Food for Sport: Does Exercise Increase Nutritional Requirements?

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Increased energy expenditure in sport leads to adaptive changes in the body and may increase the requirement for certain nutrients

Adequacy of food energy intake is best gauged by recording body weight. In the initial stages of training some fat loss might be expected, but in terms of body weight this may be compensated for by a gain in muscle mass. When the training routine is well established, body weight is likely to remain fairly constant.

Body fat in the well-trained male athlete is likely to be between 6 and 14% of body weight, and in the case of females will be approximately 8% higher. A minimum of body fat is an advantage because it increases the power to weight ratio of the athlete. Body fat is not easily estimated from body weight or from height-weight relationships, particularly in the case of athletes; the use of skinfold thickness is more appropriate.

Energy through Diet

Carbohydrate, fat and protein all provide energy in the diet of the athlete. It is desirable, however, for athletes to make up their additional energy requirement by the consumption of carbohydrate-rich foods. There are 2 major reasons for this:

1. Carbohydrate-rich foods are readily digestible and the carbohydrate is advantageous to the rapid repletion of muscle glycogen stores, the most immediate and important source of energy for sports with a high rate of energy expenditure.

2. It is desirable for the long term health of all individuals that fat intake should be reduced. The saturated fats of animal origin are particularly important in this regard, and these fats are also major contributors of cholesterol in the diet. The diet of a majority of Australians and New Zealanders derives 40% or more of energy from fat. A more desirable ratio would be not more than 30% energy from fat, with carbohydrate and protein contributing approximately 55% and 15%, respectively.

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It must be emphasised at this point, however, that dietary manipulation to increase endurance is of possible benefit in only a small number of sports.

Carbohydrate Loading: This is a dietary manipulation which is able to increase muscle glycogen up to twice the normal level. The dietary regimen involves 2 to 3 days of a very low carbohydrate diet coupled with heavy exercise to deplete muscle glycogen. This is followed by 2 to 3 days of a high carbohydrate diet and rest or only light exercise.

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The procedure appears to be advantageous, but only in the particular aspect of prolonging endurance in high energy expenditure events exceeding a duration of at least 1 hour, i.e. those events in which endurance might be expected to be limited by the availability of muscle glycogen. There is no advantage to performance in short term events.

Some doubts have been expressed about the side effects of such drastic dietary manipulations, though little research has been carried out on these effects. The low carbohydrate phase of the diet may cause ketosis, lethargy and mood changes. In the period immediately after the change to a high carbohydrate diet there is a marked hypertriglyceridaemia. There are also some isolated reports of ECG abnormalities on exertion in some athletes employing carbohydrate loading. Because of these concerns regarding side effects, athletes are advised not to practice carbohydrate loading more than 2 or 3 times in a year.

More recently it has been suggested that some of the advantages of carbohydrate loading (without the concomitant drawbacks) can be achieved by omitting the low carbohydrate phase of the diet (termed 'partial loading'). The athlete trains strenuously on days 1 to 3 but on a normal diet. On days 4 to 6 the athlete exercises lightly or not at all and raises the level of intake of carbohydrate with the aim of reaching maximum muscle glycogen for competition on day 6. There is a useful increase in muscle glycogen (25%) with no reported side effects.

Carbohydrate Repletion: As an alternative to carbohydrate loading, carbohydrate can be consumed during the event. A substantial increase in endurance time can be achieved by this means, provided that it is lack of muscle glycogen rather than progressive dehydration which limits performance. The use of carbohydrate solutions, particularly if hypertonic, can slow down the rate of water absorption and therefore carbohydrate repletion drinks should be dilute (see below).

Caffeine: Endurance time at high energy expenditure can also be prolonged by administering caffeine 250 to 500mg (equivalent to 4 to 8 cups of coffee). The mechanism of this effect probably involves an elevation of the level of free fatty acids in the blood, increased proportional utilisation of fatty acids as an energy source, and a consequent sparing of muscle glycogen. Other mechanisms may also be involved. A possible ban on the use of caffeine is under discussion by some sporting bodies.

Many factors are involved in the attainment of superior athletic performance. These include the appropriate genetic potential, adherence to a specifically designed training programme, a high degree of motivation and good general health supported by adequate nutrition. While attention to nutrition provides no magic ingredients to ensure success the reverse is also true – the best potential in any athlete can be prejudiced by poor nutrition.

Energy: Intake and Expenditure

Participation in sport usually involves an increase in energy expenditure, the most noticeable effect of this being an increased food energy requirement. Appetite or hunger will be stimulated and food energy intake increased. Total energy expenditure and consequent food energy intake are dependent on the type of sport, the amount of training required, and the individual (table I). Even within the same sporting team food energy intakes appear to vary widely.

Energy expenditure for a young male engaged in heavy physical activity may be up to 15MJ daily (3500 kcal). Most non-professional athletes do not exercise at this level and will probably have lower energy expenditures. Athletes in intensive training, however, may have daily energy expenditures up to 30MJ or more – more than twice the normal. The daily food energy intake of one Australian rules footballer, for example, was found to vary from 21 MJ/day to 39 MJ/day over a 6-day period, with an average of 28 MJ/day – approximately twice that expected for a non-athlete of equivalent body size.

Pre-event Food Intake

Pre-event meals should be low in fat and protein and high in carbohydrate, in order to facilitate rapid digestion and absorption and to encourage the formation of muscle glycogen. No food or glucose supplement should be consumed within 2 hours of the event in the case of short duration, high intensity events (e.g. middle-distance running), so that blood glucose and serum insulin will have returned to normal. Elevated blood glucose and insulin levels at the beginning of such an event may inhibit gluconeogenesis and reduce the rate of lactic acid utilisation, a rising lactic acid concentration being one of the major factors limiting short term energy output.

TABLE I. Characteristics of individual sports and athletes which determine energy requirements

Sports	
Low energy expenditure (dexterity)	High energy expenditure (power)
Short interval (sprint)	Endurance (marathon)
Heavyweight (lifting/throwing)	Lightweight (gymnastics)
Athletes	
Female (extra iron?)	Male
Young, growing	Mature
Overweight (excess fat)	Underweight (excessively lean)
Competitive season	Off-season, rest, recuperation

Particular Dietary Considerations

Alcohol

The consumption of alcoholic drinks by sportsmen, particularly those in team sports, appears to be high. For this reason some comment on alcohol seems justified.

In sports involving high energy expenditure, alcohol reduces energy output, impairs judgement, and can be expected to impair performance. Alcohol depresses gluconeogenesis, increasing ketone levels and reducing the rate of removal of lactic acid from the blood. Another of the metabolic effects is to stimulate the synthesis of additional fat, particularly in the liver. An important acute effect of alcohol is a reduction in cardiac output. Since the rate of clearance of alcohol from the tissues is slow, alcoholic drink should not be consumed within 48 hours of a competitive event.

Patterns of substantial alcohol intake established during an individual's period of active participation in

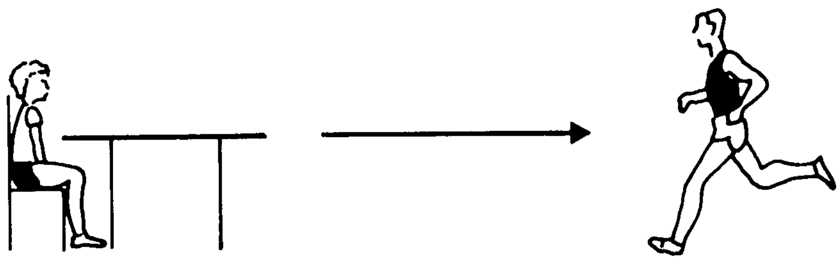

FIG. 1. Dietary needs increase as work output is increased.

team sport, may well be retained after the individual has retired from active involvement. Energy expenditure is reduced and the substantial energy input of alcoholic drinks is likely to be important in the subsequent development of obesity.

Protein

An adequate protein intake is required by all individuals, providing essential amino acids and nitrogen to make good the losses involved in normal body protein turnover. Minimum protein requirement is approximately 0.6 g/kg/day, and there is quite considerable individual variation. Normal protein intake in Australia is about 100 g/day which, for a 70kg individual, would correspond to 1.4 g/kg/day – more than twice the minimum requirement and substantially above the recommended intake of 1 g/kg/day. In the Australian diet, protein is usually equivalent in energy terms to 12 to 14% of total energy intake. Thus with the normal increase in food energy intake, there is an associated increase in protein intake. A 50% increase in energy intake might be expected to raise protein intake to close to 2 g/kg/day, i.e. approximately 3-times the amount needed to maintain nitrogen balance.

Implications for the Athlete: A normal varied diet can be expected to provide the athlete with protein in adequate quantities, and no special high protein foods or supplements are necessary. Sporting endeavour appears to increase body protein requirement only under exceptional circumstances. Strenuous physical work does not lead to a significantly increased nitrogen output unless continued over a period of several hours. Profuse sweating produces an increased loss of nitrogen in the form of urea and amino acids, but the magnitude of the increase is small when compared with normal food nitrogen intake. In unusually severe sporting events such as a 100km run, there is an apparent increase in the rate of utilisation of body protein as indicated by a rise in plasma urea and a fall in plasma amino acids. This response is probably associated with increasing gluconeogenesis as body glycogen stores become exhausted. The contribution of body protein and amino acids to total energy output, even in events extending over several hours, is not more than a few per cent.

There are 2 situations in which a high protein intake may be advantageous:

1. Where a rapid gain in muscle mass is required, there is some evidence that protein intakes as high as 2.5 g/kg/day coupled with weight training will produce a faster gain than weight training alone. Such situations may be of interest to weight lifters or throwing athletes wishing to build up muscle mass in early season training. In only a small number of sports, however, is performance likely to be improved by such a programme.

2. Severe trauma or febrile illness produces an ele-

vated metabolic rate, increased protein turnover and net loss of body protein. In the event that an athlete is affected by such a condition it might be expected that the loss of muscle protein would be minimised by adequate food energy and provision of additional protein.

Vitamins

Vitamin supplements are as popular with athletes as they are with the community at large. Nevertheless, there is no sound evidence to support the contention that vitamin supplements are either necessary or likely to improve athletic performance. The basis for believers is probably the known biochemical involvement of a number of vitamins in energy metabolism coupled with the hope that some 'magic' formula will ensure success. The B-group vitamins (thiamine, riboflavin and niacin) are involved as enzyme co-factors in energy metabolism and for this reason the recommended intake for these vitamins is usually expressed in terms of energy intake. Thus for thiamine the recommendation is 0.1 mg/MJ energy intake, and as energy intake is increased in response to exercise so too the intake of thiamine will be increased.

A frank vitamin deficiency could be expected to reduce work output and athletic performance; while such deficiencies are not unknown in Australasia, they generally occur only amongst particular at-risk groups such as the elderly, children in disadvantaged homes, alcoholics, etc.

Effect on Athletic Performance: While an adequate supply of a vitamin is necessary for normal physiological function, an oversupply is not known to confer any additional benefit. Numerous trials have been carried out to determine if supplementary vitamins can improve athletic performance [12]. In general such trials have not demonstrated improved performance in any of a variety of sports. Dwyer and Brotherhood [3] have pointed out, however, that the variance to be expected in athletic performance is large and few of the trials performed to test the effect of vitamin supplements have had adequate numbers of subjects to enable small differences in performance to be detected with any degree of confidence.

A Placebo Effect? The psychological or placebo effect of nutritional supplements such as vitamins should not be overlooked. If the athlete is stimulated to better performance by the use of a supplement, and if the supplement has no detrimental effect on health, then its use may be tolerated rather than discouraged. A moderate excess of the water soluble vitamins (2- to 3-times the recommended daily intake for vitamins C and B-complex) is rapidly excreted from the body and not known to cause ill-effects. However, an excess of the fat soluble vitamins A and, more particularly, D have marked toxic effects and should not be used. The status of the 'non-vitamins', such as B_{15} (pangamic acid), is somewhat confused, but they are not known to have any relevance to health or athletic performance [4].

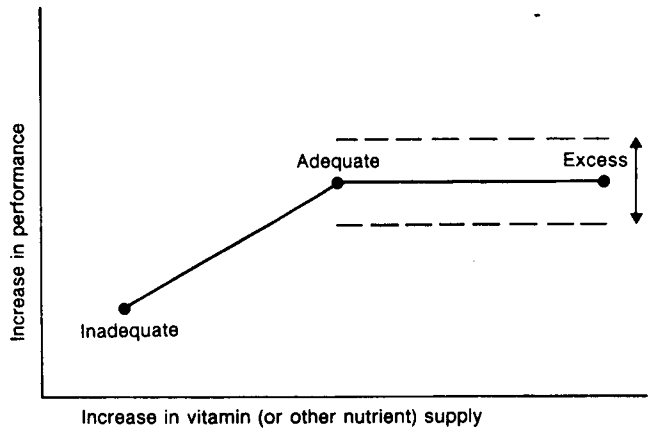

FIG. 2. Effect of nutrient supply on athletic performance. An inadequate supply will jeopardise performance, but an excess will not produce improved performance over an adequate supply. Other, less well-defined factors (e.g. competition, training, psychological) have an important influence on performance.

Minerals

Minerals usually receive less attention than vitamins in sports literature. Several of the minerals are of interest, however, particularly iron and magnesium.

Iron is important because of its role in oxygen transport and is the mineral perhaps most likely to warrant attention in the diet of the athlete. Surveys have shown an anaemia ('sports anaemia') in a small proportion of athletes, though the aetiology of this deficiency syndrome is not clear [1,5]. Nor is it clear to what extent sports anaemia affects the performance of the athlete. In some studies it has been found that additional iron has no effect on sports anaemia and that additional protein has an ameliorating effect [5].

As might be expected, studies have generally shown young women to be more often anaemic than men, and it has been suggested that iron supplementation might be desirable at least for certain athletes [6,7]. In the case of true iron-deficiency anaemia, infusion of iron dextran has been shown to raise haemoglobin and improve endurance performance. A diet which contains red meat, supplying readily absorbable haem iron, together with fresh fruits and vegetables which supply vitamin C, assisting the reduction and absorption of non-haem iron, should provide adequate total iron for the athlete in the absence of any complicating factor such as blood loss. If a true iron-deficiency anaemia is shown to persist, supplementary iron is indicated.

Magnesium is another mineral discussed with respect to athletic performance. Though magnesium is of obvious importance in muscle energy metabolism, little research has been done to determine the requirements of athletes or the effect of deficiency. The recommended daily intake (300 mg) is derived from a knowledge of normal intakes associated with good health.

Magnesium is supplied in the diet by a wide range of foods, particularly green vegetables. The efficiency of absorption is generally low and responds in a similar way to the regulatory system governing calcium levels through vitamin D. Supplements of magnesium, supplied as magnesium aspartate, have not been found to improve performance.

Water and Electrolytes

Water requirement is increased in sport because of the additional heat to be dissipated and the consequent increase in rate of sweat loss. A moderate rise in body core temperature to approximately 39°C is expected in sports involving high energy expenditure, and it is not uncommon for rates of sweat loss to reach 2 L/hour. Water loss is also accelerated by increased ventilation and evaporative loss from the lungs.

It is normally adequate to rely on salt in food to make up deficiency through sweat loss

Athletes should drink a small amount of water before the event, and small amounts (not exceeding 200 ml) at intervals during an event or training session. The hotter and drier the ambient conditions, the more important is water replacement. Physical performance is best maintained by keeping water balance as close to normal as possible; athletes should make a point of drinking plenty of water or dilute fluids after heavy exercise because the natural thirst response is somewhat slow to reinstate the balance.

Dehydration: Progressive dehydration reduces blood volume and the volume of extracellular fluid. As body temperature rises there develops a competition for cardiac output between the active muscles for oxygen supply, and the skin for evaporative cooling. Under extreme conditions blood pressure may begin to fall, cooling is jeopardised, work output falls, and body temperature may rise to 40°C or more as heat stroke develops. Heat stroke is life-threatening and requires immediate medical attention.

Salt Replacement: Since sweat contains sodium and minor quantities of other electrolytes, a deficiency of sodium may develop with excessive sweat loss. Within a single sporting event there is no need to supply sodium with water because the sodium and chloride content of sweat is less than that of blood and consequently there is a relative haemoconcentration of sodium and chloride as sweat loss continues. With continued sweat loss over a period of several days or longer, a deficiency of sodium and chloride can develop and supplementary salt may be necessary. A salt deficiency is only likely to develop if sweat lost over a protracted period is replaced by drinking pure water. In such cases salt can be taken as a 0.1 to 0.2% solution in water. It is normally adequate to rely on salt in food or applied to food to make up any deficiency. Salt tablets should be avoided because the dose is poorly regulated and a quantity excessive in relation to water intake may be consumed.

Points in Brief

Specific dietary considerations in the athlete

Carbohydrate loading
1. Extends endurance performance
2. Is of no use in short duration events
3. Has some side effects (largely unexplored)
4. Should be used with caution
5. Partial loading seems preferable in most cases (see text)

Pre-event food intake
1. High carbohydrate, readily digestible food
2. Low in fat and fibre; moderate to low in protein
3. Not closer than 2-3 hours before the event
4. No alcohol for 48 hours before event

Water and electrolytes
1. Adequate water is the most immediate need – small amounts ($\leqslant$ 200ml) before and during the activity
2. Additional salt is required only if a series of events or training sessions involving high sweat loss is involved
3. Additional salt, if required, is best supplied by salt in (or applied to) food
4. Excessive salt intake should be avoided

Excessive consumption of salt should be discouraged because of the association between long term high sodium intakes and the development of hypertension.

The use of proprietary salt repletion drinks as normal thirst quenchers is also to be discouraged. They may be properly used at intervals during or at the end of heavy training or competitive routines, but their more general use should be discouraged.

The American College of Sports Medicine [8] recommends that the total salts and sugars content of repletion drinks should not be more than 10 mmol/L and that proprietary mixtures be diluted to half- or quarter-strength for use.

In summary, increased energy expenditure in sport leads to adaptive changes in the body and may increase the requirement for certain nutrients. Total food consumption is usually increased in response to increased energy expenditure and, provided the athlete has a well varied diet, it can be expected that the increased nutrient requirement will be adequately met.

It should be noted that the demands placed on the body by participation in sport vary greatly depending on the sport involved and the individual athlete. We should be wary of making nutritional recommendations for athletes as a group in just the same way as we would be wary of making such recommendations for the population as a whole. □

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