Nutrition and Football

The FIFA/FMARC Consensus on Sports Nutrition

Edited by
R.J. Maughan

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Introduction

In 1993, a small group of experts gathered at FIFA house in Zurich, Switzerland, to discuss the role of nutrition in the performance of soccer players. Their discussions, under the guidance of Professors Clyde Williams and Bjorn Ekblom, represented the state of knowledge in the field at that time, and their recommendations were widely applied throughout the game. Indeed, the suggestion that players would benefit from better access to fluids during matches led to a change in the rules relating to the provision of drinks during games. One recurring theme throughout those discussions was the limited information specific to the game of soccer – in many cases, extrapolation had to be made from laboratory studies of cycling or running, usually involving exercise at constant power output. The inadequacies of this information were clearly recognized. Nonetheless, the information generated at this meeting was widely disseminated and was used by many players, clubs and national teams as the basis of their nutritional strategies.

Since that meeting, a lot of new information has emerged, much of it using exercise models that are more representative of the game of soccer. Intermittent shuttle running tests of various descriptions have been used to simulate activity patterns of players in competition, and soccer-specific skills tests have been used to evaluate performance after various nutritional interventions. New techniques, such as remote monitoring of heart rate and body temperature, have allowed the assessment of physiological strain with much better time resolution than before, while computerized motion analysis systems and the use of GPS technology have refined the study of movement patterns of individual players.

Completely new areas of study have emerged, including the application of molecular biology to assess the role of diet in modulating and promoting the adaptations taking place in muscle in response to training. There has been a growing recognition that the stress of frequent competition, especially in the top players, where games for club and country impose special demands, can lead to a greater risk of illness and under-performance. Again, the foods that a player chooses will influence their ability to cope with these demands. It is also increasingly recognized that the brain plays a vital role in the fatigue process, and strategies that target this central fatigue can help sustain performance, especially in the later stages of the game when deterioration in function can affect the match outcome and also the risk of injury.

Recognizing these new developments, another Consensus Conference was convened at FIFA House at the end of August 2005. With the support of FIFA and F-MARC (the FIFA Medical Assessment and Research Centre), a group of international experts spent three days reviewing the evidence relating to nutrition and soccer. Their discussions resulted in the preparation of a short Consensus Statement. The evidence on which that statement is based is presented here as a series of scientific papers, each subjected to the scrutiny of the assembled experts.

From the information presented, it was clear that the nutritional goals of soccer players at every level of the game can be achieved by using normal foods. It was also very clear that the foods that a player chooses will influence the effectiveness of the training programme, and can also decide the outcome of matches. A varied diet, eaten in amounts sufficient to meet the energy needs, should supply the whole range of essential nutrients in adequate amounts. In a few exceptional situations, the targeted use of a few supplements may be necessary, as, for example, in the case of iron-deficiency anaemia where iron supplements may meet the short-term need while an appropriate dietary solution is identified and implemented. The conference also recognized that there are special needs of the female player and of the young player, and recognized too that more information on these special populations is urgently needed. The needs of the referees were not forgotten, and the importance of the decisions made by the referee, especially late in the game when some fatigue is inevitable, was highlighted.

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Consensus Statement

Nutrition for football: The FIFA/F-MARC Consensus Conference

Soccer players can remain healthy, avoid injury and achieve their performance goals by adopting good dietary habits. Players should choose foods that support consistent, intensive training and optimize match performance. What a player eats and drinks in the days and hours before a game, as well as during the game itself, can influence the result by reducing the effects of fatigue and allowing players to make the most of their physical and tactical skills. Food and fluid consumed soon after a game and training can optimize recovery. All players should have a nutrition plan that takes account of individual needs.

The energetic and metabolic demands of soccer training and match-play vary across the season, with the standard of competition and with individual characteristics. The typical energy costs of training or match-play in elite players are about 6 MJ (1500 kcal) per day for men and about 4 MJ (1000 kcal) per day for women. Soccer players should eat a wide variety of foods that provide sufficient carbohydrate to fuel the training and competition programme, meet all nutrient requirements, and allow manipulation of energy or nutrient balance to achieve changes in lean body mass, body fat or growth. Low energy availability causes disturbances to hormonal, metabolic and immune function, as well as bone health. An adequate carbohydrate intake is the primary strategy to maintain optimum function. Players may require 5–7 g of carbohydrate per kilogram of body mass during periods of moderate training, rising to about $10 g \cdot kg^{-1}$ during intense training or match-play.

Nutritional interventions that modify the acute responses to endurance, sprint and resistance training have the potential to influence chronic training adaptations. The everyday diet should promote strategic intake of carbohydrate and protein before and after key training sessions to optimize adaptation and enhance recovery. The consumption of solid or liquid carbohydrate should begin during the first hour after training or match-play to speed recovery of glycogen. Consuming food or drinks that contain protein at this time could promote recovery processes.

Match-day nutrition needs are influenced by the time since the last training session or game. Players should try to ensure good hydration status before kick-off and take opportunities to consume carbohydrate and fluids before and after the game according to their nutrition plan. Fatigue impairs both physical and mental performance, but the intake of carbohydrate and other nutrients can reduce the negative effects of fatigue. Training for and playing soccer lead to sweat loss even in cool environments. Failure to replace water and electrolyte losses can lead to fatigue and the impaired performance of skilled tasks. Breaks in play currently provide opportunities for carbohydrate and fluid intake, and may not be adequate in some conditions. Soccer is a team sport, but the variability in players' seating responses dictates that monitoring to determine individual requirements should be an essential part of a player's hydration and nutrition strategy.

There is no evidence to support the current widespread use of dietary supplements in soccer, and so the indiscriminate use of such supplements is strongly discouraged. Supplements should only be taken based on the advice of a qualified sports nutrition professional.

Female players should ensure that they eat foods rich in calcium and iron within their energy budget. Young players have specific energy and nutrient requirements to promote growth and development, as well as fuelling the energy needs of their sport. Many female and youth players need to increase their carbohydrate intake and develop dietary habits that will sustain the demands of training and competition.

Players may be at increased risk of illness during periods of heavy training and stress. For several hours after heavy exertion, the components of both the innate and adaptive immune system exhibit suppressed function. Carbohydrate supplementation during heavy exercise has emerged as a partial countermeasure.

Heat, cold, high altitude and travel across time zones act as stressors that alter normal physiological function, homeostasis, metabolism and whole-body nutrient balance. Rather than accepting performance decrements as inevitable, well-informed coaches and athletes should plan strategies for training and competition that offset environmental challenges.

Alcohol is not an essential part of the human diet. Recovery and all aspects of performance could be impaired for some time after the consumption of alcohol. Binge drinking should be avoided at all times.

The needs of the referee and assistant referee are often overlooked, but high standards of fitness and decision making are expected of all officials. At every standard of competition, training regimens and nutritional strategies, including fluid intake during the game, should be similar to those followed by players.

Talent and dedication to training are no longer enough to ensure success in soccer. Good nutrition has much to offer players and match officials, including improved performance, better health and enjoyment of a wide range of foods.

Zurich, 2 September 2005

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1 Physical and metabolic demands of training and match-play in the elite football player

JENS BANGSBO, MAGNI MOHR AND
PETER KRUSTRUP

In soccer, the players perform intermittent work. Despite the players performing low-intensity activities for more than 70% of the game, heart rate and body temperature measurements suggest that the average oxygen uptake for elite soccer players is around 70% of maximum ($\dot{V}O_{2max}$). This may be partly explained by the 150–250 brief intense actions a top-class player performs during a game, which also indicates that the rates of creatine phosphate (CP) utilization and glycolysis are frequently high during a game. Muscle glycogen is probably the most important substrate for energy production, and fatigue towards the end of a game may be related to depletion of glycogen in some muscle fibres. Blood free-fatty acids (FFAs) increase progressively during a game, partly compensating for the progressive lowering of muscle glycogen. Fatigue also occurs temporarily during matches, but it is still unclear what causes the reduced ability to perform maximally. There are major individual differences in the physical demands of players during a game related to physical capacity and tactical role in the team. These differences should be taken into account when planning the training and nutritional strategies of top-class players, who require a significant energy intake during a week.

Keywords: Match-play activity pattern, substrate utilization, muscle metabolites, fatigue, recovery after matches, training intensity

Introduction

Since the last FIFA conference on nutrition in soccer in 1994, soccer at the elite level has developed and much research regarding match performance and training has been conducted. It is also clear that science has been incorporated to a greater extent in the planning and execution of training. Earlier scientific studies focused on the overall physiological demands of the game, for example by performing physiological measurements before and after the game or at half-time. As a supplement to such information, some recent studies have examined changes in both performance and physiological responses throughout the game with a special focus on the most demanding activities and periods. New technology has made it possible to study changes in match performance with a high time resolution. Another aspect to have received attention in practical training is information regarding individual differences in the physical demands to which players are exposed in games and training. These differences are not only related to the training status of the players and their playing position, but also to their specific tactical roles. Thus, some top-class clubs have integrated the tactical and physical demands of the players into their fitness training.

This review addresses information on the demands of the game at a top-class level and provides insights into training at the elite level. Thus, it should form the basis for deciding nutritional strategies for these players. The review deals mainly with male players, but at relevant points information about female players is provided.

Match activities

Many time–motion analyses of competitive games have been performed since the first analysis of activities in the 1960s (Bangsbo, 1994; Bangsbo, Nørregaard, & Thorsøe, 1991; Krustrup, Mohr, Ellingsgaard, & Bangsbo, 2005; Mayhew & Wenger, 1985; Mohr, Krustrup, & Bangsbo, 2003; Reilly & Thomas, 1979; Rienzi, Drust, Reilly, Carter, & Martin, 1998; Van Gool, Van Gerven, & Boutmans, 1988). The typical distance covered by a top-class outfield player during a match is 10–13 km, with midfield players covering greater distances than other outfield players. However, most of this distance is covered by walking and low-intensity running, which require a limited energy turnover. In terms of energy production, the high-intensity exercise periods are important. Thus, it is clear that the amount of high-intensity exercise separates top-class players from players of a lower standard. In one study, computerized time–motion analysis demonstrated that international players performed 28% more ($P < 0.05$) high-intensity running (2.43 vs. 1.90 km) and 58% more sprinting (650 vs. 410 m) than professional players of a lower standard (Mohr *et al.*, 2003). It should be emphasized that the recordings of high-intensity running do not include a number of energy-demanding activities such as short accelerations, tackling, and jumping. The number of tackles and jumps depends on the individual playing style and position in the team, and at the highest level has been shown to vary between 3 and 27 and between 1 and 36, respectively (Mohr *et al.*, 2003). Most studies have used video analysis followed by manual computer analysis to examine individual performance during a match. New developments in technology have allowed the study of all 22 players during each one-sixth of a second throughout a match, and the systems are used by many top teams in Europe. There are reasons to believe that in the future such systems will provide significant additional information and will soon find their way into scientific research. For example, using a high time resolution, Bangsbo and Mohr (2005) recently examined fluctuations in high-intensity exercise, running speeds, and recovery time from sprints during several top-class soccer matches. They found that sprinting speed in games reached peak values of around $32\,\text{km}\cdot\text{h}^{-1}$ and that sprints over more than 30 m demanded markedly longer recovery than the average sprints (10–15 m) during a game.

There are major individual differences in the physical demands of players, in part related to his position in the team. A number of studies have compared playing positions (Bangsbo, 1994; Bangsbo *et al.*, 1991; Ekblom, 1986; Reilly & Thomas, 1979). In a study of top-class players, Mohr *et al.* (2003) found that the central defenders covered less overall distance and performed less high-intensity running than players in the other positions, which probably is closely linked to the tactical roles of the central defenders and their lower physical capacity (Bangsbo, 1994; Mohr *et al.*, 2003). The full-backs covered a considerable distance at a high-intensity and by sprinting, whereas they performed fewer headers and tackles than players in the other playing positions. The attackers covered a distance at a high intensity equal to the full-backs and midfield players, but sprinted more than the midfield players and defenders. Furthermore, Mohr *et al.* (2003) showed that the attackers had a more marked decline in sprinting distance than the defenders and midfield players. In addition, the performance of the attackers on the Yo-Yo intermittent recovery test was not as good as that of the full-backs and midfield players. Thus, it would appear that the modern top-class attacker needs to be able to perform high-intensity actions repeatedly throughout a game.

The midfield players performed as many tackles and headers as defenders and attackers. They covered a total distance and distance at a high-intensity similar to the full-backs and attackers, but sprinted less. Previous studies have shown that midfield players cover a greater distance during a game than full-backs and attackers (Bangsbo, 1994; Bangsbo *et al.*, 1991; Ekblom, 1986; Reilly & Thomas, 1979). These differences may be explained by the development of the physical demands of full-backs and attackers, since, in contrast to earlier studies (Bangsbo, 1994), Mohr *et al.* (2003) observed that players in all team positions experienced a significant decline in high-intensity running towards the end of the match. This indicates that almost all elite soccer players utilize their physical capacity during a game. Individual differences are not only related to position in the team. Thus, in the study by Mohr *et al.* (2003), within each playing position there was a significant variation in the physical demands depending on the tactical role and the physical capacity of the players. For example, in the same game, one midfield player covered a total distance of 12.3 km, with 3.5 km being covered at a high intensity, while another midfielder covered a total distance of 10.8, of which 2.0 km was at a high intensity. The individual differences in playing style and physical performance should be taken into account when planning the training and nutritional strategy.

Aerobic energy production in soccer

Soccer is an intermittent sport in which the aerobic energy system is highly taxed, with mean and peak heart rates of around 85 and 98% of maximal values, respectively (Ali & Farrally, 1991; Bangsbo, 1994; Ekblom, 1986; Krustrup *et al.*, 2005; Reilly & Thomas, 1979). These values can be "converted" to oxygen uptake using the relationship between heart rate and oxygen uptake obtained during treadmill running (Bangsbo, 1994; Esposito *et al.*, 2004; Krustrup & Bangsbo, 2001). This appears to be a valid method, since in studies in which heart rate and oxygen uptake (by the so-called K_4 apparatus) have been measured during soccer drills, similar heart rates have been observed for a given oxygen uptake as found during treadmill running (Castagna *et al.*, 2005; Esposito *et al.*, 2004). However, it is likely that the heart rates measured during a match lead to an overestimation of the oxygen uptake, since such factors as dehydration, hyperthermia, and mental stress elevate the heart rate without affecting oxygen uptake. Nevertheless, with these factors taken into account, the heart rate measurements during a game seem to suggest that the average oxygen uptake is around 70% $\dot{V}O_{2max}$. This suggestion is supported by measurements of core temperature during a soccer game. Core temperature is another indirect measurement of energy production during exercise, since a linear relationship has been reported between rectal temperature and relative work intensity (Saltin & Hermansen, 1966). During continuous cycling exercise at 70% $\dot{V}O_{2max}$ with an ambient temperature of 20°C, the rectal temperature was 38.7°C. In soccer, the core temperature increases relatively more compared with the average intensity due to the intermittent nature of the game. Hence, it has been observed that at a relative work rate corresponding to 60% of $\dot{V}O_{2max}$, the core temperature was 0.3°C higher during intermittent than continuous exercise (Ekblom *et al.*, 1971). Nevertheless, core temperatures of 39–40°C during a game suggest that the average aerobic loading during a game is around 70% $\dot{V}O_{2max}$ (Ekblom, 1986; Mohr *et al.*, 2004b; Smodlaka, 1978).

More important for performance than the average oxygen uptake during a game, may be the rate of rise in oxygen uptake during the many short intense actions. A player's heart rate during a game is rarely below 65% of maximum, suggesting that blood flow to the exercising leg muscle is continuously higher than at rest, which means that oxygen delivery is high. However, the oxygen kinetics during the changes from low- to high-intensity exercise during the game appear to be limited by local factors and depend, among other things, on the oxidative capacity of the contracting muscles (Bangsbo *et al.*, 2002; Krustrup, Hellsten, & Bangsbo, 2004a). The rate of rise of oxygen uptake can be changed by intense interval training (Krustrup *et al.*, 2004a).

Anaerobic energy production in soccer

That elite soccer players perform 150–250 brief intense actions during a game (Mohr *et al.*, 2003) indicates that the rate of anaerobic energy turnover is high at certain times. Even though not studied directly, the intense exercise during a game leads to a high rate of creatine phosphate breakdown, which to some extent is resynthesized in the following low-intensity exercise periods (Bangsbo, 1994). On the other hand, creatine phosphate may decline (i.e. below 30% of resting values) during parts of a game if a number of intense bouts are performed with only short recovery periods. Analysis of creatine phosphate in muscle biopsies obtained after intense exercise periods during a game have provided values above 70% of those at rest, but this is likely to be due to the delay in obtaining the biopsy (Krustrup *et al.*, 2006).

Mean blood lactate concentrations of 2–10 $mmol \cdot l^{-1}$ have been observed during soccer games, with individual values above 12 $mmol \cdot l^{-1}$ (Agnevik, 1970; Bangsbo, 1994; Ekblom, 1986; Krustrup *et al.*, 2006). These findings indicate that the rate of muscle lactate production is high during match-play, but muscle lactate has been measured in only a single study. In a friendly game between non-professional teams, it was observed that muscle lactate rose fourfold (to around 15 $mmol \cdot kg$ dry $weight^{-1}$) compared with resting values after intense periods in both halves, with the highest value being 35 $mmol \cdot kg$ dry $weight^{-1}$ (Krustrup *et al.*, 2006). Such values are less than one-third of the concentrations observed during short-term intermittent exhaustive exercise (Krustrup *et al.*, 2003). An interesting finding in that study was that muscle lactate was not correlated with blood lactate (Figure 1). A scattered relationship with a low correlation coefficient has also been observed between muscle lactate and blood lactate when participants performed repeated intense exercise using the Yo-Yo intermittent recovery test (Krustrup *et al.*, 2003) (Figure 1). This is in contrast to continuous exercise where the blood lactate concentrations are lower but reflect well the muscle lactate concentrations during exercise (Figure 1). These differences between intermittent and continuous exercise are probably due to different turnover rates of muscle lactate and blood lactate during the two type of exercise, with the rate of lactate clearance being significantly higher in muscle than in blood (Bangsbo, Johansen, Graham, & Saltin, 1993). This means that during intermittent exercise in soccer, the blood lactate concentration can be high even though the muscle lactate concentration is

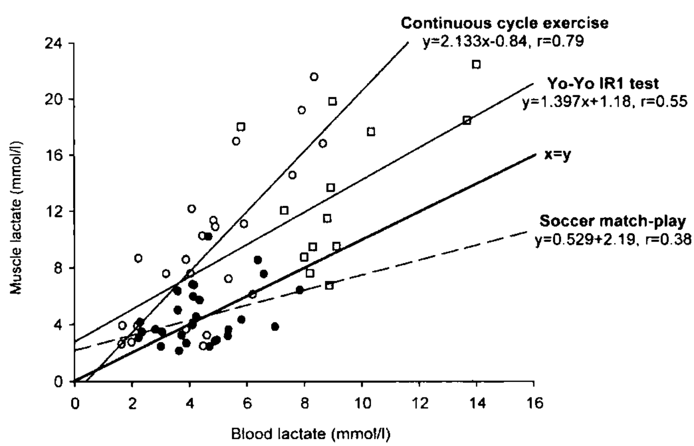

Figure 1. Individual relationships between muscle lactate (expressed in mmol per litre of cell water) and blood lactate during a soccer match (solid circles; data from the present study), at exhaustion in the Yo-Yo intermittent level 1 recovery test (solid squares; data from Krustrup *et al.*, 2003), and after 20 min of continuous cycle exercise at 80% $\dot{V}O_{2max}$ (open circles; data from Krustrup *et al.*, 2004b).

relatively low. The relationship between muscle lactate and blood lactate also appears to be influenced by the activities immediately before sampling (Bangsbo *et al.*, 1991; Krustrup & Bangsbo, 2001). Thus, the rather high blood lactate concentration often seen in soccer (Bangsbo, 1994; Ekblom, 1986; Krustrup *et al.*, 2006) may not represent a high lactate production in a single action during the game, but rather an accumulated/balanced response to a number of high-intensity activities. This is important to take into account when interpreting blood lactate concentration as a measure of muscle lactate concentration. Nevertheless, based on several studies using short-term maximal exercise performed in the laboratory (Gaitanos *et al.*, 1993; Nevill *et al.*, 1989), and the finding of high blood lactate and moderate muscle lactate concentrations during match-play, it is suggested that the rate of glycolysis is high for short periods of time during a game.

Substrate utilization during a soccer match

To provide nutritional strategies for a soccer player it is important to understand the energy demands and which substrates are utilized during a game. Muscle glycogen is an important substrate for the soccer player. Saltin (1973) observed that muscle glycogen stores were almost depleted at half-time when the pre-match values were low (~200 mmol · kg dry weight^{-1}). In that study, some players also started the game with normal muscle glycogen concentrations (~400 mmol · kg dry weight^{-1}), with the values still rather high at half-time but below 50 mmol · kg dry weight^{-1} at the end of the game. Others have reported concentrations of ~200 mmol · kg dry weight^{-1} after a match (Jacobs, Westlin, Karlsson, Rasmusson & Houghton, 1982; Krustrup *et al.*, 2006; Smaros 1980), indicating that muscle glycogen stores are not always depleted in a soccer game. However, analyses of single muscle fibres after a game have revealed that a significant number of fibres are depleted or partly depleted at the end of a game (Krustrup *et al.*, 2006; see below).

It has been observed that the concentration of free fatty acids (FFA) in the blood increases during a game, most markedly so during the second half (Bangsbo, 1994; Krustrup *et al.*, 2006). The frequent periods of rest and low-intensity exercise in a game allow for a significant blood flow to adipose tissue, which promotes the release of free fatty acids. This effect is also illustrated by the finding of high FFA concentrations at half-time and after the game. A high rate of lipolysis during a game is supported by elevated glycerol concentrations, even though the increases are smaller than during continuous exercise, which probably reflects a high turnover of glycerol (e.g. as a gluconeogenic precursor in the liver; Bangsbo, 1994). Hormonal changes may play a major role in the progressive increase in the concentrations of free fatty acids. The insulin concentrations are lowered and catecholamine concentrations are progressively elevated during a match (Bangsbo, 1994), stimulating a high rate of lipolysis and thus the release of free fatty acids into the blood (Galbo, 1983). The effect is reinforced by lowered lactate concentrations towards the end of a game,