SUPPLEMENT

Nutrition and hydration concerns of the female football player

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There is little information on the nutritional habits of female football players at any level of the game. There is also a shortage of information on the nutrition and hydration strategies that players should adopt. In general, differences in nutritional needs between males and females are smaller than differences between individuals, so that principles developed for male players also apply to women. There is a need to address energy balance and body composition: prolonged energy deficits cannot be sustained without harm to health and performance. Published reports show mean carbohydrate intakes for female players of about 5 g/kg/day, and this seems to be too low to sustain consistent intensive training. The timing of protein intake may be as important as the amounts consumed, provided that the total intake is adequate. Dehydration adversely affects skill and stamina in women as it does in men, so an individualised hydration strategy should be developed. The prevalence of iron deficiency in women generally is high, but it seems to be alarmingly high in female players. All players should adopt dietary habits that ensure adequate iron intake. Football training seems to increase bone mass in the weight-bearing limbs, with positive implications for bone health in later life, but some players may be at risk from inadequate calcium dietary intake.

An extensive series of reviews on all aspects of nutrition for football has recently been published.[1] It is immediately evident from these reviews that there are abundant experimental data relating to the nutrition and hydration practices of male football players, but information on female players is less easy to find.[2] There are many reasons for this, but the growing popularity of the women's game means that the nutritional needs of the female player need to be urgently considered. Owing to the shortage of gender-specific information, nutrition and hydration guidelines developed for male players are often applied to the female player. This is sometimes appropriate, but for many reasons this may not always be so. There are gender-related differences in the physical demands of training and match play, and also some differences in the nutrition needs of men and women generally, and of male and female athletes in particular. It is important to recognise at the outset, though, that the differences between the nutritional needs of men and women are generally small in comparison with the wide range of nutritional needs of the population as a whole.

In addition to the physiological and metabolic demands that shape nutritional needs and eating habits, players are subject to many of the societal issues that affect the general population. Female football players are not immune to these external pressures. The women's game is generally less well developed—at least in most countries—than the men's game. This may mean that less emphasis is placed on training, nutrition and other means of enhancing performance. It may also mean that there is more scope for the committed player to gain an advantage by exploiting these opportunities. Most of the world's football players take part for enjoyment: only a few are professionals. The nutritional strategies of the elite player, who trains most days of the week and perhaps competes more than once most weeks of the year, will be different from those of the player who trains no more than once a week. The general nutritional principles are the same, however, and are aimed at promoting health, fitness and match performance.

ENERGY BALANCE AND BODY COMPOSITION

From a review of energy intake of male and female athletes in different sports, Burke *et al* concluded that the energy intake of female athletes, expressed relative to body mass, is about 70% of that of their male counterparts.[3] This can be explained by the lower intensity, frequency and duration of the training programmes of most female athletes. Many studies, however, report that some athletes seem to be in negative energy balance, and such observations seem to apply more often to female athletes than to their male counterparts: these observations and the potential explanations have been reviewed in detail by Loucks.[4] It does seem that some female athletes are in precarious energy balance, and maintain a low body mass and low body fat content by prolonged energy restriction, including some periods of negative energy balance. This is not unique to female athletes, in many societies women are under greater pressure to maintain a low body fat content. At a time when the prevalence of obesity is increasing rapidly, some parts of the population are moving in the opposite direction.

In a comprehensive review of match activities, patterns of play and energy demands of both training and match play, Bangsbo *et al* were able to present little information on the female player.[5] There also seem to be rather few data on the energy intakes of female players (table 1), and most of those are based on short-term measurements (typically three days) using household measures to estimate portion sizes that were then recorded in a food diary. Fogelholm *et al* used a seven-day food record: indirect calorimetry was used to assess resting metabolic rate and a physical activity diary was used to estimate energy expenditure.[6] The mean (SD) estimated energy expenditure (9.42 (0.90) MJ/day) was not different from the mean estimated energy intake (8.97 (1.68) MJ/day). It is interesting to note that the estimated energy intake was also equal to energy expenditure in a control group in this study, but a group of gymnasts recorded energy expenditure that was more than 3 MJ/day higher than the estimated energy intake.

Any restriction of energy intake with the aim of reducing body fat content requires careful attention if injury and illness are to be avoided. This is because of the potential for adverse effects of prolonged energy restriction, including delayed recovery from exercise, impairment of adaptation to the training stimulus, suppression of immune function, and disruption of reproductive function. Loucks has pointed out that achieving energy balance should not be an objective of the

Table 1 Physical characteristics and energy intake of female football players during training. Values are mean (SD)

Study	Population	Data collection	Age (years)	Body mass (kg)	Body mass index (kg/m^2)	Energy (MJ)	Energy (kJ/kg)
Fogelholm *et al*[6]	Finnish national league players (n = 12)	7-day food diary (household measures)	19 (2)	61 (6)	22.2 (1.8)	9.0 (1.7)	147
Clark *et al*[7]	US collegiate players (n = 13)	3-day food diary (household measures) before and after the season	20 (1)	62 (5)	22.5	9.6 (1.3) 7.8 (2.2)	155 126
Gropper *et al*[8]	US collegiate players (n = 15)	3-day food diary (household measures)	19 (1)	59 (5)	20.6 (1.4)	8.5 (2.5)	143
Mullinix *et al*[9]	US national U21 team players	3-day food diary (household measures)	19 (1)	60 (7)	21.8 (1.6)	8.1 (0.1)	135

player's nutrition strategy, but rather that they should aim to achieve appropriate fat-free mass, fat mass and carbohydrate stores.[4]

CARBOHYDRATE

Carbohydrate, in the form of glycogen stores in liver and skeletal muscle, is an essential fuel during training and match play, and carbohydrate availability is a limiting factor during prolonged fatiguing exercise. In male players, the glycogen content of the active muscles substantially decreases during training and match play, but the muscle glycogen content at the end of a game remains much higher than the values found in typical laboratory studies in which subjects run to fatigue.[5] However, studies (on male players) have shown that an inadequate intake of dietary carbohydrate in the days before a match will impair running performance, reducing both the distance covered and the speed of running, especially during the second half of a game.[10] This last finding suggests that, even though we have no good understanding of why players slow down and show signs of fatigue late in a game, it seems prudent to ensure that the muscle glycogen stores have been replenished since the last training session or game. This can be a problem for elite players when the fixture list becomes congested. However, it is less of a problem for those who play only once a week and can adjust training to ensure sufficient recovery prior to games.

It is no longer appropriate to think of carbohydrate needs as a fraction of total energy intake: rather they should be expressed as an amount of carbohydrate relative to body mass. Burke *et al*, considering primarily male players, recommended that daily carbohydrate intake during periods of moderate training, periods of energy restriction to achieve fat loss, and for less mobile players, should be about 5–7 g/kg body mass.[11] For more mobile players and during periods of twice-daily training or in preparation for match play, they recommended increasing this to 7–12 g/kg. This is a wide range, and it has important implications for overall energy balance and also raises practical issues relating to the amount of food that must be consumed.

From the limited data available, it seems that female players typically consume rather less than Burke and colleagues' recommendations.[11] Mullinix *et al* reported average daily intakes of 4.7 g/kg for US national U21 players.[9] Unfortunately the range of values was not reported but the standard deviation of 2.0 g/kg/day suggests that there were extremely low—perhaps even improbably low—values in some individual players. Although most of the players may be able to cope at this level of intake, those at the lower end might well benefit from an increased intake while remaining within their total energy budget. Clark *et al* reported intakes for American division 1 college players of 5.2 g/kg/day before the season, when training twice daily, and 4.3 g/kg/day when measured again about 10 days after the end of the competitive season.[7] The interindividual variability was smaller for these players, with a standard deviation of about 1.1 g/kg/day.

These observational data do not answer the question of whether the carbohydrate intake of these players was adequate or whether there would be performance—and possibly health—benefits of a higher intake. They are, however, consistent with data suggesting that early reports of women being less able than men to achieve supercompensation of muscle glycogen stores by manipulation of diet and exercise were the result of inadequate carbohydrate intake of the female subjects.[12] Later studies are less clear, but suggest that, notwithstanding some fluctuations in glycogen storage capacity over the course of the menstrual cycle, women can effectively achieve supercompensation of muscle glycogen stores if the dietary carbohydrate intake is adequate.[13]

PROTEIN

If the diet does not supply sufficient protein, and more particularly enough essential amino acids, the functional capacity of muscles and of all other tissues will eventually decline. An adequate intake of protein is essential for muscle growth and repair, and also for a healthy immune system and a whole range of other physiological functions. However, what constitutes an adequate protein intake has been widely debated. More recent investigations suggest that besides the amount of protein, the timing of intake and the presence or absence of other nutrients can affect the ability of an athlete to adapt to a training stimulus. The aim of training is to promote changes in tissue structure and function that lead to improved performance. This requires a constant turnover of protein molecules with a net breakdown of those proteins that are not required and a net synthesis of proteins that are required. These changes require the application of an appropriate exercise stimulus; the nature of the adaptation is specific to the type of training stimulus, and the extent of adaptation is a function of the training load. We now know that the nutritional and hormonal environment will modulate these changes, making training either more or less effective. Whereas it was formerly thought that the main role of nutrition was to enhance recovery, thus allowing athletes to train harder, it is now recognised that a good dietary strategy can perhaps allow the same training adaptations with a reduced training load. This is important in reducing the risk of chronic fatigue and injury, and may allow more time and effort to be devoted to technical training rather than to strength and endurance training.

Athletes wishing to build and repair muscle have traditionally been concerned about achieving high protein intakes.[14] There is some increase in the protein requirement during periods of stress, including those imposed by exercise training and competition. The protein requirement, assuming that the diet provides mixed proteins containing all of the essential amino acids, is about 0.6 g/kg/day. However, a safety margin is added to this to account for variations in the composition of the protein ingested as well as individual variation in the requirement, so that the recommended intake is usually set at about 0.8 g/kg/day for both men and women.[15] This is easily achieved with normal levels of intake. Even a player eating a diet that provides only 2200 kcal/day (8.8 MJ/day) with 10–15% of total energy from protein will have an intake of 55–82 g/day. Assuming a body mass of 60 kg, this will give a daily protein intake of about 0.9–1.4 g/kg/day. Recommendations for football players have been set at various levels, but are commonly in the range of 1.4–1.7 g/kg/day.[16] It is difficult not to reach this value with a typical Western diet if energy demand is met, but some players with restrictive eating practices and limited food choices may not.

Athletes, especially those in strength and power sports, argue that much higher levels of protein are required, even though the scientific evidence does not support this. Part of this apparent discrepancy may be explained by Millward's Adaptive Metabolic Demands model for protein.[17] This says that a protein balance can be sustained on a wide range of protein intakes, but that sudden changes in intake are accommodated only slowly. The athlete on a high protein intake (3–4 g/kg/day) who suddenly reduces this will experience a loss of muscle during the process of accommodation but will eventually adapt to the new lower intake.

Much interest in recent years has been on the timing of protein intake in relation to training, and we now know that training may be more effective if a small amount of protein is consumed just before or just after the exercise. A recent study found that provision of a protein/creatine/carbohydrate supplement just before and just after a resistance training programme that was carried out three times weekly for 10 weeks was more effective in promoting lean body mass and muscle strength than when the same supplement was given in the morning and late evening—that is, separated from the training.[18] This is consistent with numerous studies using isotopic tracer methodology to show that ingestion of protein around the time of training can promote a positive nitrogen balance across the active muscles.[14]

WATER AND ELECTROLYTE BALANCE

Sweat rates in women are lower than in men across most activities for which data are available.[19] Broad *et al* investigated the sweat losses and drinking practices of female football players.[20] Sweat rates (mean (SD) 0.8 (0.2) l/h in training, 0.8 (0.2) l/h in a match) and drinking rates (0.4 (0.2) l/h in training, 0.4 (0.2) l/h in a match) tended to be lower than those observed in elite male players in training.[21] This reflects in part the smaller mass of female participants but is largely a consequence of the lower rates of metabolic heat production. Losses in sweat electrolytes in both England U21 female players (n = 14) during training and England senior international players (n = 25) during a friendly match were less than those of their male counterparts, but this was solely due to smaller volume losses: the sodium concentrations were similar (mean (SD) 44 (18) mmol/l).[22]

Where sweat losses are small, there is little need for fluid replacement during training or match play. Performance, however, is impaired when the sweat-induced loss of body mass reaches about 1–2% of the pre-exercise body mass, and sufficient fluid should be consumed to prevent net loss exceeding this amount.[22] Drinking fluids containing small amounts of carbohydrate and electrolytes may be better than drinking plain water. Water is adequate when sweat losses are small or when activity levels are not high. Where large sweat losses are anticipated as in games or hard training in the heat, players should be careful to ensure they are well hydrated beforehand. Self-monitoring by attention to the frequency, volume and colour of urine may be helpful when fluid balance is stressed—for example, in tournament situations in warm climates.

MICRONUTRIENTS

The diet must provide sufficient amounts of micronutrients that are essential for the normal function of the body. Deficiencies of any or all of the micronutrients are possible, and may occur because of inadequate dietary intake, impaired absorption or utilisation, excessive losses or metabolic abnormalities. Deficiencies are generally rare in individuals who eat a varied diet sufficient to meet energy needs, but the risk is increased by any dietary restriction, such as vegetarianism, avoidance of dairy produce, etc. Conspicuous exceptions are calcium and iron. These two essential elements can be particularly problematic for women, and the female athlete is no exception.

Most of the body's store of calcium is found in the bones, and the amount of calcium deposited there as calcium phosphate reaches a peak in young adulthood before beginning to decline thereafter. After the age of 40, bone mass is lost typically at a rate of about 0.5–1.0% a year.[23] Anyone who reaches adult life with a low peak bone mass, or who experiences a high rate of loss, is at risk of increased bone fragility: a third of women who reach the age of 90 will have fractured a hip, about twice the rate in men. Oestrogen has a major role in calcium homoeostasis in women, so women with late menarche and early menopause are more likely to have osteoporosis and associated weakening of the bone structure. An adequate intake of calcium is essential for bone health, but so too is vitamin D, either ingested as the preformed vitamin or synthesised in the skin on exposure to sunlight. Imposed stress, in the form of weight-bearing exercise, stimulates bone formation, while bedrest promotes bone loss. Female football players have higher bone mineral density than sedentary women.[24 25] Lean players who experience amenorrhoea should be especially conscious of the risk of problems in later life. Dairy produce is the best source of dietary calcium, but it is often avoided by weight-conscious athletes because of the fat content. All players should be encouraged to consume adequate low fat dairy produce.

Iron is a key component of haemoglobin, the protein responsible for transport of oxygen from the lungs to the active tissues, and low levels of haemoglobin are associated with reduced exercise performance. Iron deficiency affects both men and women: the consequences are probably the same for both genders, but it seems that more women are at risk. The prevalence of iron deficiency in the general population is higher in women than it is in men, so it is not surprising that female athletes also show a higher prevalence than their male counterparts. It is difficult to compare studies as many different criteria have been used, and generalisations are also fraught with difficulties. Data from Australia suggest that the prevalence of deficiency, defined as abnormal serum ferritin and/or transferrin saturation with or without anaemia, is about 8% in women and 2% in men: in the vegetarian population, however, this rises to 27% of females and 5% of males, and in the Aborigine population the prevalence is estimated at 12–20%.[26] The prevalence in Côte d'Ivoire has been estimated at 13% in men and 41–63% in women, reflecting the presence of common diseases such as malaria and the prevalence of dietary inadequacies.[27] Data from the USA show an increased prevalence in women from minority populations and from lower socioeconomic groups.[28] This high prevalence in disadvantaged populations is a particular concern, but in the USA the prevalence of iron deficiency has been estimated to be up to 20% in young women. This figure may increase to 25–35% or even more in women competing in a variety of sports.[29] Of 28 players in the Swedish national squad, 59% were found to have iron deficiency and 29% iron deficiency anaemia six months prior to the Fédération Internationale de Football Association

(FIFA) Women's World Cup.[30] These values are alarmingly high, and although iron deficiency without anaemia has little effect on exercise performance, it may be the prelude to a fall in circulating haemoglobin concentration and lead to a fall in aerobic capacity.

All individuals diagnosed as having iron deficiency anaemia should take iron supplements in the form of ferrous sulphate in an appropriate dose. The treatment will probably take months rather than weeks to be effective, and dietary changes should be started concurrently. Strategies should include:

- an increased intake of iron-rich foods, such as red meat that contain haem iron;
- use of fortified foods, such as breakfast cereals;
- use of nutrients that promote iron intake, such as vitamin C and meat with the iron-rich meals;
- a reduction in the intake of inhibitors of iron absorption, such as fibre and tannin.

Note that supplementation should not be started on a "just in case" basis, but should follow a full investigation that includes blood parameters. The routine use of iron supplementation is common, but is probably not wise as it may do more harm than good.

DIETARY SUPPLEMENTS

Few dietary supplements have anything to offer to the female player. Of all the many thousands of different products on sale to athletes, there may be some situations where creatine and caffeine have something to offer to the football player, but even then some caution is required. Creatine has attracted enormous attention over recent years, and there is a solid body of evidence showing that some individuals may benefit by an increased ability to perform repeated sprints and an increased lean body mass.[31] Studies that have used performance tasks that simulate football have not been entirely convincing. Equally, there is no evidence of harm, so players may feel inclined to see whether they experience a benefit. Any player adopting this approach must be aware that a large fraction of the dietary supplements on sale to athletes may contain agents that will cause a positive doping test, even though these are not declared on the label.[32] There is some evidence for benefits of caffeine in a football environment, but it is less strong than it is for endurance running or cycling events.[31] Again, any player contemplating this should experiment in training with low doses of caffeine before trying it in competition.

ALCOHOL

Alcohol is not an essential part of the human diet, but is consumed by a large part of the world's population. In small amounts, alcohol has little effect on exercise performance, but large intakes prior to exercise adversely affect several physiological and psychological functions, leading to greater indiscipline and greater risk of injury. After exercise, alcohol may delay recovery if it displaces carbohydrate from the diet and may also encourage high-risk behaviours at a time when players should focus on recovery.[33]

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REFERENCES

1 **Maughan RJ**, ed. *Nutrition and football.* London: Routledge, 2006.
2 **Rosenbloom C**. Special populations: the female player and the youth player. *J Sports Sci* 2006;**24**:783–93.
3 **Burke LM**, Cox GR, Cummings NK, *et al.* Guidelines for daily carbohydrate intake: do athletes achieve them? *Sports Med* 2002;**31**:267–99.
4 **Loucks AB**. Energy balance and body composition in sports and exercise. *J Sports Sci* 2004;**22**:1–14.
5 **Bangsbo J**, Mohr M, Krustrup P. Physical and metabolic demands of training and match-play in the elite football player. *J Sport Sci* 2006;**24**:665–74.
6 **Fogelholm GM**, Kukkonen-Harjula TK, Taipale SA, *et al.* Resting metabolic rate and energy intake in female gymnasts, figure-skaters and soccer players. *Int J Sports Med* 1995;**8**:551–6.
7 **Clark M**, Reed DB, Crouse SF, *et al.* Pre- and post-season dietary intake, body composition, and performance indices of NCAA Division I female soccer players. *Int J Sport Nutr Ex Metab* 2003;**13**:303–19.
8 **Gropper SS**, Sorrels LM, Blessing D. Copper status of collegiate female athletes involved in different sports. *Int J Sport Nutr Ex Metab* 2003;**13**:343–57.
9 **Mullinix MC**, Jonnalagadda SS, Rosenbloom CA, *et al.* Dietary intake of female U.S. soccer players. *Nutr Res* 2003;**23**:585–93.
10 **Saltin B**. Metabolic fundamentals of exercise. *Med Sci Sports Ex* 1973;**15**:366–9.
11 **Burke LM**, Loucks AB, Broad N. Energy and carbohydrate for training and recovery. *J Sports Sci* 2006;**24**:675–85.
12 **Tarnopolsky A**, Atkinson SA, Phillips SM, *et al.* Carbohydrate loading and metabolism during exercise in men and women. *J Appl Physiol* 1995;**75**:2134–41.
13 **Tarnopolsky MA**, Zwada C, Richmond LB, *et al.* Gender differences in carbohydrate loading are related to energy intake. *J Appl Physiol* 2001;**91**:225–30.
14 **Tipton KD**, RR Wolfe. Protein and amino acids for athletes. *J Sports Sci* 2004;**22**:65–79.
15 **Institute of Medicine**. Dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. Washington, DC: National Academies Press, 2002.
16 **Lemon PW**. Protein requirements of soccer. *J Sports Sci* 1994;**12**:S17–22.
17 **Millward DJ**. An adaptive metabolic demand model for protein and amino acid requirements. *Br J Nutr* 2003;**90**:1–13.
18 **Cribb PJ**, Hayes A. Effects of supplement timing and resistance exercise on skeletal muscle hypertrophy. *Med Sci Sports Ex* 2006;**38**:1918–25.
19 **Burke LM**, Hawley JA. Fluid balance in team sports: guidelines for optimal practices. *Sports Med* 1997;**24**:38–54.
20 **Broad EM**, Burke LM, Cox GR, *et al.* Body weight changes and voluntary fluid intakes during training and competition sessions in team sports. *Int J Sports Nutr* 1996;**6**:307–20.
21 **Maughan RJ**, Merson SJ, Broad NP, *et al.* Fluid and electrolyte intake and loss in elite soccer players during training. *Int J Sports Nutr Ex Metab* 2004;**14**:333–46.
22 **Shirreffs SM**, Sawka MN, Stone M. Water and electrolyte needs for football training and match-play. *J Sports Sci* 2006;**24**:699–707.
23 **Cohn SH**, Vaswani A, Zanzi I, *et al.* Changes in body chemical composition with age measured by total-body neutron activation. *Metabolism* 1976;**25**:85–95.
24 **Pettersson U**, Nordstrom P, Alfredson H, *et al.* Effect of high impact activity on bone mass and size in adolescent females: a comparative study between two different types of sports. *Calcified Tissue Int* 2000;**67**:207–14.
25 **Soderman K**, Bergstrom E, Lorentzon R, *et al.* Bone mass and muscle strength in young female soccer players. *Calcified Tissue Int* 2000;**67**:297–303.
26 **Australian Iron Status Advisory Panel**. Iron deficiency in adults. 2006. http://www.ironpanel.org.au/AIS/AISdocs/index.html (accessed 6 February 2007).
27 **Asobayire FS**, Adou P, Davidsson L, *et al.* Prevalence of iron deficiency with and without concurrent anemia in population groups with high prevalences of malaria and other infections: a study in Cote d'Ivoire. *Am J Clin Nutr* 2001;**74**:776–82.
28 **Looker AC**, Dallman PR, Carroll MD, *et al.* Prevalence of iron deficiency in the United States. *JAMA* 1997;**277**:973–6.
29 **Sinclair LM**, Hinton PS. Prevalence of iron deficiency with and without anemia in recreationally active men and women. *J Am Diet Assoc* 2005;**105**:975–8.
30 **Landahl G**, Adolfsson P, Borjesson M, *et al.* Iron deficiency and anemia: a common problem in female elite soccer players. *Int J Sport Nutr Ex Metab* 2005;**15**:689–94.
31 **Hespel P**, Maughan RJ, Greenhaff PL. Dietary supplements for football. *J Sports Sci* 2006;**24**:749–61.
32 **Maughan RJ**. Contamination of dietary supplements and positive drugs tests in sport. *J Sports Sci* 2005;**23**:883–9.
33 **Burke LM**, Maughan RJ. Alcohol in sport. In: Maughan RJ, ed. *Nutrition in sport.* Oxford: Blackwell, 2000:405–14.