as the microwave oven. People in paid employment tend to spend less time on shopping, cooking and other household tasks, so that the demand for "convenience" food products has increased. People may no longer have the time, energy, motivation or skills to prepare food from the basic ingredients. In the USA, the percentage of food dollars spent on eating outside the home increased by about 40% between 1980 and 1990 (*79*).

Changes in social structures

Changes in social structures have also led to an increasing proportion of the population working in service, clerical and other professional

occupations that demand considerably less energy expenditure than the physically demanding manual work of more traditional societies.

Globalization of world markets

Food and food products are now commodities that are produced, traded and sold for profit in a market that is no longer largely local but increasingly global. Foods are less often seen as a matter of life and death, or of religious or cultural significance. Manufacturers and retailers seek to minimize uncertainties and costs, and to maximize returns. Competition is intense, both within and outside areas where these manufacturers and retailers are operating (*80*).

Large companies have expanded to control ever-increasing shares of trade in agriculture, manufacturing and retailing, and smaller farms and shops are being squeezed out of business (*81*). The effects of the debt crisis in the developing countries, the collapse of communism in eastern Europe and the former Soviet Union, and the dominance of free-market ideologies are promoting globalization and the development of market economies throughout the world, drawing even the most isolated self-supporting peasants into a global market (*63*). The concentration of food supply in the hands of a small number of multinational companies reduces their responsiveness to consumer or government pressure, and increases their influence on government policy (*82*).

7.4.2 *Variation within societies*

Socioeconomic status and obesity

Socioeconomic status is usually measured in terms of a composite index combining income, education, occupation and, in some developing countries, place of residence (urban/rural). However, its individual components may have independent and even opposite effects on dietary intake and physical activity patterns, so that it is often very difficult to make generalizations about the relationship between socioeconomic status and obesity.

Despite these problems, studies have repeatedly shown that high socioeconomic status is negatively correlated with obesity in developed countries, particularly among women, but positively correlated with it in populations of developing countries (*83*, *84*). Further evidence suggests that, as the less developed countries attain higher levels of affluence, the positive relationship between socioeconomic status and obesity is slowly replaced by the negative correlation seen in developed countries (*78*).

Developing countries. In developing countries, the lower obesity rates observed in the populations of lower socioeconomic status are

associated with a situation where people are limited in their ability to obtain enough food, yet still engage in moderate to heavy manual work and have little access to public transport. Hence, thin adults are considered poor, and overweight and obesity are a sign of affluence.

However, as per capita income increases, the nature of the diet in traditional societies tends to change in a pervasive and well documented manner (*85*). In particular, intakes of animal fat and protein increase, those of vegetable fat and protein decrease, those of total, and particularly complex, carbohydrates also decrease, and those of sugar increase.

The increase in income may be associated with increased away-from-home consumption of high-fat food items, as in the Philippines, or with increased consumption of meat, as in China. However, the overall effect tends to be a greater intake of total fat and an increased prevalence of obesity (*78*).

Developed countries. As previously mentioned, developed countries tend to show an inverse relationship between obesity and socioeconomic status, and between obesity and income, especially among women. A state of food deprivation is now very unusual in any major population groups in the industrialized countries, and the proportion of adults engaged in physical activity at home has fallen markedly with modernization. Thus, the groups of lower socioeconomic status need to be no more physically active or short of food (in energy terms) than those of higher status. In fact, studies suggest that families belonging to the lower-status groups engage in much less physical activity than those in higher ones; for instance, their obesity levels have risen in parallel with rising car ownership and they watch television for many more hours per day (*36*).

Studies indicate that change in income has little effect on dietary structure in countries where income levels are already quite high in relation to basic food needs; instead, increases in income are spent on more elaborately packaged and processed or higher-quality foods rather than on a greater quantity of food. In the poorest income groups, however, food demand is much more price- and income-sensitive, and many people struggle to obtain enough high-quality food for what is considered to be a healthy diet (*86*). The diet of households of lower socioeconomic status tends to be energy-dense, and high fat intakes are a prominent feature; the more expensive vegetables, fruit and whole-grain cereals are eaten more sparingly.

Education and health-related knowledge

Level of education appears to be inversely associated with body weight in industrialized countries. Surveys in France, the United

Kingdom and the USA all showed that the proportion of obese men and women was higher among those of a lower educational level (*87, 88*). The observed inverse relationship between education and body weight may be partly attributed to the fact that individuals of higher educational level are more likely to follow dietary recommendations and adopt other risk-avoidance behaviours than those of low educational attainment (*89*). In the USA, a trend has been emerging among the better educated sections of the population to adopt and adhere to dietary guidelines and other "healthy lifestyles" (*78*). Unfortunately, little is known about the relationship between education level and obesity in developing countries except that urban adults are more highly educated than those from rural areas.

The benefit of nutritional knowledge *per se* appears to be limited. Surveys indicate that, although some people know what constitutes a healthy diet, they prefer in practice to consume a relatively unhealthy one (*90*). Obesity rates continue to climb, despite the increased frequency of dieting among obese people, suggesting that knowledge and frequent attempts to slim are insufficient for successful weight control.[1] However, without these widespread attempts to control body weight, the prevalence of obesity in industrialized countries might be much higher.

7.4.3 *Cultural influences*

It is also essential in any international review of obesity to recognize that at least two-thirds of the world's population consists of people of African, Chinese or Indian origin, living in developing countries. For such people, the risk factors and perceived causes of obesity often differ from those of people of European origin.

Culture affects both food intake and physical activity patterns, although the "cultural attributes" responsible are not well characterized and accurately measured at present. Cultural behaviours and beliefs are learned in childhood, are often deeply held, and are seldom questioned by adults, who pass them on to their offspring. Attitudes and beliefs may change over time, however, as shown by the expectations in industrialized countries of body weight and shape that appear to be of particular importance in determining people's behaviour. Substantial differences in obesity prevalence between relatively affluent populations indicate that cultural values and traditions may mediate or moderate the effects of affluence on obesity rates.

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[1] Westenhoefer J. In: *Social and cultural issues of obesity*, 1996. Background paper prepared by Social and Cultural subgroup of the International Obesity Task Force.

Cultural influences on food intake, selection and preparation
Cultural factors are among the strongest determinants of food choice. They include peer group pressures, social conventions, religious practices, the status assigned to different foods, the influence of other members of the household and individual lifestyles. The effect of cultural factors can be seen, for example, in children who give way to peer pressure by selecting high-fat foods, and in executives dining at expensive restaurants with business colleagues.

Cultural explanations of obesity are based on what are traditionally thought of as "learned" behaviours. For example, it is not uncommon for white American parents to encourage their children to eat particular foods by rewarding them with other food items. Recent research has shown that this culturally sanctioned pattern of rewards actually contributes to a dislike of the "good" foods and a preference for the "bad" ones (*91*). In some cultures, high-fat meals are provided for family entertainment and celebration.

Few foods are unique to particular cuisines, although some may be considered suitable for consumption by one culture but not by another. Human beings value food for much more than its nutrient content, and it is used to express relationships between people as well as in celebrating religious festivities, weddings and other important social occasions.

Attitudes towards health, fitness and activity. The idea of engaging in physical activity during leisure time is not understood in many cultures and communities in which energy conservation has historically been a prime concern especially during periods of food shortage. The improvement in food availability has done little to change such attitudes to physical activity, which often persist across generations even though the original rationale for their adoption has long been forgotten.

In contrast, the people of the Nordic countries, among others, prize fitness and vitality, and thus have a positive attitude towards physical activity; in such countries, considerable amounts of leisure time are devoted to vigorous activity rather than to more sedentary pursuits.

Body image. Throughout most of human history, increased weight and girth have been viewed as signs of health and prosperity. This is still the case in many cultures, especially where conditions make it easy to remain lean or where thinness in babies is associated with increased risk of infectious disease. Fat women are often viewed as attractive in Africa, for example, where some traditional communities have "fattening huts" for elite pubescent girls to ensure that they start their

reproductive lives with a peripheral fat energy surplus (*84*). In Puerto Rican communities, weight gain after marriage is seen as showing that the husband is a good provider and that the woman is a good wife, cook and mother. Weight loss is socially discouraged, and there is a widespread fatalistic acceptance of the view that successful weight loss by the obese is not possible (*92*).

In many industrialized countries, the past three decades have witnessed a marked change in attitudes towards body shape and weight. Thinness in women has come to symbolize competence, success, control and sexual attractiveness, while obesity represents laziness, self-indulgence and a lack of will power.[1] Such ideals of thinness exist in a setting where it is easy to become fat, and tend to lead to inappropriate dieting, a failure to achieve unrealistic weight goals, and weight cycling. Recent research suggests that, as many traditional cultures embrace the values and ideals of the politically or economically dominant culture of the industrialized countries, they too are likely to see an increase in eating disorders and unhealthy weight-control practices (*93*, *94*). In the USA, concern about overweight is seen in a variety of ethnic groups (*95*), although the preferred "unhealthy" method of weight control tends to vary; as compared with white adolescent females, Hispanics reported greater use of diuretics, Asians reported more binge eating, and African Americans reported higher rates of vomiting (*96*).

Cross-cultural research reveals that the male body ideal is most often related to "bigness" (large structure and muscularity), but not necessarily to fatness (*70*, *97*). In contrast to women, men generally do not see increased size and adiposity as a problem, although they are at greater risk of developing abdominal obesity; they therefore tend not to seek the treatment they need.[2]

Television and popular magazines have been criticized for reinforcing the association between thinness and attractiveness (*98*, *99*), especially when they present conflicting messages in the form of advertisements for energy-dense and high-fat foods. Media exposure and the presentation of thin female fashion models as the ideal increase many women's dissatisfaction with their body shape and promote eating disorders (*100*, *101*). Efforts should be made to ensure that the media do not create a situation in which obesity is stigmatized and eating

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[1] Hill AJ. In: *Social and cultural issues of obesity*, 1996. Background paper prepared by Social and Cultural subgroup of the International Obesity Task Force.

[2] Astrup A, ed. *Food and eating habits*, 1996. Background paper prepared by Food and Eating Habits subgroup of the International Obesity Task Force.

disorders promoted in the many societies where such a situation does not exist.

7.4.4 *Impact of societal changes on food intake and activity patterns*

Governments, the food industry, the media and consumers, among others, have the potential to influence, positively and negatively, the impact of societal and environmental factors, particularly modernization, on the food supply and on PALs. None of them in isolation has been responsible for creating an obesity-promoting environment any more than, acting alone, any one of them can effect meaningful change. Thus a partnership is clearly required if such an environment is to be avoided.

Governments and regional authorities

Governments and regional authorities are responsible for protecting and promoting the health of the community by ensuring access to a safe, nutritious and affordable food supply as well as to facilities for regular physical activity. Modernization and the competing demands of economic development and health have sometimes created a situation where actions by governments have contributed to a decrease in physical activity and an increase in the intake of energy-dense food, contrary to their own health guidelines.

Development and adaptation of national dietary guidelines. Dietary recommendations and guidelines have often not kept pace with societal changes and advances in nutrition science or with the specific nutritional problems of communities as countries go through the nutrition transition.

Government nutrition programmes. Government feeding programmes established in developing countries to deal with undernutrition often remain in place even when there is evidence to suggest that undernutrition no longer exists. Such programmes may sometimes contribute to a worsening of the problem of overconsumption of energy that follows modernization.

Meals provided in government institutions. Governments and regional authorities are responsible for the food served in schools, hospitals, day-care centres and government organizations. Even when they do not provide such food, they have the power to lay down firm guidelines as to its quality and composition. Unfortunately, many have failed to draw up guidelines for the provision of meals in such establishments and to monitor their implementation.

Physical activity at school. Governments and regional authorities are in a position to ensure that regular physical activity is undertaken in all schools. However, many have allowed the time devoted to such activity in schools to be reduced and land on which children previously played in safety to be used for other purposes.

Regulation of food quality, advertising and labelling. Many governments have failed to respond to the changing food supply by laying down or amending food regulations governing food quality and safety, and the labelling and advertising of foods. This has led to a situation in which consumers are at risk of being badly informed or confused by poor labelling or the unregulated marketing of foods. A recent report by Consumers International (*102*) has shown that, even when regulations governing marketing and advertising exist, they are often not enforced so that compliance with them is poor.

Food production policies. Economic development and increasing involvement in free markets often result in the abandonment by governments of a food production policy based on small regional food producers and the adoption instead of one that involves large-scale or centralized farming. Such policies often increase the movement of people from rural areas to towns and cities and can result in a loss of food diversity and of the production of traditional foodstuffs in favour of the wide-scale production of cash crops for export markets.

The aim in many developing countries is still that of increasing the total food energy available to the population so that the problems of undernutrition are avoided. However, the increased emphasis in food production on oil crops or meat products may add to the problems associated with the rapidly increasing energy density of the national diet, especially when these products make their way into the local food supply and displace traditional foods that are no longer widely available.

Food surpluses. For many decades, the primary objective of governments and the food industry has been to maintain a supply of cheap food so that even the poorest sections of society can purchase sufficient amounts. The use of tax concessions, direct subsidies and rebates from the producer to the retailer, however, have often led to an oversupply of commodities, so that economic strategies now tend to be directed at increasing consumer demand to meet supply. As a result, surplus cheaper foodstuffs are exported from developed countries to markets created in developing ones (*103*). This is illustrated by the export of cheap vegetable fats from Australia, the USA and

Europe to neighbouring countries in the Pacific, South America, Asia and eastern Europe (*76*, *104*).

The food industry

Advances in food technology and product development. Technological advances in cultivating, preserving, producing, transporting and storing foods have increased the year-round availability of a wider variety of foods to a larger number of people. The continuing globalization of these processes means that such trends in food availability are spreading from industrialized countries to developing ones.

Advances in food technology have also contributed to the consumption of diets increasingly dependent on processed foods. It is now possible to produce food products having almost any variety of taste, textural quality and nutrient content. In fact, food characteristics are often manipulated to such an extent that it is difficult for individuals to associate visual, textural or taste cues with the energy content of meals. This is especially important given the increasing trend towards prepackaged foods and the concomitant decline in the use of natural and basic ingredients in food preparation in the home.[1] Consumers are losing control over the preparation of the foods that they eat, and food composition is increasingly being placed in the hands of manufacturers.

In order to survive in the modern competitive market economies, businesses cannot stand still but need to grow and maintain or increase profits for shareholders. If this cannot be done by increasing sales of basic foodstuffs to those who can afford to buy them, it can be done by turning basic foodstuffs into other, more expensive products (i.e. processed, prepackaged foods) (*63*).

Fast foods. Although it can be argued that "fast foods" have been available for centuries, such foods tended to be those of traditional diet and culture. Today, fast foods and snacks tend to be universal in nature, are often provided by large multinational corporations, and are high in fat, low in complex carbohydrates, and energy-dense (*105*). They may not be entirely satisfying and are often used as regular additions to the diet instead of being consumed as an occasional meal or treat.[2] Furthermore, beverages containing substantial amounts of sugar or alcohol are often consumed as part of a fast-food meal.

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[1] Buisson DH. *Consumer food choices for the 2000s — the impact of social and marketing trends.* Paper presented at the CSIRO Food Industry Conference, Adelaide, Australia, 1992.

[2] Astrup A, ed. *Food and eating habits*, 1996. Background paper prepared by Food and Eating Habits subgroup of the International Obesity Task Force.

Modern fast foods have proliferated rapidly, and are widely available and intensively advertised. In 1991, it was reported that fast foods accounted for 19% of the global consumer catering market, then worth US$ 730000 million, and that their market share was expected to grow to 25% by 2000. In the USA, the market for fast foods was worth US$ 78000 million in 1992 (*106*), and more than 200 people are served a hamburger every second of the day. Greater availability has been achieved by increasing the number of outlets and the opportunities to eat outside the home; the number of fast-food outlets in the United Kingdom doubled in the 10 years between 1984 and 1993, while the number of restaurants and cafes remained the same (*107*).

Direct evidence that increased consumption of fast foods leads to overweight and obesity is lacking. However, it is widely perceived that this is the case and that obesity has increased in industrialized societies as families turn away from home-prepared meals and consume more fast or take-away foods. The roles of the media and of the consumer in this process are considered below.

Marketing and advertising. The commercialization of food manufacturing and retail outlets has encouraged enthusiastic marketing. Larger portion sizes give the consumer an impression of "better value" for money, and marketing strategies such as "eat all you can for X dollars" represent an encouragement to eat beyond natural biological limits. Furthermore, these foods and outlets are backed by substantial advertising campaigns that, in stark contrast to public health or nutrition campaigns, are extremely persuasive and successful.[1]

The media

The media, including television, radio and print, play a major role in disseminating information in modern consumer societies. They are part of informal education, and both reflect and influence public attitudes. However, far more money has been spent on promoting high-fat/energy-dense foods than on promoting healthier foods. For example, £86.2 million was spent on promoting chocolate confectionery in the United Kingdom in 1992 compared with only £4 million spent on advertising fresh fruit, vegetables and nuts (*108*).

The media provide information on new and existing foods to consumers and have a pervasive influence on food choice; they have clearly been influential in changing dietary patterns in recent decades.

[1] Astrup A, ed. *Food and eating habits*, 1996. Background paper prepared by Food and Eating Habits subgroup of the International Obesity Task Force.

Television, in particular, plays a major role in informing and influencing children. This development may not be helpful, e.g. 91% of foods advertised during peak children's viewing time in the USA, and a similar proportion in the United Kingdom, were high in fat, sugar and/or salt (*109*, *110*). Although the food and advertising industries consistently argue that food advertising has little influence or detrimental effect on children's eating habits, a considerable amount of evidence now suggests that it does influence food selection by children and adolescents, especially among susceptible groups (*63*, *111*). Television viewing appears closely linked to the consumption by children of the foods that they see advertised on television (*112*, *113*).

Consumers

Consumers play a role in fuelling a demand for a wide variety of products and services conducive to weight gain; they often demand processed and convenience meals that tend to be high in fat and energy-dense, as well as labour-saving devices both at home and in the workplace that require little energy expenditure. Although it is recognized that consumer demand is itself influenced by a number of factors, including marketing, advertising, culture, fashion and convenience, the product or service is unlikely to survive in its existing form if consumers do not want it. Better educated consumers can demand better products, especially those of improved nutritional quality.

Most societies have a preference for sweet foods and prize fatty foods the most (*114*). With increasing incomes and the greater availability of such foods, there has been a marked increase in their consumption. The ability to purchase labour-saving devices is widely welcomed by consumers in all societies and ownership of a car is seen as an important status symbol. Consumers in emerging economies are likely to be reluctant to return to diets of traditional foods, to physical labour or to walking, all of which are associated with poverty, once a certain level of income has been achieved.

7.5 Individual/biological susceptibility

Epidemiological, genetic and molecular studies of populations all over the world suggest that some people are more susceptible than others to becoming overweight and obese, and that such susceptible individuals exist in countries differing widely in lifestyle and environmental conditions.

Obesity is commonly seen as a complex multifactorial disease; it is a condition resulting from a lifestyle that promotes a positive energy balance, but also one that becomes manifest more readily in people who have an inherited susceptibility to be in positive energy balance.

Furthermore, no two obese individuals are the same; there are differences in both the degree and the regional distribution of excess body fat as well as in the fat topography response of individuals to factors that promote weight gain. Such differences are due not only to genetic variation but also to the prior experiences and environments to which the individuals have been exposed. The evidence for this conclusion has been carefully reviewed (*115*). However, considerable uncertainty remains as to the genes and mutations involved, and how they operate and interact to enhance the susceptibility of some individuals to obesity.

The evidence for a role of genetic, biological and other factors in determining the susceptibility of individuals to weight gain and obesity is briefly discussed here.

7.5.1 *Genetic susceptibility*

The role of genetic factors in weight gain is currently the subject of much research, and the discovery of leptin (see pp. 136–137) has led to a renewed interest in genetic and metabolic influences in the development of obesity. While it is possible that single or multiple gene effects may cause overweight and obesity directly, and indeed do so in some individuals, this does not appear to be the case in the majority of people. Instead, it is currently considered that the genes involved in weight gain increase the risk or susceptibility of an individual to the development of obesity when exposed to an adverse environment. Only in the case of certain genetic disorders are particular gene effects "necessary" for obesity expression.

Heritability

The level of heritability is the fraction of population variation in a trait (e.g. BMI) that can be explained by genetic transmission, and a large number of twin, adoption and family studies on the heritability of different measures of obesity have been conducted. Adoption studies tend to generate the lowest estimates and twin studies the highest. Recently, however, the application of complex analytical techniques to databases encompassing all three types of studies has led to the conclusion that the true heritability of BMI in large sample sizes was likely to be in the range 25–40% (*116*, *117*). On the other hand, similar genetic epidemiological research has shown that the profile of fat distribution was also characterized by a significant heritability level of the order of about 50% of the total human variation. Finally, recent studies have shown that the amount of abdominal fat was influenced by a genetic component accounting for 50–60% of the individual differences (*118*, *119*).

Obesity tends to run in families, obese children frequently having obese parents. However, there is a dearth of data concerning the level of risk of developing obesity for a first-degree relative of an overweight, moderately obese or severely obese person in comparison with the population prevalence of the condition (*117*). One of the first papers on this topic by Allison et al. (*120*) concluded that the relative risk was about 2 for overweight, increasing to about 3–4 for higher levels of obesity.

Gene–environment interactions

While some individuals are prone to excessive accumulation of fat and struggle to lose weight, others do not have these difficulties. Studies in both animals and humans suggest that genetic factors are partially responsible for such differences in the tendency of individuals to gain fat when chronically exposed to a positive energy balance.

For example, by feeding a high-fat diet to different inbred strains of mice, scientists have found that both sensitive and resistant strains exist (*121*). More recently, a prospective study showed that high fat intake in humans was correlated with subsequent weight gain only in those subjects who were overweight at baseline and had obese parents (*122*). These studies and others suggest that the genetic predisposition to obesity observed in animal models may also exist in humans, making some individuals particularly susceptible to a high fat intake.

It is also quite clear that certain inbred strains of rodents are particularly prone to becoming obese when exposed to overfeeding or to a highly palatable diet. Similarly, in a study on pairs of identical twins, the body weight and the proportion of fat gained in response to controlled overfeeding was significantly more alike within pairs of twins than between them (*123*). This and other studies based on the same design strongly suggest that there are individuals who are more likely than others to gain body mass and body fat when challenged by an energy overload. Thus, the responsiveness to energy intake and dietary composition is partly dependent on specific genetic factors that have yet to be clearly identified.

Types of genetic effects

If the heritability estimates are correct — and the evidence for this is quite strong — the genes are exerting their influence on body mass and body fat as a result of DNA sequence variation either in the coding sequence of the genes or in the segments that affect gene expression. It is obvious that most of the genes contributing to obesity do not qualify as necessary genes, i.e. genes that cause obesity whenever one or two copies of the defective allele are present. Indeed, the

genetic susceptibility seems to be rather one caused by genes associated with an increase in the proneness to gain weight over time or, alternatively, by the absence of genetic influences that protect against the development of a positive energy balance. In general, such genes exert smaller effects on the phenotype than necessary genes—a situation that makes the identification of these genes and of the responsible mutations much more difficult. Nonetheless, even though the genetic effect associated with the risk of obesity appears to be of the multigenic type, there is some indirect evidence to support the notion that one or a few genes may play a more important role. In other words, obesity is a truly complex multifactorial phenotype with a genetic component that includes both polygenic and major gene effects.

A series of studies reported over the past several years strongly supports the view that many genes are involved in causing susceptibility to obesity. Several types of research have been used to identify these genes and the specific DNA sequence variation responsible for the increase in risk of becoming obese. The evidence accumulated so far has recently been reviewed (*124*) and provides statistical or experimental support for a role for about 70 genes, loci or markers. Many more years of research will be needed before the important genes and critical mutations are finally identified for both excess body fat content and upper body and abdominal fat accumulation.

Possible mechanisms whereby genetic susceptibility may operate include:

- *Low RMR*: e.g. studies in the Pima Indians have shown RMR clusters in families and that those with lower RMR have a greater risk of gaining 10 kg in the following 5 years (*125*, *126*).
- *Low rate of lipid oxidation*: e.g. a low ratio of fat to carbohydrate oxidation under standardized conditions is a risk factor for subsequent weight gain (*18*, *127*).
- *Low fat-free mass*: a low fat-free mass for a given body mass is a risk factor for subsequent weight gain as it tends to depress the level of RMR, thus favouring a positive energy balance.
- *Poor appetite control*: e.g. if satiety is reached at a high level of energy intake, the net result is likely to be a positive energy balance and weight gain. Here, many genes and molecules are currently under investigation. For instance, leptin, the hormone product of the *ob* or leptin gene, is an important satiety factor secreted by the adipose tissue in humans. An anomaly in the leptin receptor gene may be associated with leptin resistance in humans. However, the

Table 7.4
Some factors involved in the development of obesity thought to be genetically modulated

Macronutrient-related:
adipose tissue lipolysis
adipose tissue and muscle lipoprotein lipase (LPL) activity
muscle composition and oxidative potential
free fatty acids and β-receptor activities in adipose tissue
capacities for fat and carbohydrate oxidation (respiratory quotient)
dietary fat preferences
appetite regulation
Energy expenditure:
metabolic rate
thermogenic response to food
pattern of energy usage (nutrient partitioning)
propensity for spontaneous physical activity
Hormonal:
insulin sensitivity
growth hormone status
leptin action

genetic mutations that result in leptin insufficiency and lead to obesity in mice are not thought to exist in humans.

Many other factors, some of which are listed in Table 7.4, are currently under intensive investigation.

The place of genetic research on obesity

While research aimed at identifying genes for use in screening, and ultimately in therapy, is important, it will be many years before the results can be applied in practice. At present, the greatest value of genetic research on obesity is in the increased understanding of the pathophysiology of the disease that it provides.

7.5.2 *Non-genetic biological susceptibility*

In addition to the genetic influences discussed in section 7.5.1, a number of other biological factors have been shown to influence an individual's susceptibility to weight gain and the development of obesity. These are discussed below.

Sex

A number of physiological processes are believed to contribute to an increased storage of fat in females. Such fat deposits are believed to be essential in ensuring female reproductive capacity. Studies in humans and animals indicate that females exhibit a stronger preference

for carbohydrate before puberty while males prefer protein. However, after puberty, both males and females display a marked increase in appetite for fat in response to changes in the gonadal steroid levels. This rise in fat appetite occurs much earlier and to a greater extent in females (*128*).

Females have a tendency to channel extra energy into fat storage while males use more of this energy for protein synthesis. This pattern of energy usage, or "nutrient partitioning", in females contributes to further positive energy balance and fat deposition for two reasons. First, the storage of fat is far more energy-efficient than that of protein, and second, it will lead to a lowering of the lean-to-fat tissue ratio with the result that RMR does not increase at the same rate as body mass.

Ethnicity

Ethnic groups in many industrialized countries appear to be especially susceptible to the development of obesity and its complications. Evidence suggests that this may be due to a genetic predisposition to obesity that only becomes apparent when such groups are exposed to a more affluent lifestyle. This is demonstrated graphically by the following:

- *Pima Indians of Arizona*: members of this tribe, which has a very high prevalence of obesity (*129*), gained weight after abandoning their traditional lifestyle.
- *Australian Aboriginals*: this ethnic group tends to have a high incidence of central adiposity, hypertension and NIDDM, but this can be reduced or eliminated within a very short period simply by reverting to a more traditional lifestyle (*130*, *131*). Similar reductions in obesity and cardiovascular risk have been observed when natives in Hawaii have returned to a traditional diet after abandoning the usual modern diet (*132*).
- *South Asians overseas*: the prevalence of NIDDM and mortality from CHD are higher in people of south Asian (Bangladeshi, Indian and Pakistani) descent living in urban societies than in other ethnic groups. This is related to a greater tendency to accumulate intra-abdominal fat for a given BMI compared with other populations (*133*).

It appears from the foregoing that a number of ethnic groups are more prone to the risks of obesity when exposed to the lifestyle common in industrialized countries. For the majority, this problem seems to result from a combination of genetic predisposition and a change from the traditional to a more affluent and sedentary lifestyle

and its accompanying diet. However, susceptibilities to obesity comorbidities are not uniform across groups. In Mexico, for example, NIDDM is more common than hypertension among the obese population, whereas in other areas of the world CVD may be more common.

Other environmental factors may also be important in promoting obesity in ethnic minority groups in industrialized countries, e.g. in African Americans in the USA, where the highest rates of obesity are found in the poorest communities. In these populations, fat-rich, energy-dense diets are likely to be the cheapest, and reduced levels of activity stem from unemployment. Other factors associated with poverty may also be involved.

The problem of obesity in ethnic minorities demonstrates the need for targeted prevention and intervention strategies.

Critical periods for weight gain

Although a general rise in body weight and a modest increase in percentage body fat over the lifespan can be expected in developed countries, at least until 60–65 years of age (*134*), recent studies have shown the importance of nutrition during certain critical periods when an individual may be more vulnerable to the development of obesity in the future. However, until longitudinal studies have been completed, the contribution of each of the periods shown in Table 7.5 to the prevalence of obesity and its comorbidities remains unclear (*135*).

7.5.3 *Other factors promoting weight gain*

An individual's tendency to gain weight may be increased by certain factors such as smoking cessation, the development of a disease, or treatment with drugs that promote weight gain as a side-effect. These are considered briefly below.

Smoking cessation

Smoking causes a marked increase in metabolic rate and tends to reduce food intake compared with that of non-smokers (*2*). It may also cause a longer-term increase in RMR, although the evidence for this is conflicting (*148*, *149*).

Smoking and body weight are inversely related (*150*), and smokers frequently gain weight when they give up the habit. Williamson (*151*) studied a nationally representative cohort of smokers and non-smokers in the USA (1971–1984) and found that the mean weight gain attributable to smoking cessation was 2.8 kg in men and 3.8 kg in

Table 7.5
Critical periods for the development of obesity

Critical period	Reason for increased risk
Prenatal	Nutrition during fetal life may contribute directly to the development of the size, shape and composition of the body, and to the metabolic competence to handle macronutrients. Close relationships exist between patterns of intrauterine growth and the risk of abdominal fatness, obesity and their comorbidities in later life (*136–138*).
Adiposity rebound (5–7 years)	BMI begins to increase rapidly after a period of reduced adiposity during the preschool years. This period coincides with increased autonomy and socialization and so may represent a stage when the child is particularly vulnerable to the adoption of behaviours that both influence and predispose to the development of obesity. It is uncertain whether early adiposity rebound is associated with an increased risk of persistent obesity in later life (*139–141*).
Adolescence	A period of increased autonomy often associated with irregular meals, changed food habits and periods of inactivity during leisure combined with physiological changes that promote increased fat deposition, particularly in females (*142, 143*).
Early adulthood	Early adulthood is usually a period of marked reduction in physical activity. In women, this usually occurs between the ages of 15 and 19 years but in men it may be as late as the early 30s (*144*).
Pregnancy	It has been claimed that a mother's BMI increases with successive pregnancies. However, recent evidence suggests that this increase is likely to be on average less than 1 kg per pregnancy, although the range may be wide and is associated with total weight gained during pregnancy (*145*). Many study designs confound changes in weight with ageing and changes in weight with parity (*146*). In many developing countries, consecutive pregnancies at short intervals are often associated with weight loss rather than with weight gain.
Menopause	In industrialized societies, weight generally increases with age but it is not clear why menopausal women are particularly prone to rapid weight gain. The loss of the menstrual cycle does affect food intake and reduces metabolic rate slightly, although most of the weight gain has been attributed to reduced activity (*147*).

women. However, heavy smokers (more than 15 cigarettes per day) and younger people were at higher risk of major weight gain (>13 kg) after giving up smoking.

Notwithstanding the risk of gaining weight, it is important to understand that smoking cessation should be a higher priority than weight

Table 7.6
Drugs that may promote weight gain

Drug	Main condition treated or other use
Tricyclic antidepressants, lithium	Depression
Sulfonylureas	NIDDM
β-Adrenergic blockers	Hypertension
Some steroid contraceptives	Contraception
Corticosteroids	Various diseases
Insulin	NIDDM
Cyproheptadine	Allergy, hay fever
Valproic acid, neuroleptics	Epilepsy
Phenothiazine	Psychosis
Pizotifen	Migraine headache

loss in obese patients who smoke; a large number of prospective studies have shown that smoking has a larger impact on morbidity and mortality than any small rise in BMI (*152–156*). The beneficial effects of giving up smoking are unlikely to be negated by the weight gain that may follow.

Excess alcohol intake

As previously mentioned, the body is unable to store alcohol, and oxidation of ingested alcohol is given priority over that of other macronutrients. Alcohol consumption therefore meets some of the body's energy needs, allows a greater proportion of energy from other foods eaten to be stored,[1] and is thus associated with an increased risk of abdominal fat (*155*). However, in epidemiological studies, those with the greatest alcohol intakes tend to be thinner (*156, 157*), perhaps because such people eat less and have a large part of their energy requirements met by alcohol (*158*).

Drug treatment

The use of the drugs listed in Table 7.6 can promote weight gain. Adults on long-term corticosteroid therapy for rheumatoid arthritis may be at particular risk of weight gain, since the side-effects of the drug exacerbate the effects of limited physical activity.

Disease states

Certain genetic disorders, as well as some endocrinological conditions such as hypothyroidism, Cushing disease and hypothalamic tumours,

[1] Astrup A, ed. *Food and eating habits*, 1996. Background paper prepared by Food and Eating Habits subgroup of the International Obesity Task Force.

can cause weight gain. However, these are extremely rare causes of obesity, accounting for only a very small proportion of obesity in the population.

Major reduction in activity

In some individuals, a major reduction in activity without a compensatory decrease in habitual energy intake may be the major cause of increased adiposity. Examples include the weight gain often observed in elite athletes when they retire, in young people who sustain sports injuries, in young people in wheelchairs after accidents or in others who develop arthritis.

Changes in social and environmental circumstances

Marriage (*159*), the birth of a child, a new job and climate change can all lead to undesirable changes in eating patterns and consequent weight gain.

7.6 Weight loss

Although many people are successful in losing weight, between a half and one-third of this weight loss is commonly regained over the following year (*160*). This weight regain is independent of the extent of the initial weight loss or the techniques used to assist weight loss. The first year after losing weight is considered to be a particularly difficult period for weight regain prevention, because biological and behavioural processes act to drive body weight back to baseline levels (*144*). Despite the difficulty of achieving and maintaining weight loss over long periods, some people succeed in doing so (*161*). Study of these individuals may provide some clues that will help to explain their success.

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