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### **NUTRITION NEEDS FOR TEAM SPORT**

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#### **KEY POINTS**

1. High-carbohydrate, pre-exercise meals improve exercise capacity.
2. Carbohydrate-electrolyte drinks ingested during exercise are of benefit during competition and training.
3. Fluid ingestion during prolonged exercise helps delay the deterioration in motor skills.
4. Recovery is improved when about 50 g of carbohydrate are consumed immediately after prolonged exercise and at 1-h intervals thereafter.
5. During daily training or competition, recovery is likely to be improved when carbohydrate intake is increased to 10 g per kg body weight each day.
6. Rehydration is quickly achieved during recovery when athletes ingest fluids equivalent to at least 150% of the body weight lost during the exercise.

#### **INTRODUCTION**

There is a common belief that there are sport-specific diets. The truth is that there are only people-specific diets. The first nutritional requirement for athletes and their sports fans is a well-balanced diet that contains a wide range of foods and covers daily energy expenditure. As for the composition of this diet, health professionals recommend that it should be high in carbohydrate and low in fat (FAO/WHO, 1998). Ensuring that athletes follow these guidelines is the first step in the successful nutritional support for sports participation.

The focus of this brief review is the nutritional support for training, using soccer as an example of a team sport. It will, however, deal with nutrients rather than foods so it is important to recognize the essential contribution of a sports nutritionist or sports dietitian in translating the following nutritional strategies into real meals.

## PRE-GAME NUTRITION

It is now well recognized that a high-carbohydrate diet is a central part of the successful preparation for heavy training and competition (Coyle, 1991; Helge et al., 1996). The pre-exercise meal should consist of easy to digest, high carbohydrate foods and should be consumed 3 - 4 h before exercise. These high-carbohydrate pre-exercise meals improve endurance cycling and running capacity, and they are even more effective if a carbohydrate-electrolyte drink is also ingested throughout exercise (Chryssanthopoulos & Williams, 1997; Wright et al., 1991). However, those athletes who are unable to eat a meal 3 - 4 h before competition because of gastrointestinal disturbances caused by food remaining in the stomach during exercise will benefit from drinking small volumes of a well-formulated sports drink throughout exercise (Chryssanthopoulos et al., 1994).

Thomas et al (1991) suggested that there are performance benefits to be gained from eating carbohydrate foods with a low rather than high glycemic index (GI) before exercise. Low-GI carbohydrates, by definition, do not significantly raise plasma glucose and insulin concentrations after eating (Jenkins et al., 1981). The minimal perturbation of glucose homeostasis and slower digestion and absorption of low GI carbohydrates should cause a sustained and slower release of glucose into the circulation and minimize any insulin-induced reduction in plasma fatty acid concentrations before exercise. Logically, these effects might be expected to improve endurance performance.

Although Thomas et al. (1991) reported that low-GI carbohydrate (lentils) consumed 1 h before cycling to exhaustion resulted in a greater endurance capacity than when their subjects consumed the equivalent amount of carbohydrate as high-GI food (potatoes), this result has not been confirmed by more recent studies of cycling (Febbraio & Stewart, 1996) or running (Wee et al., 1998).

In the two cycling studies, the subjects consumed the test meals only 1 h before exercise, which is not the practice of athletes preparing for heavy training or competition. Eating

meals within an hour of exercise has the potential to cause gastrointestinal disturbances that may reduce exercise performance, especially during running, and is not recommended. Therefore, Wee et al. (1998) provided high and low-GI carbohydrate meals for their subjects 3 h before a treadmill run to exhaustion. Although there were marked differences in blood glucose and serum insulin concentrations during the 3 h after eating, there were no differences between the running times after the high-and-low GI meals (high GI: 111 min ; low GI: 113 min).

## DURING TRAINING AND COMPETITION

The benefits of drinking carbohydrate-electrolyte solutions during prolonged intermittent exercise of high intensity and brief duration have only recently been examined in well controlled experimental studies. However, there are some field studies that report the benefits of drinking carbohydrate solutions before soccer matches. For example, Muckle (1973) reported an increase in the number of goals scored by a soccer team during matches in the English soccer league when players supplemented their high-carbohydrate diets with a concentrated glucose syrup solution (46%). On the day before each game the players ate a high-carbohydrate diet, which included the glucose syrup solution. The same solution was also ingested 30 min before the start of play (Muckle, 1973). The team continued supplementing their pre-match diets with the glucose syrup solution for 20 matches and then continued without supplementation for the next 20 matches. The number of goals scored in the second half of the game increased and the number of goals conceded was less than during the subsequent games when glucose supplementation was withdrawn (Muckle, 1973). Unfortunately, the author did not report the dietary preparation of the players for the second block of 20 games when they were not given the glucose solution. Therefore, the team's better performances during the first 20 games of the season may have been the result of a number of influential factors, not the least of which was the dietary carbohydrate intake during the day before each

game.

In a more controlled field trial, Kirkendall et al. (1988) filmed a group of 10 collegiate soccer players during two soccer matches separated by one day. During one match the players drank 400 ml of either a carbohydrate solution (23 % CHO) or sweetened placebo before the game and the same volume at half time. The players who drank the carbohydrate solution ran about 40% more during the second half of the game than those who drank the placebo solution. A subsequent field study provided evidence to explain the improvement in the increased running capacity described by Kirkendall et al. When soccer players consumed 0.5 L of a 7% glucose solution 10 min before a practice match and the same volume again at half-time, they used 39% less muscle glycogen than did the players who drank a sweetened placebo (Leatt & Jacobs, 1989). As a consequence of this glycogen sparing, players would presumably be able to run longer before the onset of fatigue.

In an attempt to determine whether ingesting carbohydrate solutions improves the capacity for repeated bursts of sprinting for almost 2 h, we used a multiple sprint test described by Bangsbo et al. (1992). In our study, nine recreational runners on two occasions ran to exhaustion on a level treadmill that was programmed to alternate between speeds equivalent to 45%  $\text{VO}_2$  max and 80 - 90 %  $\text{VO}_2$  max for 10 s and 15 s, respectively (Nassis et al., 1998). The runners drank either a carbohydrate-electrolyte solution (6.9% CHO) or the same volume of a sweetened placebo immediately before (3 ml/kg body weight) and at 20 min intervals (2 ml/kg) throughout the run. There were no differences between the time to exhaustion during the carbohydrate trial (110.2 min) and the placebo trial (112.5 min), nor were there differences between the carbohydrate oxidation rates during the two trials. One possible explanation for the lack of differences between the two trials is that the intensity of the exercise reduced gastric emptying rate. Recovery between each high speed sprint was 10s of low-speed running, which may have been insuf-

ficient to allow adequate gastric emptying and hence the delivery of sufficient carbohydrate to the small intestine. The lack of difference in the carbohydrate oxidation rates provides some support for this explanation.

In a subsequent study, we more closely simulated the activity pattern and intensity experienced by soccer players in high-tempo games by designing a shuttle running test (Nicholas et al., 1995). The advantage of this test over a treadmill running test is that it includes a range of running speeds as well as acceleration, deceleration and frequent turning. In addition, two players can run alongside each other and so provide an element of support and competition. This test requires subjects to perform repeated 20-m shuttle runs at speeds dictated by an audio signal from a computer. In this two-part test, athletes first complete 75 min of running which involves the following sequence: 3 x 20 m at walking pace, 1 x 20 m sprint, 3 x 20 m at running speeds equivalent to 55%  $\text{VO}_2$  max and then 3 x 20 m at running speeds equivalent to 95%  $\text{VO}_2$  max. This pattern of exercise is continued for 15 min and followed by 3 min of rest. Five of these blocks of activity (and rest periods) are repeated before the subjects proceed on to the second part of the test in which the subjects run the 20 m at alternating speeds of 55%  $\text{VO}_2$  max and 95%  $\text{VO}_2$  max to fatigue. The  $\text{VO}_2$  max and the required running speeds for each subject during the test protocol are determined in advance using a multi-stage shuttle running test to exhaustion (Ramsbottom et al., 1988). The time to fatigue during the second part of the test is used as a measure of the athlete's sprint capacity. The total distance covered during the test is between 10 and 14 km, and the energy expenditure is required is roughly 1400 kcal, which is similar to the values reported in field studies.

Using this protocol, we examined the performance benefits of drinking a carbohydrate-electrolyte solution throughout intermittent free-running exercise (Nicholas et al., 1995). Seven athletes drank a carbohydrate-electrolyte solution (6.9%) or sweetened placebo, immediately before (5 ml/kg) the protocol and during the 3-min breaks (2 ml/kg) between each 15 min block of exer-

cise. They were able to run for 2.2 min longer during the second part of the test when they drank the carbohydrate-electrolyte solution than when they drank the placebo (CHO: 8.9 min; Placebo: 6.7 min) (Nicholas et al., 1995).

To clarify the mechanisms for the improved running capacity in intermittent sprints, we undertook an additional study in which the 90-min was made up of six rather than five 15-min blocks of the same intermittent exercise. Six athletes performed the 90-min protocol on two occasions separated by 7 d. They drank either the carbohydrate-electrolyte solution or the sweetened placebo in the same amounts as mentioned above. We found that less muscle glycogen was used when the subjects drank the carbohydrate-electrolyte solution than when they drank equal amounts of a sweetened placebo (Nicholas et al., 1994). A reduction in the rate of glycogen degradation may delay the onset of fatigue, which may help explain the greater running capacity of the athletes when they drank a carbohydrate-electrolyte solution. Glycogen sparing has also been reported during prolonged cycling and running (Tsintzas & Williams, 1998). Therefore, it is reasonable to conclude that drinking a well-formulated sports drink throughout exercise will help to sustain high-intensity exercise and so gain maximal benefit from a training session.

Because soccer players' skills deteriorate as they tire, we wished to know whether or not fluid ingestion can prevent this deterioration late in a game. Therefore, we designed a soccer-specific skill test to evaluate the influence of fatigue on performance (McGregor et al., 1997). Nine semi-professional soccer players were required to dribble a soccer ball ten times in and out of a line of six cones, 3-m apart, as fast as possible. They performed this test before and after the 90-min shuttle-run protocol on two occasions. On one occasion they drank water, and on another they were not given any fluid. Their performance on the dribbling skill test was significantly worse than during the control test after performing the 90-min protocol without fluid intake. However, when the soccer players drank water

during the rest periods in the shuttle-run protocol there was no deterioration in their performance on the skill test. Fluid ingestion lowers the perceived rate of exertion and improves endurance running capacity (Fallowfield et al., 1996). The improved performance may be a consequence of a reduction in catecholamine secretion and, hence, in carbohydrate metabolism, which in turn helps delay the onset of fatigue (Hargreaves et al., 1996). However, whether or not this shift from carbohydrate to fat metabolism in skeletal muscle is accompanied by changes in skill performance, remains to be established.

Although the weight of the available evidence supports a recommendation that team sport participants should drink a well-formulated sports drink throughout the game, often the rules of the sport hinder the implementation of this recommendation. Therefore, when the only opportunity for drinking is during a time-out or an unscheduled stoppage in play, it is essential to ensure that each player has ready access to prescribed amounts of fluid so that opportunities to drink are not missed.

## RECOVERY

The nutritional support for athletes to train hard and recover quickly is probably, next to the health benefits of a balanced diet, the most important contribution of sports nutrition to an athlete's performance. When several days separate periods of training or competition in sport, a normal mixed diet containing carbohydrate in amounts equivalent to about 4 - 5 g/kg body weight is sufficient to replace glycogen stores in liver and muscle. However, daily training or competition make considerable demands on the body's carbohydrate stores. For example, when the daily carbohydrate intake is 5 g/kg, cycling or running for an hour each day may gradually delay the daily restoration of muscle glycogen stores (Pascoe et al., 1990). Even increasing the carbohydrate intake to 8 g/kg per day may not be enough to prevent a significant reduction in muscle glycogen concentrations after five successive days of hard training (Kirwan et al., 1988).

## MUSCLE GLYCOGEN

Close examination of post-exercise glycogen resynthesis in muscle shows the rate is much greater during the first few hours of recovery than it is several hours later (Piehl, 1974). Subsequent studies on the amount and timing of carbohydrate intake on the glycogen resynthesis report that ingesting 0.7-1.3 g of carbohydrate per kg body weight immediately after exercise and at 2 h intervals for 4-6 h increases the rate of resynthesis to 5-8 mmol of glycogen per kg muscle in the first 2 h after exercise (Blom et al., 1987; Ivy et al., 1988; Ivy, 1991). An even more rapid rate of glycogen resynthesis can be achieved by consuming carbohydrate in smaller amounts (0.4 g/kg body weight), every 15 min over 4 h (Doyle et al., 1993). Although this particular nutritional strategy may be impractical for longer recovery periods, it does offer an option for those athletes who have only a few hours between competition or training sessions.

As for the type of carbohydrates consumed during recovery, the choice should be those that have a high glycemic index (see Sports Science Exchange 64, 1997). High GI carbohydrates can lead to a more rapid glycogen resynthesis during the first 24 h of recovery than do low GI carbohydrates (Burke et al., 1993; Kiens, 1993; Parkin et al., 1997).

The importance of overall energy and carbohydrate in recovery feedings has been demonstrated in a study on recovery from a resistance-training session. The rates of muscle glycogen resynthesis were compared in 10 healthy men who completed a resistance training session on three occasions and consumed three types of beverages. Immediately after the training sessions, and again 1 h into the 4-h recovery period, the well-trained men consumed either a carbohydrate drink (1 g/kg body weight), an isoenergetic drink containing carbohydrate, protein, and fat (66% carbohydrate, 23% protein, 11% fat) or a placebo solution (Roy & Tarnopolsky, 1998). Similar rates of glycogen resynthesis were recorded for both the carbohydrate-only trial and the carbohydrate, protein, and fat trial, both which were about seven fold greater than in the placebo trial.

## INTERMITTENT, HIGH-INTENSITY PERFORMANCE

Participation in multiple-sprint team sports such as soccer makes significant demands on the muscle glycogen concentrations of players. A close association has been shown between the muscle glycogen concentrations of players and their physical activity during a soccer match (Saltin, 1973). For example, players with low muscle glycogen concentrations at the start of the game covered less ground during the game than did players who began the game with well-stocked carbohydrate stores (Saltin, 1973). Increasing the carbohydrate consumption of soccer players before a match and at half-time improved their running capacity during the second half of the game (Leatt & Jacobs, 1989). These and other studies of soccer players confirm the need to begin a match with well-filled glycogen stores (Jacobs et al., 1982).

In most multiple-sprint sports, players rarely sprint for more than 5 or 6 s on any one occasion. However, exercise of maximal intensity for 5 or 6 s is not limited by the availability of muscle glycogen in well-fed active people. During 6 s of maximal sprinting, half of the ATP production is derived from anaerobic glycogenolysis, and the other half is from the breakdown of phosphocreatine (Boobis et al., 1982). Using maximal sprints of 6 s duration, we examined the influence of different carbohydrate diets on the recovery of sprinting ability (Nevill et al., 1993). Eighteen well-trained games players completed 30 maximal 6-s sprints on a non-motorized treadmill on two occasions separated by 24 h. Each sprint was separated by a recovery period of 114 s, during which the subjects walked and jogged on the treadmill. Mean power output decreased by 8% over the 30 sprints. After the 30 sprints, which were completed in 60 min, the subjects were assigned to one of three dietary groups, normal carbohydrate (mixed diet), low carbohydrate, and high carbohydrate. In this study, the composition of the diets was modified without changing the normal energy intakes of the subjects. Their 1-d carbohydrate intakes were 322 g (4.6 g/kg body weight), 80 g (1.1 g/kg) and 644 g (8.7 g/kg) for those consuming the normal mixed diet, the low carbohydrate diet, and the

high carbohydrate diet, respectively. After the 24-h recovery period, the subjects tried to improve their power output during each of the 30 sprints. However, there were no improvements in mean power output compared with the values obtained a day earlier. Furthermore, the mean power outputs over the 30 sprints were lower than the values recorded a day earlier.

Peak power output generated during cycling or sprint running is about two to three times greater than the maximum power output generated during a  $\text{VO}_2$  max test. Peak power output can only be achieved when phosphocreatine stores are fully stocked, and so it is not surprising that recovery of peak power is delayed until phosphocreatine resynthesis is complete (Bogdanis et al., 1996). It takes almost 60 s for half of the depleted phosphocreatine stores to be resynthesized (Bogdanis et al., 1995). Therefore, it is reasonable to conclude that the gradual fall in power output during the 30 treadmill sprints on the first day in the study reported by Neville et al. (1993) was probably the result of an inadequate recovery of phosphocreatine stores between sprints. An increase in carbohydrate intake during the recovery period appeared to have little effect on this process. Furthermore, the energy intake of the athletes was not increased during the recovery period to cover the additional energy expenditure of the 60 min of demanding exercise. On reflection, a better test of the efficacy of the high-carbohydrate recovery diet is an open-ended one in which the number of 6-s sprints completed, rather than power output per se, is assessed. This approach was later adopted by Balsom (1995) in a cycling study. He used an exercise intensity that was approximately 80% of peak power output for their subjects and reported a significant improvement in the number of sprints following 2 d on a high carbohydrate diet.

The results of the Balsom study confirmed an earlier running study reported by Bangsbo et al. (1992). In this study, seven professional soccer players were randomly assigned to two diet-and-exercise trials. In one trial they ate a mixed diet that was similar to their normal diet (39% carbohydrate, 355 g/d) and in the other

they ate a high-carbohydrate diet (65% carbohydrate, 602 g/d) for two days after a soccer match in the Danish First Division and before a running test to exhaustion. The running test consisted of two parts; the first involved 46 min of field running and calisthenics; after a 14-min rest, the soccer players then moved into the laboratory and ran to exhaustion on a treadmill. After performing seven, 5-min periods of high- and low-speed running, the duration of the alternating high- and low-speed runs was reduced to 15-s and 10-s, respectively. The soccer players completed 17.1 km of running following the 2 d on the high-carbohydrate diet, whereas on the lower-carbohydrate diet the total running distance was 0.9-km less.

Further confirmation of the value of adopting a high-carbohydrate diet as part of a strategy for successful recovery from prolonged intermittent high-intensity exercise has been provided by Nicholas et al. (1997) using the shuttle-run protocol. Six athletes performed the shuttle run on four occasions separated by one week. On one occasion they completed the shuttle-run test, and their times to exhaustion were recorded; thereafter, they ate a high-carbohydrate diet and repeated the shuttle-run protocol 22 h later. The high-carbohydrate recovery diet was accompanied by an increase in energy intake of the subjects from their normal daily intake of 2600 kcal to 3818 kcal. Carbohydrate intake was increased from a daily average intake of 381 g to 705 g for the recovery period. On the other occasion they again performed the shuttle-run protocol and during the 22-h recovery, they ate a mixed diet that contained their normal amounts of carbohydrate (381 g) and additional protein and fat to ensure that their energy intakes were the same as that of the high-carbohydrate diet. When the subjects ate the mixed diet, they were unable to match their previous day's performance. However, when they ate the high-carbohydrate diet, they ran for 3.3 min longer than on the previous day. When compared with average value for performance after the recovery diet that contained only their normal amount of carbohydrate, their improvement on the high-carbohydrate diet was an impressive additional 7.4 min of running (Nicholas et al., 1997).

## **IN SUMMARY**

Adopting nutritional strategies within the broad recommendations for healthy eating will often improve exercise tolerance and help team-sport athletes recover rapidly from training and competition. High-carbohydrate meals 3 to 4 h before heavy exercise should result in greater exercise capacity than fasting or eating pre-exercise meals containing only modest amounts of carbohydrates. During prolonged training sessions or competition, there are likely to be performance benefits gained from drinking a well-formulated sports drink in small quantities (150 ml) at 20 min intervals. Recovery begins immediately after exercise ends, so it is essential to take advantage of the opportunity to increase the rate of glycogen restoration by consuming about 50 g of carbohydrate at the beginning of recovery and every 1 to 2 h up to the next meal. The dietary carbohydrate intake for team-sport athletes should be prescribed when recovery must be completed within 24 h or less. The carbohydrate intake should be increased to about 10 g/kg body weight during the 24-h recovery period and should include mainly high-glycemic-index carbohydrate foods. During recovery periods limited to only a few hours, rehydration and some refueling can be achieved by ingesting carbohydrate-electrolyte solutions in volumes of at least 150% of the exercise-induced loss in body weight (Shirreffs et al., 1996).

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## PRACTICAL GUIDELINES FOR TEAM SPORTS PLAYERS

### Introduction

The first priority is good health, the basis of which is a well-balanced diet consisting of a wide range of foods in sufficient quantities to cover the daily energy needs (maintenance or growth, training, and recovery). Carbohydrate-containing foods should provide about 55 to 60% of daily energy intake with fat providing not more than 30% and protein about 15%. Short term nutritional strategies can be adopted by athletes to prepare for, to participate in and to recover from competition and training. The following are some of the general principles and strategies.

### Before Exercise: Pre-event (competition or training) meals

#### Consume:

- Easy to digest, high-carbohydrate foods
- 3 hours before the exercise

#### If an athlete has pre-game gastrointestinal discomfort, try these options:

- Eat small amounts of food more frequently before exercise
- Try moderate- to low-glycemic foods 4 hours or more ahead of exercise (see SSE #64, 1997)
- Avoid foods and instead use a well-formulated sports drink before exercise  
500 mL, or about 16 oz, two hours before, and another 250 mL, or about eight oz, 15-30 min before exercise

In general, athletes need to determine through their own experiences what foods and quantities help, not hinder, their performance.

### During Exercise

- Drink a well-formulated sports drink throughout exercise. Carbohydrates in the beverage can help delay fatigue and the fluid helps prevent dehydration.
- Guidelines for fluid intake are 600-1200 mL (20 to 40 oz) per hour.
- In sports in which there is little opportunity to drink, develop strategies to ensure that players do have access to fluid during official and unofficial 'time outs.'

### After Exercise

- Drink a well-formulated sports drink. Sports drinks providing sodium help ensure complete rehydration; and the carbohydrate stimulates the rapid replenishment of muscle glycogen stores.
- The guideline for fluid volume to ensure rehydration when there is limited time for recovery is 150% of the fluid lost. In other words, 24 oz (1.5 lb) per one pound of body weight lost during exercise, or 1.5 liters per kg of body weight lost during exercise
- To help replace muscle carbohydrate stores, start carbohydrate intake immediately after exercise and continue at 2-hr intervals until the next meal. Attempt to ingest 50 g per hour.  
Use a sports drink to achieve this if rehydration status is also a goal.  
Use a high-carbohydrate energy drink if hydration is adequate.
- Total carbohydrate intake over the next 24 hours should be about 9 to 10 g per kg of body weight (4 to 4.5 g per lb)
- Choose high-glycemic index foods (see SSE #64, 1997)

Effective recovery after each game in tournaments is essential to ensure advancing to the next round of competition and eventually to the final championship. Voluntary eating according to hunger and appetite alone will generally not result in adequate recovery. A team dietitian can prescribe meals and snacks for each team member to ensure their recovery and readiness to play. Flexibility will be required to provide adequate meals. For example, during some tournaments, games are played in the evening and thereby force the main meal of the day to be very late. A more reasonable approach is to schedule an easy-to-digest carbohydrate meal after the game and to have a larger meal for breakfast the following day. These and other nutritional strategies should be a central part of a team's game plan for successful competition.