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Dietary macro- and micronutrient requirements of endurance athletes

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Most endurance athletes train for many hours per week to compete in events which generally last no longer than 2–3 h. However, there are exceptions and these include the full-course triathlon in which competitors swim 2·5 km (1·5 miles), cycle 180 km (112 miles) and finally run 42·2 km (26·2 miles). Elite athletes win this competition in a little over 8 h. In cycling, there are competitions which last for 2–3 weeks, such as the Tour de France, the Giro de Italia or Vuelta Ciclista a Espana. Gruelling as these competitions are, the preparation required to complete them is as impressive as the events themselves. Daily training is a way of life for endurance athletes and so they should be aware of the best ways to restock their fuel stores.

Although research interest in the metabolic responses to exercise has grown exponentially throughout the last century, there were no research-based nutritional recommendations to guide athletes in their preparation for training and competition. In an attempt to redress the balance, an International Consensus Conference was convened in 1991 to review the scientific literature on the links between food, nutrition and sports performance (Devlin & Williams, 1991). The Consensus Conference concluded that the most significant influence on endurance capacity was the size of an athlete's pre-exercise carbohydrate stores, i.e. muscle and liver glycogen concentrations. The Consensus Conference recommended that athletes should eat a diet in which carbohydrate-containing foods provide between 60 and 70 % of their daily energy intake, fat should provide no more than 30 % and protein should provide the remainder of their energy requirements. The very high carbohydrate intakes were not intended to be part of the athletes' habitual diet but part of the short-term preparation for, and recovery from, heavy exercise.

The Consensus Conference also concluded that if athletes eat a wide variety of foods in sufficient quantity to cover their daily energy expenditure, then there are no benefits to be gained from supplementing their diets with additional vitamins and minerals (Devlin & Williams, 1991). The exceptions are those athletes who reduce their energy intake to lose body mass as part of a strategy to improve their performance. A reduction in their macronutrient intake will result in an inadequate intake of micronutrients. Young female athletes who reduce their food intake are at particular risk of receiving less than they need of Fe, Ca and folic acid. Furthermore, frequent attempts to 'diet' to compete at a lower body mass can lead to a range of eating disorders (Sundgot-Borgen, 1993).

Athletes tend to overestimate their need for protein and underestimate the importance of fluid balance. Even in the power sports, where strength is essential for success, the protein requirements of these athletes is only of the order of 1·7–2·0 g/kg body weight (BW; Lemon, 1991*b*). In contrast, endurance athletes require a daily protein intake of only 1·2–1·5 g/kg BW (Lemon, 1991*a*). Thus, endurance athletes can achieve these recommendations for protein intake without modifying their habitual diets.

Energy and nutrient intakes of endurance athletes

Nutritional analyses of diets of endurance athletes (for examples, see Tables 1 and 2; van Erp-Baart *et al.* 1989; Grandjean & Rudd, 1994; Hawley *et al.* 1995) show that their energy and carbohydrate intakes are greater than those of the population at large (Table 3; Gregory *et al.* 1990). It appears that sports have not evolved their own diets. The range of energy and macronutrient intakes reported for athletes in different sports generally reflects the overall energy demands of training and competition. There is some evidence that when sedentary people undertake endurance training for a prolonged period, they increase the amount of

Abbreviations: BW, body weight.

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carbohydrate in their diets (Janssen *et al.* 1989). However, the assessment of energy and nutrient intake is fraught with difficulties. The assessments use methods which range from dietary recall to week-long records of weighed food intake. All the methods used rely on the compliance of the athletes to provide a thorough description of what they eat and drink. Lower energy intakes than expected are a common feature of the results of nutritional surveys. The reasons are usually associated with under-reporting rather than under-eating (Livingstone *et al.* 1990). Black and colleagues (Black *et al.* 1991; Goldberg *et al.* 1991) suggest that one way of checking the validity of reported energy intakes is to express them as multiples of BMR of the individuals. The BMR can be calculated from equations derived from population studies (Food and Agriculture Organization/ World Health Organization/United Nations University, 1985). Values which are less than, for example, 1·3 or 1·4 times the BMR represent very low daily energy expenditures (Black *et al.* 1991) and are unlikely to accurately reflect the actual energy intake of healthy active and free-living individuals. The low energy intakes typically recorded by female endurance athletes may also be the result of under-recording. However, athletes are often eating less than expected because they are trying to achieve or maintain a lower body weight as a strategy to compete in lower weight classes or to enhance their performance in events in which they have to carry their body mass. Furthermore, athletes are very active during training, but they may lead very sedentary lives during the time between training sessions (van Erp-Baart *et al.* 1989). Although it is reassuring to achieve good reproducibility in studies on energy and nutrient intakes, the results may only reflect a consistently low energy intake rather than values which match energy expenditures (Rosetta *et al.* 1997).

Accepting these limitations, the largest energy intakes of athletes in endurance competitions are those of professional cyclists (Saris *et al.* 1989; Garcia-Roves *et al.* 1997). For example, the overall mean daily energy intake of five professional cyclists competing in the 22 d Tour de France was estimated to be 24·7 MJ, with a maximum value of 32·4 MJ achieved during the mountain stages of this 4000 km race. Daily carbohydrate intake during the race was approximately 850 g, representing 61 % of the average daily energy intake (Saris *et al.* 1989). These cyclists were able to maintain energy balance even though their daily energy expenditures are amongst the highest values recorded for sustained physical activity (4·3–5·2 × BMR). Similar results have been reported for ten cyclists competing in the Vuelta Ciclista a Espana which lasts 3 weeks and has no rest days (Garcia-Roves *et al.* 1997). Mean energy intake was 23·5 MJ and daily carbohydrate intake was 841 g, which was equivalent to 60 % of their energy intake. Average daily protein intake was 201 g, which was equivalent to 14·5 % of the daily energy intake.

The problem encountered by these professional endurance athletes is how best to consume all the food they require to maintain daily energy balance. Failure to maintain energy balance inevitably leads to premature

Table 3. Daily intakes of energy (MJ), carbohydrate, fat and protein of UK men and women, representative of the population at large (From Gregory *et al.* 1990)

Variable	Men	Women
Energy (MJ)	10·3	7·05
Carbohydrate: g	272	193
% energy intake	44·7	44·2
Fat: g	102·3	73·5
% energy intake	40·4	40·3
Protein: g	84·7	62·0
% energy intake	14·1	15·2

Table 1. Examples of daily intakes of energy (MJ), carbohydrate (CHO), fat and protein of well-trained male endurance athletes

			CHO		Fat		Protein		
	n	Energy (MJ)	g	% energy intake	g	% energy intake	g	% energy intake	Reference
Distance runners	10	12·7	396	49	115	34	128	17	Grandjean (1989)
Marathon runners	19	14·9	487	52	128	32	128	15	Burke *et al.* (1991)
Distance runners	50	13·3	417	53	116	33	114	14	Williams (1992)
Triathletes	25	17·2	627	60	127	27	134	13	Burke *et al.* (1991)

Table 2. Examples of daily intakes of energy (MJ), carbohydrate (CHO), fat and protein of well-trained female endurance athletes

			CHO		Fat		Protein		
	n	Energy (MJ)	g	% energy intake	g	% energy intake	g	% energy intake	Reference
Distance runners	18	9·0	296	55	62	29	86	16	van Erp-Baart *et al.* (1989)
Distance runners:									
Eumenorrheic	14	9·2	280	50	88·7	35	73·2	14	Rosetta *et al.* (1997)
Distance runners:									
Eumenorrheic	33	10·4	352	53	97	35	81	12	Deuster *et al.* (1986)
Distance runners	44	8·1	290	53	60	28	70	19	Williams (1992)

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retirement from the competition because daily competition leaves insufficient recovery time to make up the energy deficit. These endurance cyclists, therefore, eat carbohydrate snacks and drink carbohydrate–electrolyte solutions throughout the race which helps them achieve a daily carbohydrate intake of 10–12 g/kg BW (Saris *et al.* 1989; Garcia-Roves *et al.* 1997).

Diet and endurance performance

The reason for recommending high-carbohydrate diets is that fatigue during prolonged heavy exercise occurs when muscle glycogen stores are reduced to such low concentrations that they can no longer contribute to the high rate of ATP resynthesis. Thus, the glycogen-depleted fibres cannot contribute to overall muscle function and so exercise intensity must be reduced and eventually the athlete has to stop exercising completely. Increasing pre-exercise muscle glycogen stores improves endurance capacity during subsequent prolonged heavy exercise (for review, see Spriet & Peters, 1998). Although dietary carbohydrate loading before prolonged exercise has been shown to improve endurance capacity by as much as 40–50 % (Ahlborg *et al.* 1967; Bergstrom *et al.* 1967), such large improvements in endurance performance have not been reported. Endurance capacity is usually assessed as the time taken to exercise to exhaustion at a predetermined exercise intensity, whereas endurance performance is the time taken to complete a predetermined work-load on a cycle ergometer or run a predetermined distance.

In one of the first studies on the influence of carbohydrate loading on endurance performance, Karlsson & Saltin (1971) reported a 5·4 % improvement in running times for a 30 km cross-country race when their subjects increased their muscle glycogen concentrations before the race. Ten runners completed the 30 km race on two occasions, and although carbohydrate loading did not improve their choice of speed early in the race, it did allow them to maintain their chosen pace for longer than when they ran the race without carbohydrate loading. One of a number of interesting aspects of this study is that after carbohydrate loading the post-race muscle glycogen concentration of the runners was higher than their pre-race glycogen values when they consumed their normal mixed diet. This suggests that carbohydrate loading produced sufficient muscle and liver glycogen to allow the runners to sustain their optimum running speeds by delaying the onset of fatigue which normally accompanies low glycogen concentrations. Although the improvement in endurance performance was much less than improvements in endurance capacity following carbohydrate loading, even small improvements in performance times of elite athletes can make the difference between winning and losing.

In a more recent study, the influence of carbohydrate loading on running performance during a simulated 30 km race was conducted using a laboratory treadmill (Williams *et al.* 1992). One of the aims of this study was to determine at what point during the race runners began to show signs of fatigue and how this might be modified by dietary manipulation. The treadmill was instrumented so that the subjects controlled their own speeds using a lightweight hand-held switch (Williams *et al.* 1992). Changes in speed, time and distance elapsed were all displayed on a computer screen in full view of the subjects. The runners were divided into two groups after the first 30 km treadmill time trial. One group increased their carbohydrate intake during the 7 d recovery period, whereas the other group ate additional protein and fat in order to match the increased energy intakes of the carbohydrate group. Although there was no overall improvement in performance times for the two groups, the carbohydrate group ran faster during the last 10 km of the simulated race. Furthermore, eight of the nine runners in the carbohydrate group had faster times for 30 km than during their first attempt, and better times than the control group. Even though the carbohydrate group ran faster than the control group, after carbohydrate loading they had lower adrenaline concentrations. This was attributed to the carbohydrate loading and subsequent maintenance of normal blood glucose concentrations throughout the race. Noradrenaline concentrations increased, as expected, during the simulated 30 km races following normal dietary conditions and after carbohydrate loading.

Not all studies have reported clear benefits of carbohydrate loading on running performances. Sherman *et al.* (1981) found no differences in performance when a group of six well-trained endurance athletes completed three races over 20·9 km on an indoor 200 m track. Three different dietary procedures were used to prepare for the races: a low-carbohydrate diet followed by 3–4 d on a high-carbohydrate diet (low/high; 104 *v.* 542 g carbohydrate), a normal mixed diet followed by the same period on a high-carbohydrate diet (mixed/high; 352 *v.* 542 g carbohydrate), and a normal mixed diet for the whole of the preparatory period before the race (mixed/mixed 353 g carbohydrate). The running times for the three races were 83·5 min (low/mixed), 83·63 min (mixed/high), and 82·95 min (mixed/mixed). Both the carbohydrate loading procedures (low/high and mixed/high) increased muscle glycogen concentrations in the gastrocnemius muscles of the runners before the races. The subjects who consumed their normal mixed diet throughout the week before the race also showed increased muscle glycogen concentrations, but not to the same extent as in the carbohydrate-loading trials.

The fastest time was recorded when the runners simply tapered their training and consumed their normal mixed diets. Under these conditions the runners had lower pre-race muscle glycogen concentrations and used less glycogen during the race. It is worth noting that the pre-race muscle glycogen concentrations, even without carbohydrate loading, were higher than normal. The muscle glycogen concentrations of the subjects in the study reported by Sherman *et al.* (1981) were, therefore, more than sufficient to meet the demands imposed upon them by races lasting only 83 min. It is clear from this study, however, that well-trained runners need only taper their training in preparation for races of the half-marathon distance. This and other studies suggest that dietary carbohydrate loading only confers an advantage on well-trained athletes when they undertake exercise which lasts over 1 h (Pitsiladis *et al.* 1996; Hawley *et al.* 1997).

Carbohydrate and fluid intake during exercise

During prolonged submaximum exercise, dehydration contributes to the early onset of fatigue; therefore, endurance athletes are encouraged to drink throughout exercise. Dilute carbohydrate–electrolyte solutions appear to help off-set severe dehydration more effectively than water alone (for review, see Maughan, 1998). Furthermore, the carbohydrate content of these solutions contributes to energy production in active muscles and so it is not surprising that athletes are able to cycle (Coyle *et al.* 1986; Maughan *et al.* 1989) and run (Wilber & Moffatt, 1992; Tsintzas *et al.* 1996) for longer when they ingest these solutions throughout exercise.

Although performance during heavy exercise lasting 1 h or less does not benefit from carbohydrate loading, this does not appear to be the case when athletes drink carbohydrate–electrolyte solutions throughout exercise (Below *et al.* 1995; Jeukendrup *et al.* 1997; Millard-Stafford *et al.* 1997). The explanation for these improvements in performance cannot be based on the premise that the exogenous carbohydrate helps delay glycogen depletion, because the muscle glycogen stores of active or trained people are sufficient to cope with 1 h of exercise. In contrast, improvements in performance during races lasting more than about 2 h can be explained in terms of a delay in glycogen depletion as a consequence of drinking carbohydrate–electrolyte solutions throughout prolonged heavy exercise. Even so, the improvements in performance only begin to appear late in exercise (Millard-Stafford *et al.* 1992; Tsintzas *et al.* 1993). This is illustrated in Fig. 1 which shows the changes in running speeds during two treadmill races in which seven well-trained endurance athletes completed 42·2 km. On one occasion they drank a carbohydrate–electrolyte solution containing 55 g carbohydrate/l immediately before and throughout the simulated race, and on another occasion they drank a placebo (Tsintzas *et al.* 1995). One of the advantages of undertaking this laboratory study of endurance performance is that it provides more information about the physiological responses and demands of a marathon race than can be obtained from field studies. The energy expenditure of the endurance athletes during the marathon was on average 10 MJ, which amounts to 74 % of their daily energy intake (13·6 MJ). Although the importance of carbohydrate has been stressed, because of its limited supply, fat contributed an estimated 61 % and carbohydrate 39 % to overall energy expenditure during this treadmill marathon (Tsintzas *et al.* 1995).

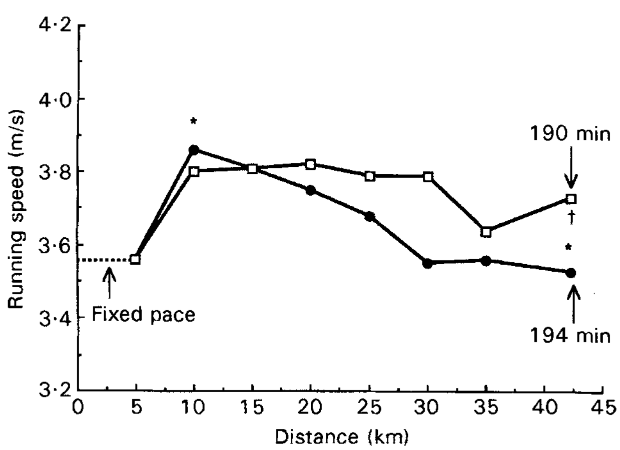

Fig. 1. Shows the running speeds of seven endurance athletes during two treadmill marathon races. Running speeds over the first 5 km were set at 70 % maximum oxygen uptake in order to compare the metabolic responses of the sports drink (55 g carbohydrate/l; □) with that of the placebo (●). For the remainder of the races the runners chose their own speeds. The difference between running speeds at 10 and 42·2 km was significant: $^{*}P < 0.05$. The differences in running speeds at 42·2 kg were significant: † $P < 0.05$.

The subjects in most of these studies performed exercise after an overnight fast and so their liver glycogen concentrations were low. Drinking carbohydrate–electrolyte solutions during prolonged exercise after an overnight fast may not improve performance when the subjects have prepared by carbohydrate loading for 2 d or more (Flynn *et al.* 1987). Similarly, when subjects eat a high-carbohydrate meal 3–4 h before prolonged heavy exercise, drinking a carbohydrate–electrolyte solution may not improve performance beyond what is achieved while drinking water alone (Madsen *et al.* 1996). Nevertheless, a carbohydrate–electrolyte solution ingested throughout prolonged exercise, which was performed 3 h after a high-carbohydrate breakfast, improved endurance capacity beyond what can be achieved following the same breakfast but ingesting water rather than a carbohydrate–electrolyte solution (Williams & Chryssanthopoulos, 1996).

Diet and recovery from exercise

In order to train or compete daily, endurance athletes have to recover over hours rather than days. Restocking liver and muscle glycogen stores is essential for successful recovery. Glycogen resynthesis can be achieved within the 24 h following prolonged exercise to exhaustion, but only when athletes eat a carbohydrate-rich diet (Keizer *et al.* 1987). Glycogen resynthesis begins immediately after exercise, and an essential contribution to this process is the exercise-induced increase in muscle membrane permeability to glucose. This increased permeability is a consequence of an increased insulin sensitivity and increased availability of glucose transporter proteins (GLUT 4) in the plasma membranes of skeletal muscles (Wallberg-Henriksson *et al.* 1988). Translocation of glucose into skeletal muscle fibres appears to be the event which dictates the rate of glycogen resynthesis rather than the sustained activation of glycogen synthase (*EC* 2.4.1.21; Nakatani *et al.* 1997).

The highest glycogen resynthesis rate occurs during the first few hours of recovery (for review, see Robergs, 1991). Blom *et al.* (1987) found that the maximum rate of glycogen resynthesis occurred when their subjects consumed the equivalent of 0·7 g carbohydrate/kg BW every 2 h during the first 6 h of recovery. This amounts to about 50 g carbohydrate every 2 h for a person weighing 70 kg. Drinking a carbohydrate solution, which provided the equivalent of 2 g/kg BW, immediately after prolonged

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heavy exercise produced a muscle glycogen resynthesis rate of about 5–6 mmol/kg per h (Ivy, 1991). This rate of glycogen resynthesis (about 5 %/h) is approximately 300 % greater than under conditions where no carbohydrate is ingested immediately after exercise. When carbohydrate intake was delayed for 2 h, the rate of glycogen resynthesis was 47 % slower than when carbohydrate was provided immediately after exercise. These and other studies are the basis for the recommendation that the optimum amount of carbohydrate needed for the rapid post-exercise glycogen resynthesis is about 1 g/kg BW, which should be consumed immediately after exercise and at 2 h intervals until meal-time (Ivy, 1991). However, the timing of the post-exercise ingestion of carbohydrate may not be as crucial as first reported. Parkin *et al.* (1997) found that there was no difference in the glycogen concentrations after 8 and 24 h of recovery when their subjects either consumed carbohydrate immediately after exercise or delayed it for 2 h into recovery. Nevertheless, drinking a carbohydrate solution immediately after exercise provides not only carbohydrate for glycogen resynthesis but it also begins the rehydration process (for review, see Maughan, 1998). Sports drinks appear to be more effective as rehydration agents than either water or some of the most popular soft drinks (Gonzalez-Alonso *et al.* 1992).

The type of carbohydrate in the recovery diet is also an important consideration for those who want to replace their muscle glycogen stores quickly. Kiens (1993) compared the muscle glycogen resynthesis rates when her subjects were fed on either high- or low-glycaemic-index foods. (The glycaemic index of a food is the area under the blood glucose curve following ingestion of 50 g of that food, expressed as a percentage of the area under the blood glucose curve following ingestion of 50 g glucose. The glycaemic index of glucose is assigned a value of 100.) Seven well-trained athletes were fed on a diet in which 70 % of their energy was obtained from either high- or low-glycaemic-index foods for 2 d after their muscle glycogen stores were reduced by prolonged cycling. The post-exercise diet of high-glycaemic-index foods produced a glycogen resynthesis rate which restored the muscle glycogen stores to 70 % of pre-exercise concentrations within 6 h, whereas the low-glycaemic-index high-carbohydrate diet restored muscle glycogen stores to only 34 % of their pre-exercise values.

Similar results were obtained by Burke *et al.* (1993) who fed their subjects on a recovery diet which provided them with the equivalent of 10 g carbohydrate/kg BW over a 24 h period. The recovery diet was divided into four equal meals, containing either high- or low-glycaemic-index carbohydrate foods. Muscle glycogen resynthesis was greater after the high-glycaemic-index carbohydrate meals than after the low-glycaemic-index meals. These studies contribute to the evidence which supports the recommendation that glycogen resynthesis after exercise is most rapid when athletes consume high-glycaemic-index carbohydrates.

Adding some protein to the carbohydrate solution increases the rate of post-exercise glycogen synthesis to a greater extent than can be achieved with a carbohydrate solution alone (Zawadzki *et al.* 1992). The addition of protein increases the concentration of plasma insulin to a greater extent than when only a carbohydrate solution is consumed after exercise. An increased insulin concentration will not only increase the transport of glucose into muscle cells, but will also help restore the K^+ balance across muscle membranes. A ratio of 3 : 1 for carbohydrate–protein supplement was used in these recovery studies but the optimum mixture of these two macronutrients has yet to be determined.

Glycogen resynthesis is delayed in skeletal muscle fibres that have experienced micro-trauma as a result of too much eccentric activity (O'Reilly *et al.* 1987). However, consuming carbohydrate (1 g/kg BW) immediately after exercise and 1 h later may decrease the breakdown in myofibrillar protein which normally occurs following repeated knee extensor exercise (Roy *et al.* 1997). This exercise is a common feature of strength training and so the obvious question is whether or not post-exercise carbohydrate ingestion will lead to a more rapid adaptation to this type of training.

Diet, recovery and performance

When several days separate periods of exercise or participation in sport, a normal mixed diet containing about 4–5 g carbohydrate/kg BW is sufficient to replace liver and muscle glycogen stores. However, daily training or competition makes considerable demands on the body's carbohydrate stores. Even when the daily carbohydrate intake is 5 g/kg BW, cycling or running for 1 h each day gradually delays the daily restoration of muscle glycogen stores (Pascoe *et al.* 1990). Increasing the carbohydrate intake to 8 g/kg BW per d may not be enough to prevent a significant reduction in muscle glycogen concentrations after five successive days of hard training (Kirwan *et al.* 1988). These studies underline the importance of prescribing adequate amounts of carbohydrate for athletes in training and justify the need for more frequent recovery days between periods of intense training.

We now know more about what factors influence the rate of muscle glycogen resynthesis than we know about the impact of restoring our carbohydrate stores on performance during subsequent exercise. Keizer *et al.* (1987) examined this question in a systematic way. They showed that muscle glycogen stores can be replenished in 22 h by administering either liquid or solid carbohydrates during the first 5 h of recovery. After the first 5 h, their subjects consumed foods which were consistent in composition and quantity with their normal diets. The amounts of carbohydrate ingested during the 22 h recovery period were 580 g for the liquid group and 602 g for the solid group. Before and after the recovery period, an incremental cycle ergometer test was used to assess the maximum physical work capacity of the subjects. Their maximum physical work capacity was 7 % lower after 24 h of recovery, even though their glycogen stores had returned to pre-exercise values. It appears, therefore, that under these conditions, the replenishment of muscle glycogen concentration alone is not sufficient to restore maximal work capacity. One additional practical observation from this study was that when the subjects were allowed to eat *ad libitum* after exercise, their muscle glycogen concentrations were significantly lower than when their food was prescribed and prepared for them.

Nevill *et al.* (1993) came to a similar conclusion to that of Keizer *et al.* (1987) after studying the influence of a high-carbohydrate recovery diet on the multiple sprint performance of a group of games players. Using a non-motorized treadmill, games players completed thirty maximal sprints of 6 s duration separated by a recovery period of 114 s. Between each sprint, the subjects walked and jogged on the treadmill. Mean power output decreased by 8·8 % over the thirty sprints. The recovery diet of the subjects was modified without changing their daily energy intakes. Their carbohydrate intakes were 322 g (4·6 g/kg BW), 80 g (1·1 g/kg BW) and 644 g (8·7 g/kg BW) for those consuming the normal mixed diet, the low-carbohydrate diet and the high-carbohydrate diet respectively. There were no overall differences in power output between each group after the 24 h, and all performances were poorer than on the day before. However, if only the first nine sprints on the second day are considered, then the high-carbohydrate group performed significantly better than the other two groups. It seems that during brief high-intensity exercise, performance may not be restored along with carbohydrate stores.

In contrast, endurance running capacity is restored after 1 d of recovery, when the daily carbohydrate and energy intake is increased. For example, when runners ate a high-carbohydrate diet (9 g/kg BW) after completing 90 min of treadmill running at speeds equivalent to 70 % maximum O_2 uptake, they were able to repeat this training run the following day, whereas runners who ate their normal mixed diets, with additional energy in the form of extra fat and protein, could only complete 78 % of the 90 min run (Fallowfield & Williams, 1993). Using the same high-carbohydrate recovery diet, six games players were able to improve on their previous day's performance in a prolonged intermittent high-intensity shuttle running test, whereas when they repeated the same test, on a different occasion, after eating a recovery diet consisting of their normal foods plus additional energy in the form of protein and fat, they were unable to even match their previous day's performance (Nicholas *et al.* 1997).

In summary, the present brief review has provided some of the evidence which suggests that athletes should eat a wide variety of foods to cover their daily energy expenditure and that more than half their daily energy intake should be derived from carbohydrates. Dietary strategies to ensure well-stocked stores of liver and muscle glycogen, before and after exercise, are the most effective nutritional contributions to improvements in the performance of endurance athletes.

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