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The Use of Beverages as Ergogenic Aids

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1. INTRODUCTION

Drinks can be used as a vehicle for ingesting a variety of substances considered to enhance athletic performance. This brief review concentrates on the use of beverages to supply nutrients rather than pharmacological agents to the athlete. The specific nutrients discussed are energy-supplying substrates, water and minerals.

All of these nutrients can be and are supplied in the form of solid food, which raises the question "what advantages do beverages give compared with solid food in providing these nutrients?" Some of the benefits of using liquids rather than solids to supply nutrients are listed in Table 1.

Table 1
Major differences between liquid and solid forms of supplying nutrients.

The rate of ingestion is faster for liquids than solids.
Liquids require no chewing before swallowing.
The rate of gastric emptying is faster for liquids than solids.
Drinks are often considered more palatable than solid food immediately following exercise.
Suitable beverages for different conditions can be easily obtained or prepared.
Drinks are readily available, are easily stored and require little preparation before use; whereas food may require special storage requirements, cooking or reheating.
Beverages tend to be less energy dense and usually contain relatively few micronutrients.

The main advantage of supplying nutrients in liquid form is that the nutrients tend to be more rapidly absorbed and assimilated. The primary reason for this appears to be the faster rate of gastric emptying of liquids compared with solid food. The presence of solid particles in the stomach inhibits gastric emptying and the liquid form of a liquid-solid meal empties more rapidly from the stomach than does the solid form [1], but there are no studies which have quantified the gastric emptying rate of iso-energetic liquid and solid meals. There are

technical reasons why this apparently simple study has not been carried out. The first difficulty is that there are only a few techniques which can reliably measure both liquid and solid meals, and to date the method of choice requires the use of radio-active tracers [1]. The second obstacle is that although energy density appears to be a major controlling factor, the volume in the stomach and the osmolality of the gastric contents also influence the rate of gastric emptying [2,3], making it difficult to control for these confounding factors in such a study. However, the requirement to chew solid food, the time required for the stomach to process food to a suitable size for emptying into the small intestine [4], and the tendency for solid food to be more energy-rich/unit size than drinks, normally ensures that the rate of gastric emptying is slower for solids than liquids. Apart from alcohol, there is little net uptake of nutrients from the stomach and therefore rapid delivery of nutrients to the absorptive surface of the intestine enhances their transport into the circulation and hence their assimilation into the body. Therefore, in situations where rapid supply of energy or water is required, the provision of suitable nutrients as liquids is preferential to that of solids. It must be emphasised that a normal balanced diet with at least 60% of the daily energy requirement being supplied as carbohydrate (CHO) is essential in order to maintain health and to prepare optimally for sport. Beverages should be used only as adjuncts or supplements to the normal diet.

2. ENERGY UTILISATION

Part of the fatigue process involves the depletion of the available energy sources and various ergogenic aids have been used to increase the amount of metabolisable fuel which the muscles can utilise. During exercise the primary source of the energy required to sustain the activity is normally derived from the oxidation of CHO and fats stored in the body. Estimates of the total endogenous CHO content stored as muscle and liver glycogen and extracellular glucose of humans may often be misleading as the amount is very labile being greatly influenced by the preceding diet, physical activity and training status of the individual. A global figure of about 530 g (8.9 MJ of energy) of endogenous CHO for a 70 kg man appears to be a reasonable approximation [5]. Fats incorporate the largest store of energy in the body. Although fat stores are not as labile as those of CHO, differences in body fat content between individuals make it difficult to calculate definitive amounts, but 10 kg of fat, which is equivalent to a body fat content of 14.3% for a 70 kg man approximates to 371 MJ of stored energy. The majority of fat is stored in the adipose tissue, with smaller reserves of lipid being present within the muscle. The majority of endogenous fats used during prolonged exercise must therefore first be mobilised from the adipose tissue and transported to the exercising muscle where the oxidation of fatty acids is closely related to the circulating free fatty acid concentration [5].

The relative proportion of fat and CHO that contributes to the overall energy expenditure depends on the exercise intensity and duration, the training status of the individual, and the pre-exercise diet and nutritional status of the individual. As exercise intensity increases so does the reliance of active muscles on carbohydrate oxidation for energy, while a greater preponderance of fat is utilised during prolonged exercise which lasts for several hours. Training, especially endurance training, increases the oxidative capacity of muscle enabling more fat and less CHO to be utilised at a submaximal exercise intensity [6]. The consumption

of a high fat diet for an extended period, particularly when coupled with endurance training, can increase the individual's maximal rate of fat oxidation [6].

Proteins are also used as energy sources during exercise, but the contribution derived from the oxidation of amino acids is small and does not increase in proportion to that of fat and CHO [7]. Increasing the exercise load may result in an increase in protein requirements for muscle repair, muscle hypertrophy and/or energy utilisation. The requirement for protein intake for the athlete can normally be met by ingesting a balanced diet which is adequate to meet the increased energy expenditure, and there is little evidence of an ergogenic benefit of acute or chronic protein supplementation [8].

2.1. Energy provision

2.1.1 Carbohydrate

As muscle glycogen depletion is closely correlated with the point of fatigue during prolonged exercise [9], the majority of studies on ergogenic nutritional supplementation have concentrated on increasing or sparing endogenous glycogen stores [5]. Ingestion of CHO has been used to increase the total amount of muscle glycogen, and maintain high levels of endogenous glycogen before exercise and to spare the body's CHO stores during exercise. A high CHO intake in the form of solid food in a balanced diet can and usually should be the main vehicle for maintaining glycogen stores before exercise. During exercise, CHO solutions, due to their faster rates of gastric emptying [1] and absorption, appear to cause less gastro-intestinal stress than solid food [10] and are usually the preferred source of exogenous energy provision [11].

A high CHO intake enhances muscle and liver glycogen stores. Dietary recommendations for athletes suggest that in order to derive optimal training-induced improvements in performance, at least 70% of energy intake should be from CHO with the fat and protein content of the diet contributing between 15-20% and 10-15% respectively. The requirement to increased dietary carbohydrate intake can often best be met by the use of CHO drinks. During periods of heavy training or competition, the time available for eating and the exercise-induced suppression of appetite which some athletes experience [12] can reduce the amount of solid food ingested. Strategies which attempt to pre-load muscle glycogen stores before exercise also demand a high CHO intake coupled with exercise over several days [5]. In both of these situations any shortfall in CHO intake can be restored by ingesting CHO drinks. Although, the ingestion of carbohydrate 30 to 60 min before exercise can increase circulating insulin levels, decrease blood glucose concentration and increase muscle glycogen utilisation during exercise [13], several studies have demonstrated an ergogenic effect of ingesting a CHO beverage within the hour before exercise [14,15].

Following exercise, the time taken to restore the body's glycogen stores may influence the amount of subsequent training which can be sustained or the performance of a subsequent bout of physical activity. Although MacDougall *et al.* [16] suggested that following high intensity exercise sufficient liver glycogen may be present to synthesise muscle glycogen without requiring exogenous CHO, considered opinion recommends consumption of CHO soon after stopping exercise that is likely to deplete muscle glycogen stores [17]. High intensity, intermittent exercise for relatively short periods is as effective as prolonged moderate intensity activity in depleting muscle glycogen [12]. The rate of muscle glycogen resynthesis is slow and it may take about 20-24 hours to recover these stores; however during the initial 2-hour

period following exercise the resynthesis rate is approximately 1.4 times faster than the rate outwit this period [17]. It is therefore important to ensure that CHO is ingested as soon as is practical after exercise if not in the later stages of the exercise [17]. In some individuals there is a suppression of appetite immediately following exhaustive exercise and CHO intake in liquid form may be more palatable and is as effective as isoenergetic amounts of solid food in supporting resynthesis of muscle glycogen [12]. For effective resynthesis at least 50 g of carbohydrates with a high glycemic index every two hours is advised [17]. This is probably best served during the first 2 hours after exercise as a drink containing glucose, sucrose, maltodextrins or corn syrups either as single sugar beverages or mixtures of some or all. When the appetite returns, solid meals containing at least 70% of the energy as carbohydrate and which will supply approximately 600 g of CHO over a 24-hour period should be eaten. Carbohydrate drinks can obviously be used to supplement the food intake. Fructose appears to be less effective in supporting resynthesis of muscle glycogen than glucose monomer, glucose oligosaccharides

During prolonged exercise CHO feeding increases exercise capacity and power output mainly due to muscle utilisation of blood glucose rather than as a result of glycogen sparing [19]. Thus CHO ingestion during prolonged exercise may only be effective if the physical activity results in hypoglycaemia. There is evidence that CHO feeding can result in glycogen resynthesis in inactive muscle fibres that have been glycogen depleted [20]; this suggests that the ergogenic effect of CHO ingestion in activities which involve intermittent high intensity exercise followed by rest periods may be due to better maintenance of muscle glycogen levels. While the main benefit of CHO feeding during exercise appears in studies where fatigue occurs after at least 60 min of exercise [5], this form of supplementation can be effective in shorter events in situations where individuals have started exercise in a glycogen depleted state [21]. Carbohydrate feeding during exercise is effective only if intake is sufficient to maintain blood glucose oxidation rates of over 1 g/min in the later stages of exercise [19]. Various strategies have been used to meet this criterion; in the majority of studies repeat ingestion of volumes of CHO drinks sufficient to supply 30-60 g of carbohydrate/h have been effective.

2.1.2 Fat

In order to spare endogenous CHO stores several studies have examined methods of enhancing fat oxidation during exercise. Although body fat stores are extensive, oxidation of lipids occurs within the mitochondria of the muscle fibres and the rate of uptake into the mitochondria is related to the concentration of circulating free fatty acids [22]. Therefore studies investigating fat utilisation have either increased plasma free fatty acids by dietary manipulation or by administration of chemicals which stimulate lipolysis.

Fasting increases the utilisation of fats, but it also depletes liver glycogen, and exercise times are invariably reduced compared with CHO feeding regimens in man [14]. Due to the protracted process of absorption and assimilation of most dietary fats it is unlikely that ingestion of lipid containing beverages immediately before or during exercise will have any ergogenic potential. The exception to this are medium chain triglycerides which are absorbed directly into the circulation, and are readily hydrolysed and transported to the mitochondria. Although fatty acid oxidation is enhanced following ingestion of medium chain triglycerides, only about 30 g of the lipid can be consumed without causing gastro-intestinal stress; this limits the contribution of these triglycerides to between 3-7% of the total energy expenditure during moderate intensity exercise [23].

At present, it appears that fat oxidation can be increased by suitable supplements, but the ergogenic benefit is usually less than that derived during CHO feeding.

3. WATER REQUIREMENTS

The requirement for water during physical activity is related to the need to replace exercise-induced sweat loss that is used to regulate deep body temperature. Heat is a by-product of metabolism: as physical activity increases so does heat production and the need to lose the excess heat from the body. As ambient temperature increases there is a greater reliance on evaporative heat loss from sweat to maintain core temperature. Even in cool conditions significant sweat loss can occur during prolonged strenuous exercise. When subjects, wearing only shorts and shoes, cycled at 70% of their VO_2max at environmental temperatures of 4 °C and 10 °C, they lost on average 690 ml and 930 ml of sweat respectively during exercise (Galloway, unpublished data). Body water turnover studies indicate that 1-2 hours of exercise outdoors in cool conditions increase the average daily non-urinary water loss by about 520-930 ml [24,25].

The thermal load imposed by exercise in the heat is additive to the environmental heat stress and will tend to stimulate maximum sweat production. The sweat loss and therefore the degree of dehydration incurred during physical activity is mainly dependent on the duration and intensity of the exercise, the ambient conditions and the maximum sweat rate of the individual. The loss of body water as sweat during exercise can be substantial [26]. Dehydration decreases the circulation volume, leading to a reduction in cardiac stroke volume and compromising the blood flow to the exercising muscles and skin. Within limits, an increase in heart rate can maintain cardiac output; however, the requirement to conserve central venous pressure and blood flow to the active tissues dictates that skin blood flow is reduced. The transfer of heat from the active muscle to the body surface is therefore restricted and hyperthermia occurs.

Ingestion of sufficient volumes of drinks of suitable composition during exercise can reduce the rate of dehydration, delay the cardio-vascular and thermoregulatory stress, and thereby increase endurance capacity and performance [26]. Compared with prolonged exercise where no fluids are ingested, drinking plain water can improve exercise capacity. Well formulated dilute carbohydrate-electrolyte solutions are quickly assimilated within the body and can promote a greater ergogenic benefit than that of plain water [27].

3.1 Water provision

Although the effects of exercise-induced dehydration are exacerbated if the exercise is started in a hypohydrated state, attempts to hyperhydrate subjects before exercise have not been as effective as ingesting suitable fluids during exercise. Before a drink can be assimilated into the total body water pool it must be absorbed; the composition of a drink affects the rate at which it is absorbed. The rates of gastric emptying and intestinal absorption are major determinants of the efficacy of a rehydration solution consumed during exercise. Many of the factors which control gastric emptying also influence the rate of intestinal absorption.

The stomach acts as a reservoir from which the flow of the drink, into the small intestine, is controlled by negative feedback mechanisms regulated by receptors in the duodenum and ileum. Many factors influence the rate of emptying of the stomach; two major inhibitory

causes are an increase in energy density or osmolality of a drink, while increasing the volume in the stomach increases the rate of emptying. The regulation of gastric emptying appears to be mainly related to controlling the amount of energy delivered to the small intestine [28]. Even dilute CHO solutions of as little as 4% glucose are emptied from the stomach more slowly than water [29]. Increasing the nutrient density of a drink will enhance the rate of energy delivery to the small intestine but will decrease the availability of the water [26,28]. Although osmolality does affect gastric emptying the effect is more marked on non-nutrient and nutrient-dense solutions. Fluids empty in an exponential manner from the stomach when given as a single bolus; that is, the rate slows as the gastric volume decreases. When the volume in the stomach is maintained by repeated drinking the initial high rates of gastric emptying can be sustained [30]. The rate of gastric emptying not only determines the availability of a solution for absorption but also affects the solute load delivered to the absorptive surface [31].

In the small intestine, water absorption is brought about by the production of suitable osmotic gradients that promote net movement of water from the mucosal surface into the circulation. When the luminal contents are relatively hypotonic compared with the tissue net water absorption occurs, and when they are relatively hypertonic there is net efflux of water into the lumen. It would appear that ingestion of water, which is rapidly emptied from the stomach and which has an extremely low osmolality, should promote optimal water absorption. However, the net movement of electrolytes, along electrochemical gradients, into the intestinal lumen is accompanied by water from the tissues which reduces the overall absorption of water. The absorption of ingested sugars, amino acids and other organic molecules and electrolytes across the mucosa creates suitable osmotic gradients for net water absorption. Among the most potent mechanisms that promote water absorption are the different active transporters which each co-transport a specific substrate with sodium. These transporters facilitate the creation of trans-mucosal osmotic gradients, but in doing so, they also open the tight junctions between adjacent absorptive mucosal cells, permitting mass movement of nutrients through these paracellular channels [32]. The glucose-sodium co-transporter, is one such mechanism which has been extensively studied.

The rate of hydrolysis of glucose disaccharides and oligomers does not appear to limit CHO or water absorption and they are as effective as glucose monomers in promoting water absorption. Fructose is absorbed by a facilitative diffusion carrier mechanism and is not associated with net sodium movement; the rate of fructose absorption is about 80% of that of an equimolar amount of glucose, and correspondingly less water uptake occurs from fructose solutions. There have been studies which suggest that sucrose or mixtures of equal amounts of glucose and fructose are at least as effective as equimolar concentrations of glucose [33]. The proposed benefit of using oligomers is that the osmolality of the rehydration drink should be less than that of a glucose monomer solution with the same CHO content. There appears to be no advantage of using carbohydrate polymers on carbohydrate or water absorption [34]; this is probably due to hydrolyse activity producing similar glucose concentrations at the brush border from all solutions, that is not reflected in the luminal bulk phase.

Dilute carbohydrate-electrolyte beverages, with an osmolality between 200-250 mosmol/kg, are more effective than concentrated sugar drinks in replacing exercise-induced water losses. This is because they empty faster from the stomach, they promote effective rates of water absorption and greater volumes can be ingested. For the same volume, dilute drinks will deliver less CHO than more concentrated drinks; however, if a greater volume of the dilute

beverage can be drunk and absorbed the amount of CHO supplied may not necessarily be very different. In situations where the main reason for drinking is to provide fluid replacement, it is important that an adequate volume of drink is consumed. When both substrate and fluid are required during prolonged physical activity, it is relatively easy to formulate a dilute carbohydrate-electrolyte drink which can supply 30-60 g of carbohydrate/h in volumes sufficient to meet most of the exercise-induced sweat loss [35]. This is provided that the volume of fluid maintained in the stomach ensures adequate rates of gastric emptying and that the individual can tolerate any possible gastro-intestinal discomfort.

Both water and electrolytes are lost from the body during sweating: the composition of sweat varies between individuals, and can also vary within the same individual depending on the rate of secretion, the state of training, and the degree of heat acclimatisation [26]. During exercise, alterations in the circulating electrolyte content are usually small and appear relatively unaffected by sweat loss [36], except under extraordinary conditions [37]. This suggests that there is usually little benefit in replacing electrolytes lost during exercise. After exercise, however, if the total body water content and distribution are to be restored, then both the water and electrolyte losses must be replaced. Given time, this will normally be achieved as a result of intake from the diet. If euhydration has to be attained rapidly, the formulation of drinks used to rehydrate after exercise must supply the sodium as well as the water lost in sweat. Replacing only the lost water results in a rapid decrease in the circulating sodium concentration and in the plasma osmolality. This reduces the stimulus to drink and increases urine output, both of which delay the rehydration process. The most effective protocol for rapid rehydration following exercise appears to be to ingest water and sodium in excess of the losses, and then allow sufficient time for the kidneys to establish homeostasis [38].

The requirement for sodium replacement stems from its role as the major ion in the extracellular fluid and to it being the main electrolyte lost in sweat. It has been suggested that the inclusion of potassium, the major intracellular cation, in a rehydration drink would enhance the restoration of the intracellular fluid volume, but there is little direct evidence to support this [39]. The supplementation of other electrolytes does not appears to be necessary unless a definite deficiency is present that the normal diet cannot meet.

Post-exercise rehydration is not normally thought of in terms of an ergogenic aid. Nevertheless, reduced performance may well occur if the individual is already hypohydrated before starting exercising.

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Discussion: The Use of Beverages as Ergogenic Aids

D.P.M. MacLaren:

Is there any evidence with regard to differences in gastric emptying with different modes of exercise? You were talking about cycling, but what about running and swimming? Also, do electrolytes such as sodium have any influence on gastric emptying rather than absorption?

J.B. Leiper:

We are not sure whether there is a marked effect of different types of exercise on gastric emptying rate. This is partially due to the large variability between individuals and the individual's habituation to exercise. It can be argued that people who normally run are perhaps better able to empty fluids during running because they are used to running, equally it might be that, because they can empty ingested liquids while running these individuals choose running as their preferred exercise. There have been a number of studies which have attempted to determinate the influence of different modes of exercise on the gastric emptying rate, but at present I would have to say that the literature is equivocal regarding any effects. It should also be remembered that exercise below about 70% VO_2max does not appear to markedly alter gastric emptying rates.

As far as the effect of electrolytes on gastric emptying is concerned, in solutions which have no energy component, the presence of electrolytes does slow gastric emptying through the change in osmolality. In energy containing solutions, the presence of electrolytes appears to have little effect on the emptying rate.

M. Orme:

Considering the prolonged gastric emptying time on exercise, I wonder whether the mechanism involved has anything to do with changes in blood flow. In other situations in the body we do see blood being 'stolen' from one anatomical area to another at times of stress in the system. It is possible that with high blood flow to skeletal muscles there could be reduced blood flow to the gastrointestinal tract.

J.B. Leiper:

I am not aware of any studies which have examined directly the effect of intestinal blood flow and gastric emptying in man. At levels of exercise which do slow gastric emptying it may well be that a reduced blood flow to the gastrointestinal tract affects the emptying of the stomach. It has been shown that exercising individuals who are dehydrated have a slower rate of gastric emptying than when they exercise while euhydrated or sit at rest while dehydrated. This effect may be due to a compromised blood flow to the gut. However, the effect of hard exercise on humoral and neural pathways is as likely to be the main effector mechanism causing a slowing of gastric emptying.

J.R. Barbany:

Some cyclists and also some endurance athletes, runners, use medium chain triglycerides during sport or before as an ergogenic aid. We did some research on them and our feeling is that they provided a slight improvement in performance. Could you comment on this kind of supplementation?

J.B. Leiper:

Some of the studies that have been carried out in Maastricht have suggested that medium chain triglycerides (MCT) are perhaps emptied faster than carbohydrate alone, when ingested as a mixture of MCT and carbohydrate. This appears to occur even when the energy density of the MCT and carbohydrate mixture is greater than that of the solution containing only carbohydrate.

F. Brouns:

Yes, as you said, we got interested in MCT, and found that they did not inhibit gastric emptying. It was an important finding, because fat normally does. So we continued with the studies. We ingested carbohydrate plus MCT or MCT alone, using ^{13}C labelled octanoate as a marker. Generally, in all of these studies it was shown that MCT are very well oxidized during exercise. But the amount you can ingest without getting gastrointestinal upset is very small. If you ingest more than 30 grams, you get diarrhoea, vomiting, etc. So that limits the use of MCT. As far as performance effects are concerned, we did different trials where we used glycogen depleted subjects, normal subjects with sufficient glycogen, etc. We did not see any effect on performance. Another thing which was interesting was that MCT are well-oxidized and this is carnitine independent, so the assumption was that if it is taken up so rapidly and goes directly into portal blood, directly into the mitochondria, does it add to the fat oxidation and if it does, does it spare glycogen? What we have found was that they are rapidly oxidized, but this does not add to fat oxidation. Total fat oxidation remains the same, which means that you spare endogenous fat and therefore there is no effect on muscle glycogen, so it fits with the fact that we did not see an effect on performance.

J.B. Leiper:

I am not convinced that fats *per se* do inhibit gastric emptying more than carbohydrate or protein. It appears that energy density is the factor which mainly influences the regulation of gastric emptying. As fats have a greater energy density per gram than either carbohydrates or proteins, then weight for weight, fats have the potential to deliver more energy to the small intestine than the other nutrients, and it is their higher energy load which causes the greater gastric slowing. You will find in the literature that studies which have examined carbohydrate, protein and fat meals having the same energy density have shown no difference in their emptying rates.

Also, when talking about carbohydrate intake for athletes we tend to emphasise the percentage of carbohydrate. Is it not the amount rather than the percentage of carbohydrate in the diet what is important?

F. Brouns:

I do think there is evidence that fat potently inhibits gastric emptying. If one infuses fatty acids directly into the duodenum, it leads to strong contractions of the duodenum and of the pylorus. These contractions reduce gastric emptying and are also referred to as the intestinal break mechanism. However, if you ingest fat orally, with a meal, it increases the energy density of the meal and then you see the same effects as with different amounts of carbohydrate.

I agree that the amount of carbohydrate is important. We have to look at daily quantities with respect to energy. If you ingest 1000 kCal/day you may need 70-80% carbohydrate of

energy to have sufficient carbohydrate. If you ingest 5000 kCal, it is quite a bit different. The most pronounced effect of this you see not with carbohydrate but with protein. Generally, it is thought that protein intake should be about 10-12% percent of energy intake. In a normal situation, that is right. However, in the Tour of France, the cyclists also ingest 10-12 energy% of protein. While ingesting 6500 kCal/day over 22 days, this leads to a protein intake of > 2 g/kg of body weight per day.

P.M. Clarkson:
Is there any interest in supplementing glucose electrolyte drinks with chromium to potentiate glucose uptake?

J.B. Leiper:
I am aware of this suggestion, however, I have no data on this point and I think that the evidence to date is insubstantial. I personally have strong doubts whether chromium supplements will induce a measurable effect. I think that the techniques which we currently have for measuring glucose uptake by the intestine are not sufficiently sensitive to reliably demonstrate any effect of chromium, and perhaps one could argue that if any possible effect is so small then it is unlikely to produce much of an ergogenic aid.

B. Ekblom:
We have only talked about endurance with regard to supplement glucose and so on, but I should mention that we did a study a few years ago where we looked at the precision in sport after two hours of exercise, and with everything else equal, the group that got carbohydrate during exercise did perform much better in precision sports afterwards. So, it is not only endurance. Other aspects of sport performance are enhanced by carbohydrate supplementation.

D.P.M. MacLaren:
A number of athletes, if they feel thirsty after exercise will drink volumes of water. I wonder whether a carbohydrate-electrolyte or an electrolyte alone solution, rather than water, would be a better rehydrating agent.

J.B. Leiper:
There has been quite a lot of work carried out recently on post-exercise rehydration drinks; studies from our laboratory and from others identify water alone as a very poor rehydration fluid. We now advocate that after finishing exercise, athletes drink a volume of at least one and a half times their sweat loss of a solution which contains at least 50 mmol/l of sodium. We suggest that this drink should contain some carbohydrate to promote glycogen resynthesis and to improve palatability. A general recommendation would be that athletes weigh themselves before and after exercising, convert their weight loss from gram to mls, and drink one and a half times this loss as a dilute carbohydrate solution containing 50 mmol/l sodium.