Childhood and adolescence

GROWTH IN CHILDHOOD

Weight and height

Many changes occur in the time between birth and the attainment of maturity. One of the most obvious is growth in body size.

Body weight increases approximately 20-fold and height three-fold. During childhood (2 to 10 years) the rate of increase in weight and height is essentially linear and occurs at a rate of about 2 to 2 kg and 5 to 6 cm per year. At adolescence there is a marked increase in both gain in weight and height, which is referred to as the adolescence growth spurt. On average the spurt in height begins at 10 to 11 years in girls and 12 to 13 years in boys and usually lasts 2 to 2 ½ years.

While the time of onset can vary widely in individuals, it lasts for about the same length of time. During the adolescence growth spurt boys, on average, gain about 20cm in height and 20kg in weight while girls gain about 16cm in height and 16kg in weight. The peak velocity for weight gain tends to occur about three months later than for height. In girls, the onset of menstruation (menarche) generally occurs after the peak in height velocity, while in boys the development of secondary sexual characteristics is much less closely related to the adolescence growth spurt.

Organ and tissue growth

The different organs and tissues of the body do not all follow the same pattern of growth. The growth of the brain and the reproductive tissues differ from the overall growth of the body.

Almost all of the post-natal growth in the brain occurs in the first five years of life, whereas there is virtually no growth in the reproductive organs until the teens. The early rapid growth of the brain and head is one of the reasons why malnutrition in early childhood is particularly serious. The differences in growth rate of the various parts of the body are also evident in the changes in the body proportions, which occur with age.

Body composition

The changes that occur in the body composition are less obvious. At birth, the lean tissues contain both more water and less protein than later in life, while the body as a whole contains less fat. In full-term infants body fat content is around 15% and differs more with gestational age than with gender. During childhood girls tend to have slightly more fat than boys, but the marked difference in body composition with gender, which are seen in adults do not emerge until adolescence. Adolescence is also accompanied by major differences in the rate and amount of lean tissue gained.

Boys show a rapid and sustained spurt in lean weight and only a moderate increase in body fat while girls experience a smaller gain in lean weight and a larger gain in body fat. During the second decade of life, boys double their lean weight; in girls lean weight increases by only about 50%. The end result is that fat-free weight makes up about 85% of the total body weight of the mature male, but only 75% of the total body weight of a mature female. This difference in body composition is physiological and provides mature females with an energy reserve for the demands of pregnancy and lactation.

Energy and nutrient requirements for growth

An adequate food supply is essential for normal growth and children who do not have access to sufficient food gain less weight and height than those who are adequately fed. There are two approaches to estimating energy and nutrient requirements of children. The first is to observe the food intake of healthy infants and children; and the second is to base requirements on the amounts of nutrients accumulated in the body during growth. In most instances the recommendation for dietary intake (RDI) are based on both kinds of information. The energy requirement for basal metabolism and activity increases proportionately with body size, while the energy requirement for growth is relatively small after the first year of life. Activity is a major component of the energy requirement and varies considerably among individuals. It is not unusual, for example, to find healthy children of similar age and body size that the energy intake of some is twice that of others. This difference in energy intake is due largely to differences in the energy expended in physical activity. Dietary recommendations for energy intake are thus only average values and do not apply to all individuals of a given age group, but merely represent an estimate of the average needs of the group. Expressed in terms of energy requirement falls from around 350kj to 400kj per kg in the first year to around 200kj per kg in late adolescence. Nutrient requirements also gradually increase, but not necessarily in relation to energy intake.

WHAT DO AUSTRALIAN CHILDREN EAT?

The most comprehensive data currently available on the food intake of Australian children are those from the 1985 National Dietary Survey of Schoolchildren (DCSH, 1985). This survey collected and recorded data for one day’s food intake from a national sample of over 5000 children, between the ages of 10 and 15 years.

While the diets of boys and girls were essentially similar in terms of the foods and food groups, which contributed energy and nutrients, the amounts of food consumed by boys to girls were quite different. Girls consumed smaller amounts of most foods than boys at all ages. While the difference was small at 10 years of age, by 15 years of age boys were consuming about twice as much bread, breakfast cereal, meat, milk and milk products as girls. The intake of these foods hardly increased with age in the girls, while boys consumed about 50% more of these foods at age 15 than at age 10. The differences for vegetables and fruit were smaller, but only because boys did not increase their intake of these foods by much. The average intake of core cereals, fruit and vegetables fell well short of the amounts that are currently recommended (NHMRC, 1995).

NUTRITION RELATED CONCERNS DURING CHILDHOOD

Food refusal

During the early pre-school years the rate of growth is relatively slow compared with that during infancy. The toddler also learns new skills and becomes more interested in activities other than eating. Parents are often concerned by the fact that their two year old refuses to eat much of the food that has been prepared for the family. This behaviour is not uncommon and many children in this age group accept only one or two foods for short periods of time. Although this kind of behaviour is worrying to parents it does not usually pose a nutritional problem and is usually self-limiting. Other children of the same age may continuously demand food. Like the previous behaviour, this may be a way of seeking attention rather than a sign of hunger.

Anaemia

Iron deficiency anaemia is the most common nutritional deficiency of early childhood. In Australia, iron deficiency anaemia is most likely to occur:

1. When young children are given large quantities of cow's milk in the absence of foods that are good sources of iron.
2. When children have repeated attacks of gastroenteritis
3. When children are given a vegetarian diet, which is high in bulk and from which iron is not readily absorbed.

Full term infants usually have sufficient iron stores to meet their requirements for iron until about six months of age. After six months, however, unless infants receive an infant formula fortified with iron or adequate amounts of foods which are good sources of iron, such as an infant cereal preparation, breakfast cereals fortified with iron, meat or dark green leafy vegetables, the body store of iron will become exhausted, the haemoglobin level will fall and eventually anaemia will develop. There are several reasons why anaemia in early childhood is of special concern. Firstly, it can lead to retardation in both physical and mental development that may not be reversible, especially if it occurs in infancy. Secondly, it also appears to decrease resistance to infections and to increase morbidity, particularly in pre-school children. A recent study in Sydney has found that 10% of a population based sample of pre-school children, and 20% of children between the ages of nine and 24 months, were iron depleted (serum ferritin level of less than 11 ng per mL). Serum ferritin provides an indication of the amount of iron available in the body and a value of less than 11 ng per mL is indicative of low stores. Iron deficiency in this age group can e prevented by breastfeeding rather than bottle feeding where possible, by introducing solids at four to six months and by delaying the introduction of cow's milk as a major drink until the second year of life (Mira, 1994).

Dental caries

Dental caries affects children of all ages and socio-economic backgrounds. Once the teeth have erupted through the gum they are vulnerable to the effects of the bacteria present in the mouth. These bacteria are responsible for the formation of dental plaque, for the fermentation of dietary carbohydrates to acids and for the production of other substances that have the potential to degrade both tooth enamel and dentine and lead to cavities. Sugars are the principal substrate for plaque formation and fermentation. The potential to produce tooth decay (cariogenicity) of a food, however, is not simply a function of its sugar content and the amount that is consumed depends on a number of other factors including:

1. Frequency of use.
2. Effects on saliva production.
3. Time of retention on the tooth.
4. Effects on dental plaque formation.
5. Its ability to dissolve enamel.

There has been a marked reduction in caries experience in Australian children since national records in the School Dental Service began in 1977. The mean number of 'decayed, missing or filled permanent teeth' (DMFT) in 12 year olds has declined by 46% between 1977 and 1990.

This decline in caries experience is partly attributable to increased use of preventative practices and treatment strategies and partly to the increasingly extensive application of fluorides in several forms, including water fluoridation, fluoridated toothpastes, direct applications to the teeth and dietary supplements (AIHW, 1994). When the data from the 1995 National Nutrition survey become available it will be possible to see if there has been a decline in the amount of sugars consumed since 1985.

Obesity

Obesity is defined as an excessive deposition of adipose tissue and is usually diagnosed formally if a child has a body weight that is greater than 120% of that expected for his or her age. Children who are obese are often tall for their age and it is therefore important to take height and maturity into consideration also. In practice 'eye balling' is unlikely to lead to an incorrect diagnosis. Unlike dental caries, there are currently no nationally representative Australian data on the prevalence of obesity in childhood and so it is not possible to say whether the prevalence of childhood obesity has increased or decreased in recent years. What is clear is that once established obesity is difficult to treat. While the prevalence of obesity appears to be greater during the periods of most rapid growth, that is during the first year of life and at adolescence, it can develop at any time during childhood. There is, however, evidence to suggest both infancy and adolescence, and possible the period of adiposity rebound between five and seven years of age, are particularly critical periods for the development of obesity since obesity that begins at these times appears to increase the risk of persistent obesity (Dietz, 1994). Regular growth monitoring during childhood enables the early detection of excess weight gain relative to height gain, but such monitoring is neither routinely practiced nor reported in Australia.

In treating obesity in childhood, two factors need to be stressed. First, very low energy diets are not suitable for the growing child as it is difficult to ensure an adequate intake of essential nutrients when energy intake is low. Food intake, therefore, needs to be sufficient to provide intake of essential nutrients vitamins and minerals. The best way to achieve this is to limit the intake of foods most likely to be contributing to energy intake such as:

- High energy between-meal snacks
- Large volumes of fruit juice, fruit juice drinks and cordial
- High fat varieties of foods such as milk, cheese and meat

Second, activity levels also need to be considered. Obese children are often inactive by nature and spend more time watching TV than in more active pastimes such as swimming, cycling and ball games. Family participation in both dietary and activity strategies is important if they are to be effective.

NUTRITION CONCERNS AT ADOLESCENCE

Adolescence eating patterns

The hallmark of adolescence is change. This includes change in physical characteristics, in psychological development and in social roles and responsibilities. One important consequence of these changes is the assumption by adolescents of increasing g control over their own eating patterns. The foods eaten will now depend not primarily own family food patterns, but also on many other factors including self-image, peers, the media, cultural and social expectations in relation to body shape and size, access to money for food and the proximity of food outlets. Consumption of snacks both between and instead of meals is a common feature of adolescent diets. There is often concern that this kind of eating pattern cannot meet the high nutritional requirements associated with the adolescent growth spurt. Clearly, however, the nutritional implications of an eating pattern that is sometimes described as 'grazing' depends more on what is eaten than when or how it is eaten. The fact that an adolescent actually has higher total energy requirement than a young adult is often overlooked. On average, adolescent energy requirements are about 1000kj higher per day than those of adults and consequently more freedom needs to be allowed for the consumption of foods with a higher energy density. Although many snacks (chocolate bars, potato chips, crisps, cakes, pies, biscuits and soft drinks) may be high in fat or sugar and energy, and correspondingly low in nutrient content, this is not an invariable feature of snacks. Fruit, raw vegetables, cheese, bread, breakfast cereals, eggs, meat and fish can all be eaten in the form of snacks that have a high nutrient concentration. It is important, therefore, to distinguish between the question of eating snacks (as opposed to meals) that does not necessarily constitute a problem if a wide selection of foods is chosen, and the question of consuming only a limited range of snacks that are relatively high in energy and low in nutrients.

Dieting

One consequence of over-consumption of energy dense snack foods during adolescence may be obesity. Usually, however, this is not the sole reason for obesity that develops at this time and there are other reasons that may be social, psychological or physiological. For example, individuals who mature earlier appear to have a greater tendency to become obese at this time. Whether this is because over nutrition leads to earlier maturation, or because the increased energy intake associated with adolescence continues after growth has already ceased is not clear. Whatever the reasons for the development of obesity in adolescence, the effects on the individual are particularly distressing at this time, and may lead to a situation in which food and eating assume unusual importance. The fear of becoming overweight is particularly strong in adolescent girls and dieting and other forms of weight control behaviour are common in this age group. Dieting is likely to be at least a partial explanation for the fact that the reported food intake of the 15-year-old girls in the 1985 National Dietary Survey of Schoolchildren was no higher than that of the 10-year-old girls. Attempts to lose weight, or simply to prevent weight gain, by means of extreme diets that are inadequate or imbalanced in their energy and nutrient content, sometimes combined with excessive physical exercise, tend to result in the loss of more water and lean tissue from the body than fat. Moreover, quite apart from their negative impact on growth and development during adolescence, they may also have longer-term undesirable effects on health in later life. When such behaviours continue for any length of time they constitute an eating disorder.

Foods, physical activity and sport

PHYSICAL ACTIVITY

According to the World Health Organisation there are indications that great numbers of people (estimated half of the world's population) are functioning below, often far below, their biological potential for good health because of inadequate physical activity. WHO along with the International Federation of Sports Medicine have issued a joint statement to promote and enhance programs of physical activity. The statement is based on the following (WHO/FIMS, 1995):

1. Physical activity needs to be integrated into the routine of everyday living (e.g. using stairs instead of lifts).
2. Children and adolescents should be provided with the opportunity to take part in daily programs of enjoyable exercise so that physical activity can develop into a lifetime habit.
3. Adults should be encouraged to increase habitual activity daily, aiming to carry out at least 30 minutes of physical activity of moderate intensity every day e.g. brisk walking. Higher energy expenditure activities and sports such as jogging, cycling, tennis and soccer may provide additional benefits.
4. Women should be offered a variety of opportunities to engage in healthy exercise.
5. The elderly should be encouraged to lead active lives so as to maintain their independence of movement and personal autonomy, to reduce the risks of body injury and to promote optimum nutrition by assisting adequate food intake.
6. People with disabilities or those suffering from chronic disease should be provided with advice on exercise and facilities appropriate to their needs.
7. The fact that benefit is to be gained by starting physical activity at any age should be broadcast more widely.

This statement also suggests that governments should promote action at all levels to increase physical activity; for example, appropriate transport policies and town planning and the provision of convenient and affordable facilities to promote increased physical activity.

Physical activity and health

Physical activity has been consistently associated with an increased sense of well being as well as a decrease in the risk of the diseases of affluence and ageing, including obesity, hypertension, cardiovascular disease and diabetes. Lifelong exercise also reduces the risk of osteoporosis and consequent fracture in the later decades of life. The use of exercise to benefit health must be planned and carried out over the longer term. Intermittent heavy exercise such as the occasional run or a game of squash may actually increase the risk of heart attack (coronary occlusion) (Puddey & Cox, 1995). Similarly, excessive training, inadequate diet and a low body weight may combine to produce amenorrhoea in women, which may lead to accelerated osteoporosis.

Cardio respiratory fitness, activity-specific fitness and metabolic fitness

It is important to note that there is a difference between doing aerobic exercise to get fit and doing gentle exercise to lose fat and to improve cardiovascular risk profile. Moderately intense aerobic exercise (e.g. jogging) improves cardio respiratory fitness by strengthening the heart and lungs and requires 3 to 4 sessions weekly at approximately 70% of maximal aerobic capacity (VO2 max). VO2 max refers to the maximum rate of energy expenditure that can be maintained over an extended period of about 10 min or more. It corresponds to the rate of energy expenditure at which the rate of oxygen uptakes plateaus and cannot be further increased. This relationship holds because the energy required over extended periods of physical activity is derived from the oxidation of fuels such as carbohydrate. In contrast, only gentle exercise is needed at about 40% to 50 % of VO2 max (i.e. brisk walking) on a daily basis to assist the loss of fat (especially abdominal fat) and to lower blood pressure, blood fats and glucose (metabolic fitness). Studies have shown that it is not necessary to achieve cardio respiratory fitness in order to improve metabolic fitness and to reduce abdominal obesity (Depress, 1994). Fitness may be defined as 'physical capacity': the ability of the body to cope with demands or achieve certain goals. Fitness takes a variety of forms and the characteristics of fitness achieved are specific to the sport or training program. As examples, training for sprinting, distance running and weight lifting bring about different adaptations in the body; and these different adaptations have different implications for long-term health. Furthermore, fitness is a continuum from a low to a high level, and every individual maintains a level of fitness that is in equilibrium to his or her usual daily level of exercise. As an example, the average office worker who does no regular exercise other than walking to the car park or the corner shop, is relatively fit compared to a similar individual who has been confined to bed for several weeks because of an illness. But the same office worker is relatively unfit compared to a major league footballer.

Fitness will only be maintained as long as exercise is maintained. As soon as exercise is stopped, fitness tapers down over succeeding weeks to establish a new equilibrium with the current level of exercise. Different forms of exercise are not equally beneficial to long-term health. The weight lifters muscle development may look impressive, but there is no evidence that muscular fitness is beneficial to long-term health. In contrast, endurance training involving longer periods of running or other exercise brings about adaptations (cardio respiratory fitness) that are clearly beneficial to long-term health. These include lower average blood pressure, a lower level of body fat, more favourable levels of blood fats including cholesterol, development of a more substantial blood vessel system in the heart, greater sensitivity to insulin and resistance to the development of diabetes. The amount of regular exercise required to maintain sufficient fitness for substantial health benefits, termed *metabolic fitness*, is not large. Regular and relatively mild exercise such as brisk walking (40% to 50% VO2 max) on a daily basis has been shown to reduce body fat, especially abdominal fat, lower blood pressure and other health risk factors (Depress, 1994).

Exercise, weight control and health

Exercise assists control of body fat because the additional energy expenditure helps to use up any excess of food energy that might otherwise accumulate as body fat. Exercise alone has a comparatively small effect on existing overweight; it is much more effective to combine exercise with a moderate restriction of food energy, in particular restriction of dietary fat. Exercise combined with diet is clearly more beneficial than diet alone in controlling overweight. Restricting food intake without accompanying exercise leads to a loss of lean tissue (muscle) as well as fat, since body protein functions also as glucose reserve. Protein is continually turned over, freeing amino acids that can be metabolized to produce glucose that will be used as an energy source if food intake is restricted. By stimulating muscle development, exercise helps to maintain muscle mass, thus resulting in preferential loss of fat. It is important to differentiate between change in weight and change in body fat. Exercise combined with modest restriction of dietary fat may result in a relatively small reduction in body weight. However, the overweight individual who begins regular exercise may maintain (or even gain) muscle while losing fat, and gain in health benefits (blood pressure, insulin sensitivity, etc) with only a small reduction in body weight (Depress, 1994). It is the internal abdominal fat that constitutes most risk, but it is this fat which is more readily mobilized and used with regular exercise, resulting in a reduction in abdominal girth and a favourable reduction in waist to hip ratio. It is weight to hip ratio rather than total body weight (or body fat) that is the most sensitive indicator of the health risk of overweight.

Under conditions of rest or light exercise, both glucose and fat (fatty acids) are used as fuels for muscular work. The ratio of fuels used depends on several factors, one of which is the time since the last meal. In the period one to four hours after a meal, blood glucose will be above the fasting level, and glucose will provide a higher proportion of the energy used. From the point of view of controlling excess body fat it is advantageous to maximize the use of fatty acids as fuel. Recent work (Schneiter et al., 1995) has shown that fat utilization in a state of fasting (with exercise before breakfast) was more than 50%greater than after eating, even though the total energy use in calories was not significantly different.

Recommended levels of exercise

Exercise for general fitness and health for non-athletes need not be strenuous, and, indeed, should not be; unaccustomed heavy physical exercise for the person who has not exercised regularly poses significant risk – the older and more overweight the individual, the greater the risk. Any person of middle age or greater should have a medical check before commencing an exercise program in order to exclude the possibility of risk due to some pre-existing condition. As a general rule exercise should begin lightly: a walk for 20 to 30 minutes, 3 to 4 times a week. This may be increased to brisk walking speed (40 to 50% VO2 max) for 30 to 60 minutes daily. Research has shown that this level of exercise delivers as much benefit as more vigorous exercise.

SPORT

There are many different sports played by people of all ages, and the term ‘sport’ includes such diverse activities as sprinting, marathon running, weight lifting, gymnastics, football, sailing or bowls. Successful competition in any of these different sports requires different body and skill characteristics. The physiological characteristics favouring success vary according to the sport concerned; a great sprinter is rarely, if ever, a good marathon runner, and a runner would be unlikely to success at weight lifting. In some sports, skill is of overriding importance (eg sailing) and body shape and size are most irrelevant. Many of the characteristics of successful sports players are inborn.

A simple example of an inborn advantage is the person who is 220 cm or more in height and by virtue of this characteristic is more likely to be more successful at basketball than another person who is 20cm shorter. Other characteristics of importance are much less obvious; for example muscles having a large proportion of fast-twitching fibres favouring sprinting. Characteristics such as muscle fibre type are also largely determined by genetic inheritance. Success in sport is therefore at least partly dependant on chance; that is, whether the individual inherits characteristics which favour success in one sport or another. The effects of nutrition are additive to both inheritance and adaptation training. Good nutrition promotes:

1. Optimum health, lean body weight and reduced fat mass
2. Adaptation to training
3. Improved sports performance, through appropriate
    a. Food and fluid intake in the pre-game meal

b. Food and fluid intake during the event
c. Food and fluid intake after the event, thereby promoting faster recovery

Effect of training

Training brings about adaptations that modify the inherited characteristics; for example, one of the key effects of running training is an increase in cardiac stroke volume. Another important role of training is that it helps reduce body fat and to increase lean mass resulting in a greater power to weight ratio. Body fat plays a number of roles but predominately it functions as a portable energy source. A 70kg individual with a normal 14% body fat would have an energy reserve of approximately (10kg fat x 37kj/g) 370000kj, which, if used at 10kj/min, would last for more than 600 hours. Fatty acids are mobilised in response to the energy demands of exercise, but the rate of transport is limited so the rate of energy supply is limited. Extra fat is therefore of no benefit to the athlete, with the possible exception of long-distance ocean swimming where fat would provide buoyancy and insulation.

Excess body fat adds to body weight and reduces the power to weight ration which can be detrimental to performance in many sports. Men, in general, have a higher level of athletic performance than women. This is due to:

1. Larger body size and muscle mass
2. The normally higher level of body fat in women

Part of the beneficial effect of both training and appropriate nutrition is the improved power to weight ratio resulting from reduction in body fat. Power to weight is significant in sports such as gymnastics, and female gymnasts are often at their best shortly before puberty. The addition of significant body fat at puberty reduces power to weight ratio. Young women may severely limit food intake to reduce body fat (gymnasts, ballet). A variety of deficiencies can result, especially iron (anaemia), calcium (reduced bone mass) and zinc (growth). Amenorrhoea can result, typically when body fat falls to around 10%. In numerous weight-limit sports, competitors compete in a weight class, e.g. boxing, wrestling, lightweight rowing, etc. Being able to 'make the weight' is important to success. Because the energy equivalent of adipose tissue is high (around 30kj/g) there is no practical way of removing fat quickly. Even starvation is a relatively slow method. Athletes needing to lose weight to 'make the weight' usually resort to dehydration techniques, including avoiding drinking, using sweatboxes, excess clothing or diuretics that increase salt and water loss through the urine. Such athletes need to be made aware of the potentially dangerous effects of going into competition in a still dehydrated condition. Losing weight or holding weight down while training is best achieved by severely limiting fat in diet while taking adequate, but not excessive, carbohydrate.

Nutrients, Water, Electrolytes, Supplements and Sports Performance

Energy expenditure varies greatly in different sports. Metabolic rate when completely at rest is 3.5kj to 5kj/min. Light sporting exercise is usually around 6 times BMR (20 to 30 kj/min) and heavy physical exercise over a prolonged period up to 12 times BMR. Short bursts of activity, in a sprint for example, can be much higher; exceeding 200kj/min. Maximum aerobic capacity (2 to 3 hours) is about 60kj/min, equivalent to the rate of energy expenditure in a marathon for example. Maximum aerobic power output tends to be limited by the maximum rate of oxygen delivery to the muscles and, at a later stage, by fuel availability. Maximum power output in short events exceeds VO2 max and is referred to as anaerobic exercise. Anaerobic exercise leads to the production of lactic acid as a by-product, and it is the rising lactic acid that limits power output. Lactic acidity affects the enzymes of the muscle and produces profound fatigue.

Fuel sources

The mix of fuels used by the body depends on the level of energy expenditure. At rest the body obtains roughly 50% of energy from carbohydrate, principally glucose and 50% from fat. As the rate of energy expenditure increases, the fuel use by muscles swings towards carbohydrate.

Muscle glycogen, a glucose polymer, is the principal carbohydrate store used in high intensity exercise; mobilisation of liver glycogen to blood glucose also supplies carbohydrate to the muscle. Carbohydrate is favoured because the muscle glycogen store is the most rapidly mobilised energy source. Lactic acid produced by heavily exercising muscles diffuses out of the working muscles and is carried to the heart and liver where it is partly oxidised and partly reconverted to glucose for use in the muscles and other tissues. The mix of fuels being used by muscle is indicated by the respiratory quotient (RQ), which is the ratio of carbon dioxide output to oxygen uptake. The RQ when glucose is the sole fuel is 1.0 and when fat is used, 0.71 to 0.72. At the start of a competitive marathon, RQ is close to 1.0 and close to the end when exhaustion is near, RQ falls toward 0.72. This shows that at high rate of energy expenditure at the beginning, the fuel most used is glucose, and by the end the athlete’s glucose stores are almost exhausted, fat becomes a major fuel and the rate of energy expenditure begins to fall. As glucose stores run out and signs of exhaustion appear, body protein starts being used as a source of fuel. Protein can be broken down to produce glucose, but this is an energy source of last resort, and normally should not occur. Marathon runners use the term ‘hitting the wall’ for the intense exhaustion that occurs when the carbohydrate stored as glycogen is used up. The runner is forced to a walk and may suffer nausea and cramps. For the marathon runner judgement is everything, the pace must be maintained at a maximum without running out of glycogen and ‘hitting the wall’. In any sporting event lasting more than about an hour, exhaustion of glycogen may limit performance.