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PEAK PERFORMANCE

Special issue

Food and drink

In this issue

MACRONUTRIENTS

Carbohydrates: the fuel of choice for serious athletes

As an athlete you expect the best from your body. You put in hours of training and preparation to get into peak condition to compete. But it's a tough world, and there are many others putting in equal training efforts – so just how do you get the edge on the rest of the pack?

The answer is: through nutrition and diet.

Whether you are aiming to win an international championship, top your age group category or simply complete your first marathon, you must ensure you are optimally fuelling your body.

To back up all your hard work with the right nutrition you need to start with the basics. To compete you need to train; to train you need energy; to recover from training you need to replace the energy used in training. Where does that energy come from?

The answer is: from carbohydrates.

Our diet is composed of macronutrients (protein, fat and carbohydrates) and micronutrients (vitamins and minerals). Carbohydrate accounts for, on average, 50% of total energy intake, with fat supplying around 30% and protein the remaining 20%.

Carbohydrates exist in several formations, of which the most commonly consumed are monosaccharides (one sugar unit, also known as simple carbohydrates) and polysaccharides (many sugar units, or complex carbohydrates). Some examples are shown in table 1, overleaf.

The type of carbohydrate consumed determines how quickly it becomes available to your body as an energy source, although most naturally-occurring foods contain a mixture of carbohydrate types, along with varying amounts of protein, fat and other nutrients. Good carbohydrate sources are often referred to as 'carbohydrate-rich'. Not all carbohydrate sources are of equal value, and those that are also high in fat are not particularly useful to athletes. Different carbohydrate sources elicit different

FROM THE EDITOR

Stealing a tasty march on the opposition

Just as the most finely-tuned engine in the world will splutter, judder and finally fail for want of the right high-octane fuel, so the athlete's finely-honed body will perform below par if it is denied the best diet.

These days there are very few coaches or athletes who will deny the crucial importance of diet for peak performance. Indeed, as Clare Miller points out in her lead article on the role of carbohydrates, with many others putting in equal efforts on track, road, field or water, tailoring your diet closely to the needs of your body and the demands of your sport is one way to steal a march on the rest of the pack.

Of the three macronutrients (the other two being protein and fats), carbohydrates have the most immediate impact on athletic performance, as anyone who has experienced the unpleasant sensation of plummeting blood sugar towards the end of an endurance event will know. And this comprehensive piece tells you everything you ever wanted to know – and a lot more besides – about your body's carbohydrate needs during training, recovery, pre-competition and competition itself.

In fact, Clare Miller's main research interest is hydration – an equally vital concern for sportsmen and women. Whereas most people, given the chance, will eat as much food as they need – and usually more – the evidence suggests that people tend to underestimate their fluid needs, with thirst a poor guide to hydration status. In a second article on page 9, Clare presents a useful strategy for fluid replacement, especially in the heat. If you're heading for balmier climes for warm-weather training in the New Year, be sure to pack this article with your kit!

Food supplements are an integral aspect of diet for many athletes, but even the most innocuous preparations may present hidden dangers, as Ron Maughan points out on page 7. No one who faces the prospect of random dope testing should miss this worrying and thought-provoking piece.

Isabel Walker *Associate Editor*

metabolic responses when eaten. If, for example, you are looking for a quick energy boost during or just before competition, it is best to consume a carbohydrate-rich food that enters your bloodstream quickly and is made rapidly available to your exercising muscles. Foods that work like this are said to have a high 'glycaemic index'[1].

At rest, ingested carbohydrates travel via the bloodstream to your liver and skeletal muscle, where it is stored as glycogen. Skeletal muscle stores the bulk of glycogen in your body and acts as the main energy source during exercise. The amount of carbohydrate you can store varies and is greatly influenced by exercise, dietary carbohydrate intake and training status. The muscle carb stores of a man weighing 70kg may vary from as little as 300g to as much as 900g. By contrast, the liver can store only around 70g, with a range of 0-135g.

Liver glycogen reserves may be small, but they play a crucial role of delivering a constant supply of glucose to your brain, and muscles during exercise. Liver glycogen is broken down to glucose, which is the primary fuel source for the brain. If, during exercise, your liver fails to maintain blood glucose levels, you will experience the familiar light-headed feeling which is known technically as 'hypoglycaemia'.

At rest, skeletal muscle stores are hardly taxed at all, but during exercise their stored glycogen is rapidly depleted, and if your tank isn't full beforehand you will soon experience the unpleasant sensation of running on empty.

During prolonged low-intensity exercise, such as a long Sunday morning training run or bike ride, fat and carbohydrate oxidation provide the majority of energy required. As intensity increases, carbohydrates become the primary fuel source, as fats cannot be burned fast enough. If glycogen stores run empty, you must revert to fat oxidation, reducing the intensity at which you can exercise.

Many studies have shown that increasing the availability of glycogen to the muscles improves endurance exercise performance. And it may surprise you to know that muscle glycogen levels are also depleted by short repeated stints of high-intensity exercise, suggesting that middle distance runners and athletes whose sport involves repeated stints of running – such as football and tennis – would also benefit from high-carbohydrate diets. And that's not the end of the story! During any form of prolonged or high-intensity exercise carbohydrate stores are taxed, and if the athlete is required to perform again the following day they must be refilled as fast as possible. To accomplish this, large amounts of rapidly-absorbed carbohydrates are needed soon after exercise and for the following 24 hours.

Considering the crucial role of carbohydrates during exercise, it should come as no surprise to learn that increasing the proportion of carbohydrates in your diet would help improve your performance. This theory first enjoyed popularity in the 1970s, when studies showed that dietary manipulation to increase pre-exercise muscle glycogen levels led to increased time to exhaustion. These early studies involved drastic emptying of muscle glycogen stores, then 'loading' them to higher levels, allowing glycogen 'supercompensation'. There were unpleasant side effects to this carbohydrate loading method, though, and later studies have shown the same benefits can be reaped by simply tapering training and increasing your carbohydrate consumption to over 70% of total energy intake[2].

Table 1: common carbohydrate formations

Type of carbohydrate	Example	Food sources
Monosaccharides	Glucose Fructose	Fruit & veg, Processed foods
Polysaccharides	Starch	Potatoes, pasta, rice

'If, during exercise, your liver fails to maintain blood glucose levels, you will experience the familiar light-headed feeling known technically as hypoglycaemia'

A high carbohydrate intake is essential for maintaining hard training and good performance. But stores are not infinite, and constantly need topping up. So how do you go about implementing an increased carbohydrate diet to enhance training capacity, improve competitive performance and speed recovery?

There are two separate aspects of nutrition to be addressed: *the training diet*, which is consumed on a daily basis for most of the year, and the *competitive diet*. The aims of the training diet are to ensure an adequate energy supply to enable you to carry out repeated hard-training sessions in order to improve fitness and perform in your sport. The aims of the competitive diet are split into three parts: pre-competition, during competition and post-competition.

During training, energy intake must be sufficient to meet the enhanced energy costs of exercise. When regular strenuous exercise is performed, at least 65% of total calorie intake should be from carbohydrates. Studies suggest that to meet the energy demands of a moderately intense training programme, 5-7g of carbohydrate per kg body mass per day is adequate. A more demanding training programme, *eg* that of an élite triathlete carrying out several training sessions per day at moderate-to-high intensities, would require 10-12g per kg,

Table 2: carbohydrate (CHO) intake in relation to training intensity[3]

Training Intensity	CHO intake(g)/kg body mass/day	CHO intake per day (g) for average 70kg male	CHO intake per day (g) for average 60kg female
Moderate intensity: less than 1 hour training/day	5-7	350-490	300-420
High intensity: more than 4 hours training/day	10-12	700-840	600-720

as shown in table 2, above.

If you are training at the lower end of the intensity scale, putting in around 6-8 sessions a week, it is still important to maintain a high carbohydrate intake, although not as high as for two sessions a day. Simply adjust the total daily intake to around 5g/kg body mass/day. Carbohydrates should still make up the same percentage of your overall energy intake, but it is important to keep fat intake low to ensure you can eat enough carbohydrates without pushing your overall total calorie intake high enough to cause weight gain.

Achieving a high carbohydrate intake is difficult unless you are able to choose from a range of carbohydrates. Some carbohydrate-rich sources are also high in fat, and should be eaten only occasionally or sparingly. Most naturally-occurring carbohydrates are low in fat, and there are often low-fat alternatives available for convenient processed foods. Table 3, below, gives some examples of carbohydrate-rich foods.

Complex carbohydrates such as rice, pasta and potatoes can form a main meal base. When you are striving to achieve a high daily carbohydrate intake, it is often necessary to supplement your main meals with convenient carbohydrate-rich snacks or fluids consisting predominantly of simple sugars. These are less bulky, contain less indigestible fibre and have lower water content than complex carbohydrates.

As mentioned, you should consume the high-fat carbs listed in the table only in limited amounts. Remember that since all milk has the same carbohydrate content, differing only in fat content, semi-skim and skim milk is more suited to an athlete's need.

When carbohydrates are accounting for a large proportion of the training diet, it is important to ensure that your needs for other macro- and micronutrients are met. It is common for athletes to focus on achieving a high-carbohydrate diet at the expense of the nutritional quality of their diet as a whole, and this can lead to other problems associated with a poor diet, such as anaemia. It is possible to meet all the nutritional demands of your body with some carefully planned food combinations, involving nutritious high-carbohydrate foods. Table 4, overleaf, offers some suggestions.

After a hard training session, whether it was an interval session involving short intense bursts of exercise that rapidly depleted your glycogen stores, or a prolonged endurance session, your goal is to get those muscles resynthesising glycogen again as soon as possible for fast recovery. There is an abundance of evidence showing that by rapidly replenishing muscle glycogen stores you can reduce the time needed to recover before the next hard training session and enhance subsequent performance.

By ingesting carbohydrate-rich foods immediately after exercise, when muscles are most receptive, you will put yourself in a good position to recover as fast as possible. During the

'It is important to keep fat intake low to ensure you can eat enough carbohydrates without pushing your overall total calorie intake high enough to cause weight gain'

Table 3: carbohydrate sources and their fat content[3]

Low-fat, high-CHO sources	Amount required for 50g CHO	High-fat, high-CHO sources	Amount required for 50g CHO
Rice(white)	170g (1 med serving)	Ice cream	210g (3 scoops)
Pancakes with syrup	138g + 20g (2 med + 2 tsp)	Full fat milk/yoghurt	1,000ml (5 servings)
Popcorn	75g (1 bag)	Crisps	100g (4 small bags)
Breakfast cereals	60-70g (1 med bowl)	Croissant	100g (1 small)
Coca Cola	450ml	Pastries	About 100g
Milk, flavoured: semi or skim	1,000ml	Pizza	1 large thick slice
Fruit juice	500ml	Tortilla wraps	55g (2 wraps)
Fruit, eg apples, bananas	3 medium pieces		
Sweets, eg jelly beans	60g		
Toast with honey	3 slices, spread thickly		
Muesli bar	1 large		
Dried fruit, eg dates	3 dates		
Rice pudding	50g (1 med bowl)		
Kit Kat	4.5 fingers		

Post-exercise is not the time to restrict your calorie intake. A high-carbohydrate feeding now will mean you are ready for the next session sooner

Table 4: nutritious carbohydrate-rich foods

Food sources	Meal suggestions
Flavoured low fat yoghurt	Fresh fruit and yoghurt
Semi-skim/skim milk	Fortified breakfast cereal with milk
Milk	Fruit smoothie
Dried fruit	Porridge with dried fruit and honey
Wholemeal bread	Tuna salad sandwich
Fruit	Fruit salad
Potatoes	Baked potato with egg mayo
Brown rice	Curried chicken with rice
Pasta	Spaghetti bolognese

first two hours post-exercise, muscle resynthesis rates are maximal and you should take advantage of this by eating as soon as you can.[1]

Recovery from lower-intensity sessions does not require as high a carbohydrate intake as hard or prolonged sessions, but make it a habit to eat a high-carbohydrate snack or meal straight after training. Post-exercise is not the time to restrict your calorie intake. A high-carbohydrate feeding now will mean you are ready for the next session sooner. And it is the repeated hard training – not starving yourself – that will help you lose pounds.

The optimal rate of carbohydrate ingestion post-exercise appears to be at least 50g every two hours, for at least 20 hours, to provide approximately 500-600g carbohydrate in total. Larger amounts of carbohydrate do not appear to produce any further benefits.

Foods with a high glycaemic index increase the rate of glycogen synthesis following exercise. Remember, the higher the glycaemic index, the more rapidly the food is absorbed and is therefore available to your muscles. By avoiding low-glycaemic-index foods in favour of those with a moderate-to-high index, you will be more successful in promoting muscle glycogen synthesis.

Table 5, opposite, shows the glycaemic index of some carbohydrate-rich foods. Providing you select foods that are rapidly absorbed, it does not matter whether the carbohydrate is in solid or liquid form; neither does it matter whether you consume small frequent meals over 24 hours or a few large meals, as long as you replace the glycogen.

Fluid replacement is also vital after hard exercise, and by taking in some of the carbohydrate in liquid form, you will achieve the dual benefit of replacing lost fluids. Appetite is often suppressed after hard exercise, so it is important to choose food or drinks that stimulate your taste buds. If liquids are preferred, there are many sports drinks that supply around 6g carbohydrate per 100ml, such as PowerAde and Gatorade. Ordinary soft drinks such as Ribena and Oasis are also good sources of carbohydrates.

It may not be practical to consume 50g of carbohydrate every two hours, in which case you could go for 100g per 4 hours or 150g per 6 hours, to allow for such activities as sleep, travel and work. If solid foods are preferred, compact high-energy sources are best, such as muffins, energy bars, sweets and bananas. The wide range of low-fat biscuits, cakes and snacks marketed for promoting weight loss include very good sources of concentrated carbohydrates; for example, McVities Go Ahead! crispy slices provide 10g of carbohydrate per slice (that's 70% carbohydrate), while a 500ml bottle of Lucozade Sport and two NutriGrain bars will provide you with enough carbohydrate to keep you going until you can sit down to a proper meal.

The competition diet differs from the training diet in that it is tailored towards a specific event and is consumed with the aim of maximising your performance in that event. In the short term it may not be nutritionally sound, as you will be aiming to squeeze in as many carbs as you can at the expense of other nutrients.

How you prepare for a competition depends on the challenge the race poses in terms of taxing your fuel resources. A race of over 90 minutes of moderate-to-high intensity will certainly require glycogen supplies to be maximally topped up beforehand, and studies have shown that increasing glycogen stores will improve performance of even short intense exercise periods. If the race is less than an hour, and you have maintained a high-carbohydrate training diet, a final high-carb meal the evening before, as described below, should be sufficient.

As competition day looms, taper off training to a reduced daily load of 30-60 minutes of low-intensity exercise, while aiming for a high-carbohydrate intake of 500-600g per day. This will encourage your muscles to store over 20% more glycogen. If you have been following a high-carbohydrate training diet throughout the previous months, your muscles should be well stocked up, but this tapering régime will ensure they are maximised.

What you eat on the day of competition depends on the time and length of the race as well as personal issues, such as what you can stomach, and what is convenient. If the race is scheduled for first thing in the morning, it is unlikely that you are going to feel like getting up at 3 or 4 am to eat a carbohydrate-rich meal. Instead, on the evening before eat around 200g of carbohydrate, by basing your meal around pasta or rice. A typical meal could consist of the following:

- 3 cups pasta;
- tomato-based pasta sauce;
- small topping parmesan cheese;
- 1 scoop ice cream;
- 1-2 pieces fresh fruit;

● 500ml sports drink, or fruit juice.

Before going to bed, if you feel peckish, two slices of toast and jam or a cup of hot semi-skim milk with two low fat biscuits, such as Jaffa Cakes, should suffice.

On the morning of competition, the aims of your final feeding are to:

● top up muscle glycogen stores;
● replenish liver glycogen stores that will have dropped overnight;
● keep hunger at bay without causing discomfort;
● promote the use of CHO as a fuel during exercise.

Choose a small snack first thing in the morning that is densely packed with carbohydrates but contains little in the way of fat, protein or fibre. To reduce fibre content, choose 'white' carbohydrate sources over 'brown'. Some ideal breakfast choices include:

● 1 small bowl cereal with semi-skim milk, half a banana and 1 tsp honey;
● 2 slices toast with honey or jam;
● energy bar or drink.

For competitions later in the day, your pre-event meal will contribute to the fuel available during exercise. For prolonged endurance exercise, it should meet the same criteria as the evening meal described above, containing around 200g of carbohydrate. This meal will provide carbohydrates for oxidation during the later stages of the competition, helping you to maintain your pace for longer. An example of a suitable breakfast is:

● 1 large bowl Fruit'n'Fibre with semi-skim milk and 2 tsp honey;
● 1 medium banana;
● 100ml natural yoghurt;
● 2 slices white toast;
● 2 tsp jam;
● 250ml fruit juice.

You have eaten your high-carbohydrate, low-fat meal four hours before competition, and there is just one hour to go. Do you have a quick sugar fix now? Many athletes believe a high-carbohydrate snack just prior to exercise will lead to reduced exercise performance; this misconception arose from a single study carried out in the 1970s that showed a reduction in performance time following ingestion of glucose 30 minutes before exercise. But this study has not been backed up by any further research, and the theory that a sugary snack immediately prior to exercise will impair performance is not widely accepted today.

The theory was based on the idea that the glucose would raise insulin levels, and therefore reliance on muscle glycogen, during the early stages of exercise. Many subsequent studies do back up this theory, but nevertheless fail to show any detrimental effect on exercise performance, since the effect is short lived. In other words, the pros of an extra supply of carbohydrate just before you begin exercise far outweigh any cons[4]. This last feeding should be a palatable and rapidly-absorbed snack containing around 50g carbohydrate, such as an energy bar, a handful of raisins, a small banana or a sports drink.

Table 5: carbs and their glycaemic index

High glycaemic index CHO foods	**Serving size for 50g CHO**
6% sports drink	825ml
White or wholemeal bread	201g (about 4 slices)
Bagel	89g (1 bagel)
Baked potato	200g (1 medium)
Boiled sweets	50g
Raisins	78g
Banana	260g (3 small)
Moderate glycaemic index CHO foods	
Pasta	198g (2 cups)
Porridge	69g (1 cup)
Muffins	90g (1 medium)
Grapes	300
Low glycaemic index CHO foods	
Apples	400g (4 small)
Dried dates	70g (about 8)
Baked beans	485g
Milk (skim)	1,000ml
Ice cream	202g

The best way to find out what suits you is to experiment during training. Don't wait until race day to find out the hard way that you can't cope with fluids 30 minutes beforehand!

Why do you need to ingest carbs during prolonged exercise? You already know the answer if you have ever been in a competition situation, feeling good, pushing hard, when suddenly, bang, you run out of energy. Call it what you want – hitting the wall, bonking, knocking – it's all the same: you've used up all your carbohydrate stores and you're running on empty. However, you can delay if not prevent this disaster altogether by taking a few precautionary measures during the event.

Despite all the knowledge on pre-event carbo-loading, it has only been relatively recently that attention has focused on fuelling up *during* exercise. Watch any big endurance event on television – an Ironman, for instance – and you'll see athletes collect their own specially-formulated sports drink or food at a drinks station. And that is part of the key: choosing what suits you. Know the basics, try out a few formulations during training, find out what you can tolerate and then practise until you are sure you can ingest the required amount under race conditions.

But why is this necessary if you have successfully loaded up your glycogen stores prior to competition? At the onset of moderate-

'The theory that a sugary snack immediately prior to exercise will impair performance is not widely accepted today'

intensity exercise, around 50% of energy will come from fat and 50% from muscle glycogen. Straight away muscle and liver stores begin falling. Although muscle glycogen continues to supply energy throughout exercise, blood glucose starts being delivered to your muscles as a fuel source. If this blood glucose isn't maintained, levels will fall and you will have to rely more heavily on muscle glycogen.

Remember, though, that your muscle glycogen stores aren't unlimited, and following two hours of continuous exercise they will have fallen low. If you can keep topping up blood glucose by eating carbohydrates and save glycogen stores until you need them later, you can delay fatigue by as much as 30-50 minutes. What's more, should you find yourself in a sprint finish situation at the end of a long endurance event, a bit of saved muscle glycogen could just give you an edge.

It's not just endurance performance that benefits from carbo-feeding; intermittent exercise performance of varying intensities, such as in hockey and football, is also improved. Taking in a carbo drink at half time can improve sprinting ability in the latter stages of the game, making all the difference as the opposition tires[4].

The major factors to consider when taking on fuel during competition are:

- length and intensity of the event;
- ease of taking on food and fluids;
- what can be tolerated.

A 70kg athlete should aim to ingest 30-60g of carbohydrates per hour, depending on the length and intensity of competition. A 60kg athlete should aim for 25-50g. Don't wait until you feel hungry to eat and don't wait until you feel thirsty to drink. Once you start to feel fatigued it is too late, and you will struggle to take on enough fuel to reverse the adverse effects.

Begin regular small feedings in the early stages of competition. Have foods readily available and easy to find, open and ingest. If you think you might forget, set the alarm on your watch to go off every hour, reminding you to eat something.

Many endurance athletes carry small bags of pre-portioned food supplies in a bum bag or saddle bag. Sports drinks should be measured into water bottles and be easy to reach. If you know the race route, ask friends to stand at certain points with drinks or food; or leave your own drinks at drink stations beforehand.

What should be in these food packages or water bottles? How much food and what type of carbohydrates? Because energy needs to be delivered as rapidly as possible to your hard-working muscles, it is best to choose foods with a high glycaemic index. Those listed in table 5 (*previous page*) are all suitable, but not necessarily convenient. Sweets like jelly babies are ideal to stuff into a pocket, as are energy bars or gels. There are many different commercial sports fuels to choose from now, so why not buy several brands and experiment?

During a competition you may not feel much like eating or drinking, but you are more likely to do so if you actually *like* the food and drink you have with you. Other options include bananas, raisins, fig rolls, and honey or jam sandwiches. Avoid foods with high fat, protein or fibre content, as they can cause gastric discomfort.

If, like many athletes, you find it hard to tolerate food at all while competing, try fluids alone. A water bottle may be more bulky to carry than an energy bar, but fluids are often better tolerated in your stomach if you are prone to gastrointestinal distress. Commercial sports drinks of 6-10% carbohydrate content will rapidly supply you with both fuel and fluids, killing two birds with one stone. Good examples include Gatorade, Lucozade and High 5.

Athletes were refuelling before the advent of commercial sports drinks, however, and home-made sports drinks are just as effective as well as cheaper. Diluted Coca-Cola is a favourite among cyclists, and fruit juice diluted with equal parts water is just as good.

Go for small frequent drinks

As the carbohydrate content of the drink increases, the rate at which it is emptied from your stomach falls; above 10%, the delivery rate is too slow for during competition, and below 6% the volume required to provide enough energy would be so high as to be impractical. Drinking small frequent volumes is generally advised, as this will be better tolerated than a single large bolus.

Remember, though, it is possible to train your stomach to tolerate larger food and fluid loads during exercise by starting with a small amount of food in your stomach and building up to being able to ingest larger amounts during training.

After competition, your refuelling requirements are the same as after a hard training session. Aim to ingest at least 50g of carbohydrates as soon as possible. Remember, in those first two hours after competition, your muscles are far more receptive to carbohydrates than they will be several hours later. Don't wait until you get home to eat; plan ahead and have a sports drink and a couple of energy bars in your bag, or a packet of jelly babies and a can of juice. Your muscles aren't fussy, and as long as the food is carbohydrate-rich, they will use it. And if you can take in 100-200g in the first few hours after exercise, you're well on the way to the goal of a total 500g.

Carbohydrates are the fuel of choice for serious athletes who strive to get the most out of their bodies. To train hard and compete successfully, go for carbs every time!

Clare Miller

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DIETARY SUPPLEMENTS

When the price for 'harmless' tablets is just too high

At a time when world standards in sport are moving to ever-higher levels, and training programmes are becoming ever-more demanding, the athlete who wants to make it to the top – and stay there – must explore all possible means of securing an advantage. Nutrition offers one obvious way to get ahead.

A varied diet, consumed in quantities sufficient to meet the energy needs of the athlete in training, should provide all the essential nutrients in adequate amounts. But not all athletes eat a varied diet, and total food intake may at times be restricted, which can lead to deficiencies of some nutrients. Because these deficiencies may be difficult to detect in their early stages, athletes are often tempted to take individual nutrients in a concentrated form as a precaution. And an enormous multinational industry has grown up to cater for this demand.

However, athletes should take supplements only after balancing the potential rewards against the very real risks. For although vitamin and mineral supplements are perceived as harmless, and the daily multivitamin is regarded as an insurance policy, supplements are not always benign.

Routine iron supplementation, for example, can do more harm than good, and the risk of toxicity is very real. It has been estimated that, in industrialised countries, twice as many men suffer from iron overload due to excessive use of supplements than from iron deficiency.

But there are other risks associated with taking supplements – risks that are less physically threatening but may be more difficult to reverse.

More exotic supplements, many of which have names – and promotional material – that suggest an anabolic action, have become a prominent feature on the shelves of sports nutrition stores in the last decade or two. Some of these products make extravagant claims about building bigger, stronger and faster muscles, repairing the damage caused by hard training, resisting infections and illnesses, and preventing chronic fatigue. They usually come with fancy price tags, but for the athlete who is training to the limits no price seems too high.

This may be true in a strictly financial sense but, if we are to believe some of our top athletes, they have paid a far higher price in recent years. Being labelled a drug cheat is something no athlete wants and no innocent athlete deserves. Every effort must be made to ensure that athletes who use illegal drugs to enhance performance are caught and punished but, at the same time, the innocent must be protected.

Which brings us to the thorny issue of Nandrolone in sport. Nandrolone is the popular name for the anabolic androgenic steroid more properly known as 19-nortestosterone. Many different androgenic anabolic steroids, including nandrolone and testosterone itself, have been used by athletes over the years, and well-established measures are in place to detect abuse.

The apparent spate of nandrolone cases in British athletics over the last couple of years has cast a shadow over the sport as well as the individuals involved. Dougie Walker, Linford Christie and Mark Richardson are among the top athletes from various countries who have produced positive tests for nandrolone, although Walker continues to protest his innocence even after completing the two-year suspension from competition that effectively ended his career, and the others also vigorously deny any wrongdoing.

This problem is not unique, either to athletics or the UK. Football, boxing, cycling, rugby, weightlifting and many other sports have seen similar cases. Nonetheless, UK Athletics has taken the lead in investigating the possible reasons for the positives.

Were the athletes cheating?

The problem was approached with an open mind, and all possibilities were considered, including the possibility of deliberate and systematic cheating by the athletes concerned. A review of the positive cases within athletics revealed that all of the athletes had reported using a range of dietary supplements, mostly from the same supplier.

A study carried out at Aberdeen University showed that administration of these supplements to athletes and to healthy volunteers training at a more modest level resulted in some positive tests. And those who tested positive recorded concentrations of 19-norandrosterone (the nandrolone metabolite whose presence is taken as evidence of nandrolone in the system) of up to about 30ng per ml of urine: anything above 2ng/ml and 5ng/ml for females counts as a positive.

Initial analysis of the supplements taken by the athletes and volunteers did not detect nandrolone or any other related steroids that could explain these positive tests. The International Athletic Federation (IAF) did not accept these results, which were, in truth, difficult to explain. But, because of the time pressures, it was not possible for the researchers to test a large number of supplements or a large number of athletes before presenting these data to the IAF.

However, when the analysis of some of the dietary supplements was repeated, using an

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improved method developed by the IOC-accredited laboratory in Cologne, the Aberdeen and Cologne laboratories both found tiny amounts of a number of different steroids in several of these supplements. The amounts of steroids, although sufficient to play havoc with the careers of these athletes, were far too small to have any beneficial effects on performance. The supplements did not say on the label that they contained any banned substances and the athletes involved believed them to be suitable for use.

At about the same time as these results were coming out of Aberdeen, similar findings were reported from IOC-accredited drug testing laboratories in Germany, Canada and the USA. In Italy, two athletes tested positive after taking iron tablets, and nandrolone precursors were later found to be present in some of the tablets. In Germany, nandrolone has been found in creatine powder sold to athletes.

Strict liability still applies

There is now a considerable weight of evidence to show that not all dietary supplements can be regarded as safe, even when the label or promotional material says they are. As before, however, the principle of strict liability applies (meaning that the athlete is responsible for whatever is in his or her body, irrespective of how it got there) and athletes who test positive in these circumstances are technically guilty.

Dietary supplements are not evaluated by regulatory agencies, and inaccurate labelling of ingredients is known to be a problem. Most supplements, it has to be said, will not cause problems for the athlete, and most companies that manufacture and supply these supplements are anxious to ensure the welfare of their customers. Nonetheless, the supplements reported to have been used by athletes who gave positive tests, backed up by the Aberdeen research, were all apparently innocuous substances, which should not have resulted in positive tests, even in the high doses used by some of these athletes. Until the picture is clarified, the only safe course for prudent athletes would seem to be to avoid anything that cannot be absolutely trusted.

An authoritative paper published in the scientific literature in November 2000[1] provided some of the first solid evidence of steroid contamination of dietary supplements.

This study reported the results of analysis of three legitimate dietary supplements – Chrysin, Tribulus Terrestris and Guarana – none of which declared on the label that they contained steroids or might reasonably have been expected to do so. The researchers found nandrolone, testosterone and other steroids in these supplements: when they were fed to healthy volunteers, they gave positive nandrolone urine tests, with urinary concentrations of up to 360ng/ml (remember, the threshold for a positive test is 2ng/ml for men and 5ng/ml for women).

The Cologne laboratory followed up with a much bigger study of 634 different product samples from 215 different suppliers in 13 countries around the world[2]. The samples were analysed for the presence of steroid hormones and their precursors, and 94 supplements (14.8% of the total) were shown definitely to contain prohibited substances. In another 66 samples (10.4% of the total), the analysis was inconclusive, but steroids may have been present. Substantial numbers of positive tests were obtained from products bought in The Netherlands (26% of 31 products tested), Austria (23%), the USA (19%), UK (also 19%) and elsewhere.

The supplements which produced positive results have not been identified, but they included vitamins and minerals, protein supplements, creatine and many others. It was interesting to note that 21% of products from companies selling prohormones (substances converted in the body into active hormones) tested positive, while only 10% of samples from companies that did *not* sell prohormones were positive.

The IOC-accredited laboratory in Vienna has repeated the Cologne study, albeit with a smaller number (54) of supplements. They found that 12 of these (22%) contained prohibited steroids – almost the same proportion as the Cologne lab found for supplements bought in Austria. Unlike the German results, the identities of the companies and their products have been published on the Internet, and can also be found on the Cologne website at www.dopinginfo.de.

Events took a more sinister turn in 2002, when the laboratories in Cologne and in Vienna found one of the 'hard' anabolic steroids (methanedieneone) in a supplement purchased in England. This drug was present in high enough amounts not just to have an anabolic effect but also to produce serious side effects. The presence of this steroid has been described as a 'deliberate and criminal act (remember that this was the drug that caused problems for British athletes Janine Whitlock and Perris Wilkins).

So where are we now? In some ways it does not help to know what was positive last year because the market keeps changing, with old products disappearing and new ones appearing on a regular basis. It is also true that products from the same batch – or even the same bottle – may be either clean or contaminated.

In a future article, we will look at some of the steps athletes can take to protect themselves and at some of the proposed legislation changes that might make the supplement industry more accountable than at present.

Ron Maughan

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1. *Dtsch Z Sportmed 51, 11 (2000) 378-382*

2. *Dtsch Apoth Ztg 142, 29 (2002) 50*

HYDRATION

Fluid: the one thing your body can't learn to do without

You can train yourself to cope with many situations: adjust to crossing time zones, adapt to climate changes and acclimatise to altitude; you can learn to use carbohydrates more efficiently and to make fats go further. But there's one thing you can't learn to do without – and that's water.

The human body has a core temperature of 37°C. Fluctuations can only be tolerated within a narrow range, and an increase of only 5°C or a loss of just 10°C can be fatal. During exercise, muscular activity adds a considerable amount to heat production; metabolic rate can be increased as much as 25-fold, producing heat at a rate of 80kJ min^{-1} (20kcal min^{-1}) and leading to rapid increases in core temperature.

The body's primary line of defence against a rising temperature is evaporation by means of increased sweating; the rate of heat loss by evaporation can be enough to regulate body temperature within 2-3°C of resting levels, even in a hot environment. For every litre of vaporised water, 2.4MJ or 580kcal of heat is removed from the body. With several million sweat glands covering the body's surface skin, the potential for water loss is great. In response to heat stress, these glands are opened, allowing secretion of sweat onto the skin, which then evaporates into the environment. It is not the *production* of sweat but its evaporation from the skin that allows the skin to cool. If the surrounding air is cool and has a low humidity, sweating is much more efficient. If the environment is warm, sweat is still produced but is unable to evaporate so that the cooling effect is reduced.

Sweat rates can reach 2-3 litres per hour in extreme circumstances, and water loss will rapidly reach a significant level. If fluid losses are not matched by increased fluid intake, exercise performance will deteriorate as body temperature rises unchecked. In other words, this very useful mechanism of controlling core temperature through evaporation of sweat is lost if fluids are not replaced. Furthermore, if an athlete is already dehydrated before exercise, the ability to lower body temperature by evaporative sweat loss is rapidly reduced.

Fluid balance is a vital issue in many situations, including marathon or Ironman training. For athletes travelling overseas to compete or for warm weather training, it is particularly important to prevent the debilitating effects of dehydration and overheating by practising a carefully planned drinking strategy. But even indoor training sessions in the gym or at home pose risks to fluid balance because still indoor air is not conducive to sweat evaporation. In every situation, though, adequate and effective fluid replacement will allow maintenance of optimal performance.

When exercise duration exceeds an hour, athletes must also bear in mind the need for carbohydrate replacement. Carbohydrate is the main source of fuel for muscles during endurance exercise but, if stores are not frequently topped up, fatigue due to glycogen depletion occurs. By regularly ingesting small amounts of carbohydrate it is possible to delay fatigue by up to an hour.

Unfortunately, though, this is not simply a matter of adjusting the carbohydrate content of a drink. An ingested drink only becomes useful to an athlete after it has left the stomach, passed through the intestine and been absorbed into the blood stream, where it maintains blood glucose concentration. Typically, stomach emptying occurs at a rate of around 600ml per hour, and increasing the carbohydrate concentration of a drink actually *reduces* the rate of emptying. Therefore a high-carb drink will deliver less fluid than either plain water or a low-carb drink.

A drink with a 2-3% carbohydrate content will deliver fluid at almost the same rate as water; a 4-8% carbohydrate drink will reduce the rate of emptying slightly but insignificantly. Optimal for prolonged moderate-intensity exercise is a 6-8% carbohydrate content, which helps to replace carbohydrate losses without greatly hindering the emptying of fluid from the stomach. This is the range of concentration offered by most sports drinks, including Lucozade Sport, High5 and Isostar. If a greater rate of carbohydrate delivery is required, you need to choose a drink with carbohydrate concentration of 10% or more, *eg* Coca Cola.

Drinking strategies must be rehearsed

The volume of fluid in the stomach also affects the rate of emptying, in that a larger volume encourages more rapid emptying, and *vice versa*. Starting exercise with a moderate amount of fluid in the stomach (about 500ml) and topping it up every 15 minutes will allow you to maintain a high rate of emptying. But this is a strategy that must be rehearsed before competition and often takes some time to get used to.

A study I was involved with as an undergraduate student nicely demonstrated the two major factors affecting fluid uptake from the stomach[1]. The study contrasted two drinks – one containing 2% glucose and the other 10% – delivered in two different ways: in one pair of trials, subjects ingested only a single 600ml bolus

'Even indoor training sessions in the gym or at home pose risks to fluid balance because still indoor air is not conducive to sweat evaporation'

of each drink and in another they initially drank the same amount of either drink, 'topping up' with a further 100ml every 15 minutes for an hour.

The rates at which the fluids left the subjects' stomachs were measured, and the results are summarised in table 1. The highest rate of emptying from the stomach occurred when the 2% solution was drunk and then topped up, but the greatest energy delivery occurred with the 10% top-up trial. Thus, increased fuel delivery comes at the expense of fluid, and *vice versa*.

Sports drinks come in a range of carbohydrate concentrations and flavours, and every athlete should be able to find something to his or her taste. Whether or not you like the taste of a particular drink is as important as its content and volume, because the plain fact is that if you don't like it you simply won't drink enough. Table 2 shows some of the drinks currently available.

For an athlete performing prolonged exercise on a very warm, humid day, fluid replacement is the prime need, with carbohydrate replacement being a secondary consideration. Therefore a low-carbohydrate content sports drink, such as Gatorade or Lucozade Sport, will be the best option. For a home-made alternative, mix 200ml of concentrated orange juice with 1 litre of water. Ingesting 200ml every 15 minutes can maintain sufficient volume in the stomach to promote emptying as well as providing enough water and carbohydrate to meet temperature regulation and muscle glycogen needs. If fluid needs are of even greater significance, a 4% carbohydrate concentration may be more suitable; to make this at home, reduce the concentration of orange juice to 100ml.

Table 1

Trial	Volume of fluid emptied (ml)	Amount of CHO emptied (g)
600 ml 2% CHO	580	12
600ml 10% CHO	490	46.8*
600ml 2% + 100ml/15 mins	770*	16
600ml 10% + 100ml/15 mins	580	61*

*Significantly more than other trials

On a cooler day, when high-intensity exercise is planned, carbohydrate replacement becomes the primary need because fluid losses will be lower and carbohydrate usage higher. In this case, a sports drink with a higher carbohydrate content would be best, such as Coca-Cola or a drink made up of 400ml orange juice with 1 litre of water. In extreme cases, when optimal carbohydrate replenishment is required, Lucozade Energy contains 17% carbohydrate and Gatorade Energy a massive 20%. In longer events, it may be appropriate to choose a 2-3% drink for the first hour to promote fluid uptake, then move onto a 6-8% drink in the later stages of the race, when glycogen replacement is more important.

There is a considerable amount of individual variation in fluid loss, with some people sweating more profusely than others and some being able to empty fluids from their stomach more rapidly. This makes it difficult to be too prescriptive about how much an athlete should drink. One way to work out how much fluid you lose during exercise is to weigh yourself immediately before and afterwards: any loss in weight will be due to sweat loss, and indicates the amount you need to ingest to maintain fluid balance.

Finally, follow these tips to achieve adequate fluid intake during exercise:

- Be aware of your fluid requirements;
- Make fluids as readily available as possible;
- Ensure you are well-hydrated before exercise (500ml of a 6% sports drink 1 hour beforehand will suffice);
- Empty your bladder before exercise;
- Drink small amounts regularly during exercise;
- Start drinking before you feel thirsty;
- Practise a drinking régime during training;
- Aim to drink 150-200ml every 15 minutes.

It really boils down to establishing your body's particular fluid requirements, finding out what you can tolerate and then making sure it is available when you really need it. Don't blow up for want of a water bottle!

Clare Miller

Reference

1. Journal of Physiology, February 2002, vol 539p, 40p

Table 2

Drink	Carbohydrate content (%)	Flavours available
Gatorade	6	Tangerine, orange, berry, lemon-lime
Gatorade Energy	20	Orange, wild berry, grape
Isostar	8	Lemon, orange, grapefruit
Lucozade Energy	17	
Lucozade Sport	6	Orange, berry
PowerAde	8	Mountain Blast, Fruit Punch, Lemon-Lime, InfraRed Freeze, Arctic Shatter, Green Squall and Jagged Ice (not all available in UK)
Coca-Cola	10	

WHAT THE PAPERS SAY

Reports by Isabel Walker

How diet impacts on prolonged walking

The popular belief that high-carbohydrate diets aid weight loss by suppressing appetite has been challenged by the results of a British study examining metabolic and appetite responses to prolonged walking under different dietary conditions.

Eight moderately-trained male hill walkers undertook three 450-minute walks, at intensities varying between 25-30 and 50-55% of VO_2max, under each of the following dietary conditions:

1. *High-fat*, including breakfast cereal with double cream and milk, bread and cheese sandwiches, ice cream, and snack foods like coconut and almonds;
2. *High-carbohydrate*, including cereal with skimmed milk, banana, white toast and jam, low-fat yoghurt, orange juice and dried fruit;
3. *Mixed*, including elements of both the others.

Each dietary condition, including breakfast, lunch and two snacks, produced the same total calorie count, even though the contents were radically different.

The researchers had hypothesised, among other things, that at this intensity of exercise a high-fat diet would be associated with decreased ratings of fatigue and perceived exertion through sparing of carbohydrate stores and enhanced fat utilisation.

But in fact there were no significant differences in fatigue ratings between the three dietary conditions. Neither were there any significant differences in any of the following: heart rate, perceived exertion, hunger, fullness, satiety, strength of appetite or desire to eat.

According to the researchers, 'the absence of any change in heart rate, (rating of perceived exertion) or subjective ratings of fatigue between the dietary manipulations during prolonged exercise is an important…observation. This suggests that dietary composition will not adversely affect physiological and subjective factors over one day'.

And the fact that the three diets resulted in a similar energy deficiency at the end of the day suggests that 'a wide range of dietary patterns may be acceptable for those trying to lose weight by incorporating moderate-intensity exercise into their routine'.

Although diet influenced the degree of total carbohydrate and fat oxidation, fat was the main source of energy in all three trials.

The main drawback of the high-fat diet, however, was that it resulted in a negative carbohydrate balance over the exercise period, suggesting that it might not allow for further exercise, even at low-to-moderate intensities.

'Decreases in the glycogen stores…, especially if continued over a few days of walking, would be detrimental to the ability to sustain the activity,' the researchers point out.

J Appl Physiol 2002 May;92(5), pp2061-70

What works best for fluid replacement?

Flavoured drinks are associated with enhanced fluid balance during exercise – even in those who claim to prefer unflavoured drinks. That's the somewhat surprising conclusion of an Australian study investigating the effect of different drinks on preference and fluid balance in team sports.

The researchers monitored fluid balance during nine separate training sessions undertaken by nine junior élite female netball players, seven female basketball players and eight male basketball players (the controls). Each subject completed three sessions while drinking as much as they wanted of three different drinks:

- water;
- a regular sports drink (6.8% carbohydrate);
- an identically-flavoured low-calorie sports drink (1% carbohydrate).

Fluid intake and sweat loss were measured for each athlete over each training session. Additionally, they were asked to rate each of the drinks for taste, 'mouth feel', gastrointestinal comfort and desire to use again.

The researchers were testing the hypothesis that the energy content of sports drinks is perceived as a negative characteristic by female team sport players and that they would consume less of this than a low-calorie version, while the male players would not.

But in fact these expectations were confounded. The main finding was that better fluid balance was achieved when beverages were flavoured, with no significant preference for the low-calorie drink.

Paradoxically, though, water was rated significantly higher than either flavoured drink for mouth feel, gastrointestinal comfort and desire to use again. 'It appears that there is a discrepancy between the beverage type that subjects describe as their preferred exercise beverage in a survey and the amount that they actually drink when observed in practice.'

Possible explanations for the relatively poor intake of water include the suggestion that it suppresses thirst signals before fluid losses have been replaced, that lack of flavouring may provide less of a stimulus for intake and that lack of sodium chloride might lessen the 'osmotic drive for drinking'.

'Better fluid balance was achieved when beverages were flavoured, with no significant preference for the low-calorie drink'

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However the practical implication of this study is that coaches and trainers should help athletes maintain fluid balance by making sports drinks available during training and competition, while athletes who choose to drink water should pay particular attention to fluid balance, recognising that they need to drink 'beyond merely feeling refreshed'.
Int J Sport Nutr Exerc Metab 2002 Mar;12(1):81-92

Athletes need more fat

The relative importance of fat in the athlete's diet has been undervalued, with potentially harmful effects on immunity as well as endurance performance, according to New York researchers reviewing the effects of diet on immune function in athletes.

'It is of great concern,' they comment, 'that many athletes are on low total calorie and low-fat diets that result in not only depleted intramuscular fat stores and essential fatty acids, but also deficiencies in many micronutrients. The unavailability of fat to oxidise and spare glycogen and build the immune system leads to reduced exercise performance and increased stress and risk of infection.'

While carbohydrate availability is well recognised for its role in immune competency, the role of lipids (fats) in the immune response to exercise has been under-appreciated. In fact, lipids play a crucial role in building and maintaining the immune system and bolstering it against the stress of exercise.

Some experts have recommended fat intakes as low as 20% of total calories. But the New York researchers believe that endurance athletes could boost their consumption as high as 42% of total intake with beneficial effects on performance and immune function and with no adverse impact on the risk of heart disease.

They point out that fat intake may be particularly important for female athletes, in whom low-calorie, low-fat diets are associated with amenorrhea and diminished performance.

The researchers propose a 'baseline diet' consisting of 12% protein, 35% carbohydrate and 35% fat. The remaining 18% of total calories should be distributed between these three macronutrient groups in a ratio determined by the type of sport activity: for example, distance runners may take more fat, high-intensity intermittent athletes more carbs and weightlifters more protein.
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