Journal of Sports Sciences
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713721847

Special populations: The female player and the youth player

Christine A. Rosenbloom [a]; Anne B. Loucks [b]; Bjorn Ekblom [c]
[a] College of Health and Human Sciences, Georgia State University. Atlanta, GA. USA
[b] Department of Biological Sciences, Ohio University. Athens, OH. USA
[c] Department of Physiology and Pharmacology, Karolinska Institute. Stockholm. Sweden

Online Publication Date: 01 July 2006
To cite this Article: Rosenbloom, Christine A., Loucks, Anne B. and Ekblom, Bjorn , (2006) 'Special populations: The female player and the youth player', Journal of Sports Sciences, 24:7, 783 - 793
To link to this article: DOI: 10.1080/02640410500483071
URL: http://dx.doi.org/10.1080/02640410500483071

Journal of Sports Sciences, July 2006; 24(7): 783–793

Taylor & Francis
Taylor & Francis Group

Special populations: The female player and the youth player

CHRISTINE A. ROSENBLOOM[1], ANNE B. LOUCKS[2], & BJORN EKBLOM[3]

[1]*College of Health and Human Sciences, Georgia State University, Atlanta, GA, USA,* [2]*Department of Biological Sciences, Ohio University, Athens, OH, USA, and* [3]*Department of Physiology and Pharmacology, Karolinska Institute, Stockholm, Sweden*

(Accepted 16 November 2005)

Abstract
Females and youth are frequently described as "special" populations in football literature, but together these two populations outnumber male players. What makes females "special" is that they tend to eat less when training and competing than their male counterparts, leading to lower intakes of energy, carbohydrate, and some nutrients. Youth football players are special in regard to energy and nutrient requirements to promote growth and development, as well as to fuel sport. There is limited research on the dietary habits of these two populations, but the available literature suggests that many female and youth players need to increase carbohydrate intake, increase fluid intake, and develop dietary habits to sustain the demands of training and competition.

Keywords: *Female athletes, young athletes, energy intakes*

Introduction

Although exact numbers are not available it is safe to assume that, when combined, women and youth football players outnumber male players. Yet, there is insufficient research on the nutritional needs of these two groups of athletes. Most information on energy demands, training and conditioning strategies, and dietary habits is extrapolated from the research on male footballers. The purpose of this article is to review what is known about the nutrition needs and dietary habits of women and youth football players and to identify what is not known to encourage research of these two populations to gain a more comprehensive picture of these footballers.

Female players

FIFA estimates that in the year 2010, there will be more women playing football than men (Davies, 2005). Women have come a long way since the days when the Football Association of England (FA) banned women from playing on Football League grounds in 1921, stating that "the game of football is quite unsuitable for females and ought not to be encouraged" (The Football Association, 2002). Data from the Football 2000 Worldwide survey (www.FIFA.com) indicated that women in 132 countries played football. In 2002, the FA reported there were 131,000 registered female players and about 1.4 million females played football at various levels of competition in England (The Football Association, 2005). In the USA, it is estimated that 5.5 million women over the age of 7 years play football (NSGA, 2004a). Understanding the usual dietary patterns and nutritional intakes of females could help coaches, trainers, and sports dietitians to develop nutritional strategies to fuel performance and prevent fatigue over the course of a long competitive season.

Energy demands of football

Bangsbo (1994) reported that male players cover an average distance of 11 km during a match coupled with other energy-expending activities, including tackling, turning, and accelerating. Use of distance covered in a match as a way to assess energy expenditure underestimates the true cost of energy used in football (Reilly, 1997). Brewer (1994) reviewed nutritional aspects of female soccer players and reported that a female player covers less distance in a match than a male, but the relative intensity of activity is maintained around 70% of maximal

Correspondence: C. A. Rosenbloom, College of Health and Human Sciences, Georgia State University, PO Box 3995, Atlanta, GA 30302-3995, USA. E-mail: crosenbloom@gsu.edu

ISSN 0264-0414 print/ISSN 1466-447X online © 2006 Taylor & Francis
DOI: 10.1080/02640410500483071

oxygen uptake ($\dot{V}O_{2max}$), which is similar to that of males. Using data reported by Ekblom and Aginger, Brewer (1994) estimated an energy expenditure of about 1100 kcal for a 60 kg football player during a match. Fogelholm *et al.* (1995) estimated total energy expenditure to be $2218\,kcal \cdot day^{-1}$ from measurements of resting energy expenditure and analyses of 7 day activity records of 12 female footballers. Because chronic undernutrition suppresses resting energy expenditure (Loucks, 2004), however, such calculations of total energy expenditure will underestimate the amount of dietary energy required to restore the healthy functioning of all physiological systems in undernourished individuals.

Energy and nutrient intakes

Information about the dietary intakes of female footballers is very limited. Two recent studies, conducted in the USA, assessed dietary intakes of female players from the U-21 national soccer team (Mullinix, Jonnalagadda, Rosenbloom, Thompson, & Kicklighter, 2003) and those competing in the National Collegiate Athletic Association (NCAA) Division I (Clark, Reed, Crouse, & Armstrong, 2003). The average energy, macronutrient, and micronutrient intakes in both groups of female athletes are shown in Table I. The athletes in the U-21 national team (mean age 19.2 years) averaged $2015\,kcal \cdot day^{-1}$, whereas the NCAA players averaged $2290\,kcal \cdot day^{-1}$. Both groups of researchers found the women consumed less energy than would be predicted from estimated energy expenditure equations, and that most athletes consumed energy more suited to individuals with low activity levels. Clark *et al.* (2003) assessed energy intake pre- and post-season and found significantly lower intakes of energy and all macronutrients post-season. Both studies had small numbers of participants, but if energy expenditure during practice or a soccer match is about 1100 kcal, these women consumed much lower energy intakes than their actual needs. Clark *et al.* (2003) also assessed body composition and reported a stable body weight in the football players from pre- to post-season, suggesting their energy needs were appropriate for the energy demands of the sport. Hinton, Sanford, Davidson, Yakushko and Beck (2004) reported nutrient intakes and dietary behaviours in 142 female collegiate athletes in the USA, including 20 footballers. Body composition was not assessed, but approximately 70% of the female footballers expressed a desire to lose weight and were intentionally restricting energy intake.

Table I. Energy, macronutrient, and micronutrient intakes in female footballers (mean ± *s*).

Nutrient	U-21 players[a] ($n = 11$)	NCAA players[b] ($n = 13$)	NCAA players[c] ($n = 13$)
Energy (kcal)	2015 ± 19	2290 ± 310	1865 ± 530
Carbohydrate (g)	282 ± 118	320 ± 70	263 ± 71
Protein (g)	79 ± 33	86.5 ± 18.7	58.8 ± 16.0
Fat (g)	67 ± 28	75.2 ± 13.3	65.9 ± 28.7
Fibre (g)	17.7 ± 5.2	14.5 ± 4.9	13.3 ± 5.7
Vitamin A (RE)	917 ± 505	894 ± 276	847 ± 425
Vitamin E (mg)	8.3 ± 8.8	7.2 ± 3.7	3.3 ± 3.3
Vitamin D (μg)	2.6 ± 2.4	2.4 ± 1.7	2.5 ± 2.6
Vitamin C (mg)	128 ± 110	100 ± 64	46 ± 32
Thiamin (mg)	1.6 ± 0.9	1.5 ± 0.6	1.0 ± 0.4
Niacin (mg)	21.5 ± 11.9	24.5 ± 8.5	15.2 ± 6.3
Riboflavin (mg)	1.7 ± 1.0	1.8 ± 0.7	1.2 ± 0.7
Folate (μg)	338 ± 213	271 ± 130	186 ± 113
Vitamin B6 (mg)	1.9 ± 1.2	1.8 ± 0.6	1.1 ± 0.6
Vitamin B12 (μg)	3.0 ± 2.8	4.5 ± 1.9	2.1 ± 1.7
Calcium (mg)	887 + 510	931 ± 223	695 ± 289
Iron (mg)	16 ± 7.8	17.3 ± 4.7	12.2 ± 5.2
Magnesium (mg)	223 ± 103	178 ± 43	127 ± 71
Zinc (mg)	9.5 ± 6.1	10.4 ± 4.6	5.1 ± 2.5
Sodium (mg)	3780 ± 1679	Not reported	Not reported
Potassium (mg)	2312 ± 1049	Not reported	Not reported

[a]Mullinix *et al.* (2003: pre-season intakes), [b]Clark *et al.* (2003: pre-season intakes), [c]Clark *et al.* (2003: post-season intakes).

Under-reporting of energy intake is common when collecting dietary information by recall methods, and stability of body weight may not be the best predictor of energy balance. Researchers have repeatedly observed endocrine signs of energy deficiency in both amenorrhoeic and eumenorrhoeic female athletes (Loucks, 2004). Research directed at accurate assessment of energy intake, energy expenditure, body composition, and hormone status would help to answer the question of energy needs in female footballers.

Absolute carbohydrate intake in these two groups of female footballers was lower than the recommendations in the Joint Position Statement of the American Dietetic Association, the Dietitians of Canada, and the American College of Sports Medicine (2000). Females were reported to consume an average of $4.7\,g$ carbohydrate $\cdot\, kg^{-1} \cdot day^{-1}$ (Mullinix *et al.*, 2003), and $5.2\,g$ carbohydrate $\cdot\, kg^{-1} \cdot day^{-1}$ in the pre-season and $4.3\,g$ carbohydrate $\cdot\, kg^{-1} \cdot day^{-1}$ in the post-season (Clark *et al.*, 2003). These values are below the recommendations of $7-8\,g$ carbohydrate $\cdot\, kg^{-1} \cdot day^{-1}$ for athletes participating in heavy training and competition. Mean carbohydrate intake failed to approach values of dietary carbohydrate sufficient to maintain glycogen levels. When carbohydrate intake is expressed as a percentage of total energy intake, these women were eating approximately 52% of energy intake as carbohydrate, but their absolute intake of carbohydrate was not optimal.

In a comprehensive review of carbohydrate needs for athletes, Burke, Cox, Cummings and Desbrow (2001) concluded that female athletes, especially endurance athletes, are less likely than their male counterparts to achieve the recommendations for carbohydrate intake. The most likely reason for a less than desirable energy intake was to achieve or maintain a lower body weight and/or percentage body fat. In a study on eating patterns of elite athletes, Burke *et al.* (2003) suggested that female athletes may ingest less energy and carbohydrate than males because women may have less rigorous training and may under-report food intake on dietary food records compared with men.

Energy and macronutrients needs – are there differences between the sexes?

It is clear that energy and macronutrient intakes of male athletes are generally greater than those of female athletes, but energy and macronutrient needs may be different in females. Loucks (2004) reported that energy intake is a special concern for females because of reproductive disorders associated with an energy intake that is too low to support high energy demands in sport. When energy and carbohydrate intakes are normalized by body weight, female athletes consume far less than men – about 30% less (Burke *et al.*, 2001; Loucks, 2004). Insufficient energy and carbohydrate intake can compromise hormonal patterns, leading to alterations in growth, impaired performance, and decreased bone mineralization. Loucks (2004) argued that because many female athletes strive for a low body weight and percentage body fat, and they find it difficult to consume sufficient energy, a focus on manipulating carbohydrate, protein, and fat intake might be a more useful, albeit challenging, strategy.

Kirkendall (2000) summarized the physiological aspects of football and concluded that there are three trends that are seen in football players: (1) pre-game concentrations of glycogen are lower in footballers than in other athletes; (2) significant glycogen depletion occurs in the first 45 min (first half) of play; and (3) at the end of the game, glycogen is totally depleted. While these trends are not specific for female athletes, the limited research suggests that female athletes ingest less energy and less carbohydrate than males, so a logical conclusion is that female players may have lower pre-game and half-time glycogen than male players. Low glycogen stores can lead to sub-optimal performance during the match.

Burke, Keins and Ivy (2004) presented practical suggestions for improving carbohydrate intake in athletes, although the recommendations are not gender-specific. Revised guidelines for carbohydrate intake include:

- Immediately after exercise (0 – 4 h): 1.0 – 1.2 $g \cdot kg^{-1} \cdot h^{-1}$ consumed at frequent intervals.
- Daily intake for recovery from training of low-intensity and moderate duration: 5 – 7 $g \cdot kg^{-1} \cdot h^{-1}$.
- Daily intake for recovery from endurance training of moderate to heavy duration: 7 – 12 $g \cdot kg^{-1} \cdot h^{-1}$.

Providing food choices to a football team, based on their training and competition schedule, is a useful tool to help athletes meet carbohydrate needs. This is especially important in the USA, where carbohydrate is often viewed as the fattening enemy.

Recent research on carbohydrate storage and utilization of both endogenous and exogenous sources has shed new light on the frequent observation that women store and utilize less glycogen than men. Although increasing the carbohydrate content of the diet to 65% increased glycogen stores only in men, the absolute carbohydrate intake of the women was substantially lower because their total energy intake was lower, even when normalized to body size (Tarnopolsky, Atkinson, Phillips, & MacDougall, 1995). When normalized, absolute as well as relative carbohydrate intakes of the women were matched to those of men in a subsequent experiment; the gender difference in glycogen storage had disappeared (Tarnopolsky *et al.*, 2001a).

Gender differences in substrate utilization during exercise also disappeared when the dietary intake of women, normalized to body size, was matched to that of men for 8 days (Roepstorff *et al.*, 2002). Similarly, M'Kaouar, Peronnet, Massicotte and Lavoie (2004) recently demonstrated that men and women utilized carbohydrate at similar levels when fed glucose during prolonged activity. Glucose ingestion during prolonged exercise increases carbohydrate oxidation with improvements in performance (Baile, Zacher, & Mittleman, 2000). Thus, the frequent observation that women store and utilize less glycogen than men may be a result of their lower carbohydrate intake.

Riddell *et al.* (2003) studied healthy females ($n = 7$) and males ($n = 7$) completing two 90 min cycle ergometer tests at 60% $\dot{V}O_{2peak}$. Exercise bouts were separated by one week. The participants were given an 8% carbohydrate drink or a placebo beverage. The researchers found that in the final 60 min of the 90 min exercise bout, women utilized more of the ingested carbohydrate than males. Exogenous carbohydrate may spare more endogenous carbohydrate in females than in males in endurance events. These data are preliminary and small numbers of participants were studied, but gender differences in utilization of fuels should be investigated.

Another concern for active women is the effect of the menstrual cycle on exercise. Campbell, Angus and Febbraio (2001) observed that women have better exercise performance (i.e. greater time to exhaustion in cycle ergometer tests) in the follicular phase than in the luteal phase of the menstrual cycle when exercising in the fasted state. When researchers fed the women glucose during the exercise trials there was no difference in exercise performance between the menstrual cycle phases. The results of this study give women another reason to consume adequate carbohydrate when training and competing.

Protein

Many athletes, as well as sedentary individuals, consume protein in excess of their biological requirement, and this holds true for men and women alike. It is generally recommended that endurance athletes and those involved in "stop and go" sports like football should consume 1.2 – 1.4 g protein $\cdot$ kg^{-1} $\cdot$ day^{-1}, with no advantage to consuming amounts in excess of 2.0 g $\cdot$ kg^{-1} $\cdot$ day^{-1} (Tipton & Wolfe, 2004). Little is known about gender differences in protein metabolism in athletes, perhaps because athletes usually have adequate protein intakes. Female athletes in the two dietary intake studies reviewed for this paper showed that females consumed protein in adequate amounts in the pre-season [1.3 g $\cdot$ kg^{-1} $\cdot$ day^{-1} (Mullinix *et al.*, 2003) and 1.4 g $\cdot$ kg^{-1} $\cdot$ day^{-1} (Clark *et al.*, 2003)]. However, these data are reported as averages and most likely there are some athletes consuming less than the recommended amount of protein in their diets. Athletes in the post-season consumed significantly less protein compared to the preseason (0.95 g kg^{-1} $\cdot$ day^{-1}) (Clark *et al.*, 2003). However, protein recommendations are established when energy intakes are adequate. If inadequate energy intake is consumed, protein needs will be higher. Lemon (1994) suggests that soccer players should consume about 1.4 – 1.7 g protein $\cdot$ kg^{-1} $\cdot$ day^{-1}, slightly more than the amounts recommended by Tipton and Wolfe (2004).

A recent focus of research has been on the timing of protein intake to support muscle anabolism. Providing essential amino acids before and after exercise has been shown to stimulate protein synthesis (Tipton & Wolfe, 2004). This dietary strategy is usually employed by strength and power athletes. Dietary protein recommendations are usually made for endurance athletes (1.2 – 1.4 g $\cdot$ kg^{-1} $\cdot$ day^{-1}) and strength athletes (1.2 – 1.7 g $\cdot$ kg^{-1} $\cdot$ day^{-1}), but footballers undertake both types of training. Presenting protein recommendations for both types of training would be useful and practical for footballers.

Fluids

Fluid losses in female footballers are not well documented. A summary of sweat losses in male players, published by Maughan and Leiper (1994), revealed that athletes can lose 1.0 – 2.5 litres in matches held in temperate climates and as much as 3.5 litres in the heat. In 2005, the FIFA Medical Committee added a provision that "players are entitled to take liquid refreshment during a stoppage in the match but only on the touch line". In many parts of the world (Central and South America, Mexico, southern USA), football is often played in hot conditions and on a field of play that offers no shade or relief from the heat. Fluid intake is especially challenging in football (whether in hot or cool climates), as there are no time-outs and at many levels of the sport matches are scheduled in short time frames with little time for recovery (Kirkendall, 2004). Coyle (2004) reviewed the fluid needs of athletes during exercise and summarized the recommendations, although no research is available to assess gender differences. For both health and performance, Coyle (2004) recommends:

- Fluid intake that matches sweating rate and, when exercising in hot environmental conditions, dehydration of 1% of body weight should be the limit of fluid loss.
- During exercise lasting more than an hour (football match), ingesting 30 – 60 g carbohydrate $\cdot$ h^{-1} can delay fatigue.

Burke and Hawley (1997) reported fluid balance of a women's football team during international competition in a hot climate. The women's mean sweat losses were approximately 0.8 litres $\cdot$ h^{-1} during training and 1.5 litres $\cdot$ h^{-1} during a match. The rate of fluid replacement was the same during training and competition at about 0.4 litres $\cdot$ h^{-1}.

Shirreffs *et al.* (2004) reviewed pre- and post-exercise hydration and concluded that athletes who fail to hydrate after exercise can compromise the subsequent exercise bout. This is especially relevant in football when training and competition frequently occur on consecutive days. Rehydrating with electrolyte-containing beverages is preferred, as volume losses as well as sodium and chloride need to be replaced (Shirreffs *et al.*, 2004). Shirreffs conducted a number of on-field tests to assess sweat sodium and hydration practices, and about 30 of the athletes were women (Burke, 2005). Shirreffs noted that many females gained weight over the training sessions. Females may be more conscious of hydration than males. Mullinix *et al.* (2003) found that women responded appropriately to questions on the importance of hydration (100% knew that fluids should be replaced before, during, and after exercise), but were not as knowledgeable about the most appropriate fluids to consume (only 11% agreed with the statement that "PowerAde and other sports drinks are better than water at replacing fluids").

Micronutrients

Micronutrient intakes of female soccer players (Table I) were adequate for all nutrients except vitamin D, vitamin E, folate, calcium, magnesium, phosphorus, and zinc, which were less than 100% of the dietary reference intakes (DRIs). The DRIs are established for healthy individuals and intense physical activity may increase the need for several vitamins and minerals. However, most authors conclude that supplementation of micronutrients does not improve performance (Akabas and Dolins, 2005; Fogelholm, 1994), but athletes with suboptimal nutrient status may see a further decline in nutrient stores with heavy exercise (Manore, 2000). In a recent review of micronutrient requirements in athletic women, Akabas and Dolins (2005) concluded that "despite an upsurge in interest in physical activity, for most vitamins and minerals, current research is not conclusive enough to provide specific micronutrient recommendations to physically active women. It is clear that they need to get at least the RDA [recommended daily allowance] for micronutrients, and that many women fail to do so for several vitamins and minerals".

Two micronutrients of concern in exercising females are iron and calcium. The impact of iron deficiency anaemia on performance is well documented. In a review on haemoglobin and iron deficiency, Ekblom (1997) states that iron supplementation in anaemic athletes can increase aerobic power and improve performance. It is less clear if athletes with iron deficiency without anaemia (usually defined as low serum ferritin with normal haemoglobin) benefit from treatment with iron supplementation. Ekblom (1997) concludes that no studies show positive effects on performance when iron is supplemented in non-anaemic athletes. In two recent studies, Brutsaert *et al.* (2003) and Brownlie, Utermohlen, Hinton, Giordano and Haas (2002) studied women with iron deficiency supplemented with iron for 6 weeks. Brutsaert *et al.* (2003) had their participants perform knee contraction and extension exercises and Brownlie *et al.* (2004) had their participants work on cycle ergometers. Both researchers found women in the iron supplementation group improved exercise tolerance compared with the placebo group. Because these studies are not soccer-specific and knee contraction exercises may be irrelevant to endurance, more research is needed on females and iron status. Athletes who manifest with iron deficiency should be monitored to make sure the deficiency does not develop into anaemia. Athletes who are vegetarian or eat little haem-iron-containing foods should be monitored for iron status. Ekblom (1997) speculated that a high-carbohydrate diet may result in a less than desirable iron intake.

Fallon (2004) screened 174 elite female athletes, 33 of them footballers, for haematological variables. Fifty-eight percent of the football players had abnormalities in their haematological profile, suggesting that elite female footballers should be routinely screened for iron deficiency with or without anaemia.

Encouraging female footballers to include haem-iron-containing foods, as well as pairing non-haem-iron-containing foods with vitamin C-containing foods, is a good strategy. In addition, many women can benefit from a vitamin – mineral preparation that contains the DRI for iron.

Football is not a sport associated with extreme leanness or thinness, but many females feel social pressure to maintain a desirable body weight and percentage body fat, which could lead to insufficient energy intake to fuel sport. The presence of menstrual irregularities is well documented in distance runners and ballet dancers (DeSouza *et al.*, 1998), but the prevalence is unclear in female footballers. Mullinix *et al.* (2003) and Clark *et al.* (2003) reported that their participants did not have amenorrhoea. However, in a higher energy demand sport, like football, females could have insufficient energy intake to support activity, leading to hormonal imbalances without obvious symptoms (Loucks, 2004). DeSouza *et al.* (1998) studied 46 women aged 18 – 36 years with normal menses and no history of eating disorders. Women were classified as sedentary or recreational runners (running at least 2 h a week or 16 km per week in the past year) and hormonal data were collected for three consecutive menstrual cycles. The recreational runners ran, on average, 32 km per week. The incidence of abnormal menstrual function in the runners was 79%, with defects noted in menstrual cycle inconsistencies from month to month. The runners presented with luteal phase deficiency and anovulation, whereas none of the sedentary group had abnormalities.

The question arises if female footballers have unrecognized menstrual irregularities that could affect their bone mineral status. Soderman, Bergstrom, Lorentzon and Alfredson (2000) measured bone mineral density (BMD) in teenage female footballers (age 16 years) who had been playing football for an average of 8 years and age-matched inactive girls. The footballers reached menarche, on average, at age 13.0 years, similar to the age of 12.8 year for the sedentary girls. The athletes had greater bone mass in the hip and lumbar spine than the sedentary girls. The authors noted that the increase in BMD is evident in early adolescence and becomes more pronounced in late adolescence as more time is spent in football practice and competition (Soderman *et al.*, 2000).

Pettersson, Nordstrom, Alfredson, Henriksson-Larsen and Lorentzon (2000) compared BMD in female footballers and competitive rope-skippers. Both groups of young women (average age about 17.5 years) trained about $6\,h \cdot week^{-1}$. The athletes were compared with age-matched sedentary controls and all had regular menses at the time of the study. Both groups of athletes had higher BMD than the controls in the sites that were most affected by weight-bearing exercise (lumbar spine, femur, tibia).

It can be concluded that female footballers have superior BMD than inactive females, indicating that hormonal status in these women is sufficient to promote bone health. However, because some athletic women strive for thinness, monitoring menstrual status in this population is warranted.

Dietary supplements

Mullinix *et al.* (2003) reported that 55% of the US Under-21 female players took nutrient supplements occasionally, 33% took supplements daily, and 11% did not take any supplements. The most popular supplements were multivitamin/mineral preparations, vitamin C, calcium, iron, and zinc. Clark *et al.* (2003) reported that female collegiate footballers took multivitamin/mineral supplements and iron, but did not report the percentage of athletes using supplements.

Although creatine use was not reported by either group of female athletes in the studies reviewed for this paper, creatine supplementation has been investigated as a performance-enhancing supplement in both endurance and power athletes. Creatine is found in the diet in meat and fish with less than $1\,g \cdot day^{-1}$ ingested from animal foods (Hespel, Maughan, & Greenhaff, 2006). Creatine supplementation is popular in strength and power sports relying on the anaerobic energy system. Creatine is also used by athletes to enhance training response (Volek & Kraemer, 1996). Creatine supplementation does not benefit endurance athletes. Balsom, Harridge, Soderlund, Sjodin and Ekblom (1993) studied 18 trained men in a double-blind design and gave them creatine monohydrate or placebo for 6 days prior to the endurance exercise trials. There were no significant differences in performance between groups, but the creatine-supplemented group gained weight after supplementation.

Larson-Meyer *et al.* (2000) studied creatine supplementation in female collegiate soccer players to assess changes in body composition and muscle strength. Fourteen members of the team were recruited to participate in the study in the off-season. Seven players were given a loading dose of creatine monohydrate ($0.24\,g \cdot kg$ body $mass^{-1}$ or about 15 g) in a sports drink for 5 days, and 5 g of creatine in a sports drink for a maintenance dose. Seven players served as controls and the sports drink without creatine was used as placebo. The participants completed strength workouts at baseline and every 2 weeks for a total of 13 weeks. Soccer practice was started 2 weeks after supplementation with creatine and consisted of soccer-specific drills. At the end of 13 weeks, both groups increased body mass with no significant difference between creatine supplementation and placebo. The creatine-supplemented group showed a greater improvement in bench press and squat and the effects were most pronounced after 5 weeks of supplementation. Despite the limitations of the study (small number of participants, not all participants completed all strength measures, and the placebo did not contain protein), the authors suggested that creatine supplementation in female soccer players could have some advantages. Players may improve maximal strength, which could help them shield the ball and maintain possession. The authors also noted that creatine supplementation did cause additional weight gain beyond usual weight gain from weight training. Many female athletes avoid creatine use because the main side-effect is weight gain.

Special considerations

There are no reports of the number of female football ers who practise vegetarianism, but vegetarian athletes face unique challenges to proper nutrition (Barr & Rideout, 2004). Vegetarians usually consume sufficient protein, but may be at risk for iron deficiency. It has been reported that vegetarians have a lower mean muscle creatine concentration than meat eaters (Delanghe *et al.*, 1989) and it has been suggested that vegetarian athletes might benefit from creatine supplementation. Vegetarianism can be a healthy eating practice if nutrient-dense foods are selected and special attention is paid to consumption of vitamin B12, calcium, zinc, iron, and magnesium. However, some women choose vegetarian diets for weight control and this practice may conceal a disordered eating pattern.

Youth players

Type in the words "youth soccer" in the search engine "Google" and 4,690,000 pages appear. FIFA reported that in 2000, almost 18 million youth played football worldwide (www.FIFA.com). The American Youth Soccer Organization (youth aged 4–12 years) identifies 50,000 teams with more than

650,000 participants (AYSO, 2005). The National Sporting Goods Association reports a 6.2% increase in the number of 7- to 11-year-olds participating in soccer since 1994 (NSGA, 2004b). The Football Association reports that girls' football is "booming" in England. Figures for May 2002 revealed that 85% of girls aged 7–15 years played football and 65% of that age group played football at least once a week, a figure of 1.4 million girls (The Football Association, 2003).

Youth players have unique physical demands for growth and development that make nutrition more important than just as a fuel for sport. In addition, there is wide variation in physical growth and maturation of young athletes at the same chronological age. Rules governing youth football are different from adult rules, and vary by age group. The purposes of the rules for youth are to make matches fun (e.g. smaller fields), make matches safer (e.g. no slide tackling), and more evenly matched (e.g. small sided) (Bar-Or & Unnithan, 1994; www.usyouthsoccer.org). For example, children under 6 play four 8 min quarters with a 2 min break between quarters and a 5 min half-time. Each player plays a minimum of 50% of total playing time. Children under 10 play two 25 min halves with a 5 min break at half-time. Many youth leagues allow unlimited substitutions during matches (www.usyouthsoccer.com).

Rowland (2000) reviewed what is known about the effects of exercise on the young athlete and concluded that both growth and functional changes that occur in children make it difficult to assess the effects of exercise on growth and development. It is clear that thermoregulatory responses of children are different from those of adults: children expend more energy per kilogram to perform work than adults and children sweat less during activity (Rowland, 2000), making thermoregulation more challenging.

Energy and nutrient intakes

Few studies have addressed the energy and nutrient intakes of youth football players (for a comprehensive review of general nutritional considerations in young, competitive athletes, see Petrie, Stover, & Horswill, 2004). Iglesias-Gutierrez *et al.* (2005) and Ruiz *et al.* (2005) recently published studies of nutritional intake in male youth players. Table II summarizes the mean energy and macronutrient intakes of young (14–16 years) players participating at high levels of the sport. Ruiz *et al.* (2005) compared young players in different age groups (14-, 15-, and 16-year-olds) and collected dietary data using weighed food records. Iglesias-Gutierrez *et al.* (2005) reported mean data obtained from the youths' home environment. Both groups of researchers reported mean data but noted a wide range in individual nutrient intakes and heterogeneity of anthropometric measures.

Iglesias-Gutierrez *et al.* (2005) estimated mean energy expenditure at 2983 kcal · day^{-1} and an energy intake of 3003 kcal · day^{-1}. Carbohydrate intake was 45% of energy intake or 5.6 g · kg^{-1} on average; this is less than the recommendations for highly active athletes. Protein intake averaged 1.9 g · kg^{-1}. Micronutrient intakes were below the DRIs for folate, vitamin E, calcium, magnesium, and zinc. Biochemical and haematological values were measured and 48% of these young athletes had iron deficiency without anaemia, as assessed by low ferritin levels, despite a diet adequate in iron (143% of DRI).

Ruiz *et al.* (2005) compared energy and nutrient intake among players of different ages (14-, 15-, 16-, and 20-year-olds). Younger athletes had higher energy intakes, consumed more monounsaturated fatty acids, and were more likely to eat breakfast than the 20-year old players, but energy and carbohydrate intakes did not meet recommendations for any age group. The researchers also collected information on consumption of meals and snacks and noted a trend

Table II. Daily mean energy and macronutrient intakes of adolescent footballers.

	Spanish adolescents (14–16 years)[a] ($n = 32$)	Arenas FC players (14 years)[b] ($n = 18$)	Arenas FC players (15 years)[b] ($n = 20$)	Arenas FC players (16 years)[b] ($n = 19$)	Arenas FC players (21 years)[b] ($n = 25$)
Energy (kcal · day^{-1})	3003	3456	3418	3478	3030
Energy (kcal · kg^{-1})	46.5	54.6	51.5	48.4	41.4
Protein (g · day^{-1})	123	128.5	141.9	150.2	132.8
Protein (g · kg^{-1})	1.9	2.0	2.1	2.0	1.8
Carbohydrate (g · day^{-1})	364	422	391	392	334
Carbohydrate (g · kg^{-1})	5.6	6.7	5.9	5.3	4.6
Fat (g · day^{-1})	127	139	142	154	128
Fat (g · kg^{-1})	1.95	2.2	2.15	2.15	1.8

[a]Iglesias-Gutierrez *et al.* (2005), [b]Ruiz *et al.* (2005).

for the older athletes to skip meals, especially breakfast, which could contribute to the decline in energy and nutrient intakes seen in this age group. The authors concluded that younger players live in a more controlled food environment (eating at school or home) than the older players. A nutrition education programme, starting with younger players, may help promote healthy dietary habits as players get older.

None of the boys in the above two studies (Iglesias-Gutierrez *et al.,* 2005; Ruiz *et al.,* 2005) consumed adequate carbohydrate to support energy expenditure in training or competition. Fat intake was adequate in both relative and absolute amounts. Boys use more fat ($\sim$70% more) and less carbohydrate ($\sim$23% less) than men during activity performed at about the same intensity (Timmons, Bar-Or, & Riddell, 2003). Recent findings that the lower carbohydrate storage and utilization of women appears to be due to their lower carbohydrate intake (M'Kaouar *et al.*, 2004; Roepstorff *et al.*, 2002; Tarnopolsky *et al.*, 2001a) support the suggestion that increasing carbohydrate intake during activity of high intensity lasting longer than 60 min may also improve the performance and spare endogenous stores for growth and development of boys (Timmons *et al.,* 2003).

Athletes who engage in regular sports activities need slightly higher protein than sedentary people (Institute of Medicine, 2002). Boisseau, LeCreff, Loyens and Poortmans (2002) compared youth football players (age 15 years) with sedentary age-matched non-athletes. Seven-day food diaries were collected and protein status was assessed by nitrogen balance techniques. Both the athletes and the sedentary adolescents needed a protein intake of $1.6\,g \cdot kg^{-1} \cdot day^{-1}$ to obtain a positive nitrogen balance. This study is the first to address protein needs of youth football players. However, researchers have questioned the benefit of using nitrogen balance as an assessment tool to recommend higher protein intake in athletes (Millward, 2004). Further research is warranted to assess protein needs in young athletes.

Fluids

Few studies have assessed the hydration status of young athletes. Active children do not adapt to conditions of high heat and humidity as effectively as adults, and the adaptation of adolescents has been described as somewhere between that of children and adults (American Academy of Pediatrics, 2000). The US Soccer Federation issued guidelines to prevent heat illness in young football players in 2002 and these are summarized in Table III.

Rico-Sanz *et al.* (1996) assessed the effect of increased fluid intake on temperature regulation in eight elite youth footballers and found that those who hyperhydrated improved the ability to regulate body temperature during a 90 min match played in hot, humid conditions. There was no effect on soccer performance.

Table III. US Soccer Federation (2002) youth soccer heat stress guidelines.

Before activity
- Players should be well hydrated
  - Check urine colour for hydration status

During activity
- Drink early
- Consume 5 – 9 ounces (5 ounces for a player weighing less than 90 pounds, 9 ounces for a player weighing more than 90 pounds) every 20 min while active
- Sports drinks are preferred to water

After activity
- Drink every 20 min for one hour after activity, regardless of thirst

Fluids to avoid during practice or a game
- Fruit juice
- Carbonated beverages
- Caffeinated beverages
- Energy drinks

Dietary supplements

Young athletes are increasingly using dietary supplements that are touted as performance enhancing. The reasons cited for use of dietary supplements in youth include the following:

- Athletes reach a plateau in training and the use of a performance-enhancing supplement may allow him or her to break through the plateau.
- Peer pressure from coaches, parents, and teammates to use supplements.
- The cultural norm in some sports is to use supplements.
- Knowledge that competitors use supplements.
- Dietary supplements are readily available for purchase and are advertised as "safe and natural" ways to improve physical and mental performance.
- Trickle down effect from elite adult athletes using supplements to young athletes who want to emulate a sports hero.
- No drug testing in many youth sports (DesJardins, 2002; Metzl, 2002; Metzl, Small, Levene, & Gershel, 2001).

While not popular in all countries, the prevalence of creatine use in adolescent athletes is reported to be 7 – 30% in the USA, with athletes as young as 12 years using creatine (DesJardins, 2002). The American College of Sports Medicine (2000) does not advise creatine use in those under the age of 18 years, but it is clear that some young athletes use this dietary supplement.

Ostojic (2004) studied creatine use in young football players. He randomly assigned 20 young soccer players (mean age 16.6 years) to creatine monohydrate (at 10 g × 3 doses per day) or placebo and measured soccer-specific skills at baseline and after 7 days of creatine or placebo ingestion. Significant improvements were noted in a dribbling test, a power test, and vertical jump between pre- and post-creatine ingestion and between the creatine group and placebo group. The authors concluded that acute creatine ingestion may improve performance in soccer-related tasks, but cautioned that creatine use is not recommended for those under 18 years. The dose of creatine given in this study ($30\,g \cdot day^{-1}$) is higher than the usual doses of creatine recommended to athletes and the placebo was a cellulose pill. Tarnopolsky *et al.* (2001b) believed that comparing a creatine supplemented experimental group with a control group receiving a non-protein-containing placebo is not a good experimental design. They showed that when energy and protein are equivalent (i.e. creatine versus a carbohydrate and a nitrogen-containing placebo), strength and mass are similar (Tarnopolsky *et al.*, 2001b).

Special considerations

Elite youth players frequently play several matches within a short time frame, which can have consequences for the immune system. Malm, Ekblom and Ekblom (2004) studied elite football players (16 to 19 years) who played two consecutive games separated by 20 h. Blood measures of cells of the immune system were taken before the first match, immediately after the second match, and at 6, 24, 48, and 72 h after the second match. Players with greater aerobic capacity demonstrated smaller changes in some measures of immunity, but at least 72 h was needed to reach normal levels of cells of the immune system after two competitive matches.

Summary and recommendations

Little is known about the nutrient intake or nutritional status of female and young footballers. From the few studies reviewed, it is clear that some female and young players do not get adequate carbohydrate to fuel the demands of training and competition. Micronutrients of concern in both females and young athletes include folate, vitamin E, calcium, magnesium, and zinc. Biochemical assessment reveals concern for iron deficiency without anaemia, although it is unlikely that this haematological abnormality affects performance. However, if left undetected and untreated, iron deficiency anaemia could be the result.

Female athletes appear to have good knowledge about hydration in general, but may need more guidance in choosing the most appropriate beverage during exercise and for recovery. Young athletes may have better nutrient intakes and food behaviours than older athletes because they have a more controlled dietary environment.

Recommendations for female players

- Provide carbohydrate recommendations in absolute terms ($g \cdot kg^{-1}$) versus relative terms (percent of energy) and provide levels of carbohydrate consumption for pre-season, in-season, and post-season.
- Monitor post-season intake to ensure adequate intake of nutrients so athletes report for pre-season training with adequate nutrient stores.
- Educate athletes on hydration and the preferred beverages for rehydration.
- Monitor iron status in females and recommend consumption of an iron-rich diet with adequate energy for those with iron deficiency without anaemia.
- Explore new methodologies to obtain dietary data. Food diaries are difficult to obtain and under-reporting is common. One methodology worthy of exploration is the use of the cell phone camera to take pictures of meals and snacks consumed, which can then be analysed and timely feedback provided. One US company (www.myfoodphone.com) is using this technology as a dieting tool but it could be adapted for use as a research tool for athletes.

Recommendations for young players

- Provide nutrition education to athletes at an early age with the goal of improving nutritional status and nutrient intakes as the players get older.
- Monitor young players for iron deficiency without anaemia.
- Provide carbohydrate to athletes during training and competition.
- Assess protein needs of young athletes to determine the most appropriate dietary protein guidelines.

References

Akabas, S. R., & Dolins, K. R. (2005). Micronutrient requirements of physically active women: What can we learn from iron? *American Journal of Clinical Nutrition*, *81*, 1246S – 1251S.

American Academy of Pediatrics (2000). Climatic heat stress and the exercising child and adolescent. *Pediatrics*, *106*, 158 – 159.

American College of Sports Medicine (2000). The physiological and health effects of oral creatine supplementation. *Medicine and Science in Sports and Exercise*, *32*, 706 – 717.

American Dietetic Association, Dietitians of Canada, and the American College of Sports Medicine (2000). Position statement: Nutrition and athletic performance. *Journal of the American Dietetic Association*, *100*, 1543 – 1556.

American Youth Soccer Organization (2005). *American youth soccer* (available at: http://soccer.org; accessed 6 July 2005).

Bailey, S. P., Zacher, C. M., & Mittleman, K. D. (2000). Effect of menstrual cycle phase on carbohydrate supplementation during prolonged exercise to fatigue. *Journal of Applied Physiology*, *88*, 690 – 697.

Balsom, P. D., Harridge, S. D. R., Soderlund, K., Sjodin, B., & Ekblom, B. (1993). Creatine supplementation *per se* does not enhance endurance exercise performance. *Acta Physiologica Scandinavica*, *149*, 521 – 523.

Bangsbo, J. (1994). Energy demands in competitive soccer. *Journal of Sports Sciences*, *12*, S5 – S12.

Bar-Or, O., & Unnithan, V. B. (1994). Nutritional requirements of young soccer players. *Journal of Sports Sciences*, *12*, S39 – S42.

Barr, S., & Rideout, C. A. (2004). Nutritional considerations for vegetarian athletes. *Nutrition*, *20*, 696 – 703.

Boisseau, N., LeCreff, C., Loyens, M., & Poortmans, J. R. (2002). Protein intake and nitrogen balance in male non-active adolescents and soccer players. *European Journal of Applied Physiology*, *88*, 288 – 293.

Brewer, J. (1994). Nutritional aspects of women's soccer. *Journal of Sports Sciences*, *12*, S35 – S38.

Brownlie, T., Utermohlen, V., Hinton, P. S., Giordano, C., & Haas, J. D. (2002). Marginal iron deficiency without anemia impairs aerobic adaptation among previously untrained women. *American Journal of Clinical Nutrition*, *78*, 702 – 710.

Brutsaert, T. D., Hernandez-Cordero, S., Rivera, J., Viola, T., Hughes, G., & Haas, J. D. (2003). Iron supplementation improves progressive fatigue resistance during dynamic knee extensor exercise in iron-depleted, nonanemic women. *American Journal of Clinical Nutrition*, *77*, 441 – 448.

Burke, L. M. (2005). Fluid balance testing for elite team athletes: An interview with Dr. Susan Shirreffs. *International Journal of Sport Nutrition and Exercise Metabolism*, *15*, 323 – 327.

Burke, L. M., Cox, G. R., Cummings, N. K., & Desbrow, B. (2001). Guidelines for daily carbohydrate intake. Do athletes achieve them? *Sports Medicine*, *31*, 267 – 299.

Burke, L. M., & Hawley, J. A. (1997). Fluid balance in team sports. *Sports Medicine*, *24*, 38 – 53.

Burke, L. M., Keins, B., & Ivy, J. L. (2004). Carbohydrates and fat for training and recovery. *Journal of Sports Sciences*, *22*, 15 – 30.

Burke, L. M., Slater, G., Broad, E. M., Haukka, J., Modulon, S., & Hopkins, W. G. (2003). Eating patterns and meal frequency of elite Australian athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *13*, 521 – 538.

Campbell, S. E., Angus, D. J., & Febbraio, M. A. (2001). Glucose kinetics and exercise performance during phases of the menstrual cycle: Effect of glucose ingestion. *American Journal of Physiology: Endocrinology and Metabolism*, *281*, E817 – E825.

Clark, M., Reed, D. B., Crouse, S. F., & Armstrong, R. B. (2003). Pre- and post-season dietary intake, body composition and performance indices of NCAA Division I female soccer players. *International Journal of Sport Nutrition and Exercise Metabolism*, *13*, 303 – 319.

Coyle, E. F. (2004). Fluid and fuel intake during exercise. *Journal of Sports Sciences*, *22*, 39 – 55.

Davies, H. (2005). The fan. *The New Statesman*, 4 April.

Delanghe, J., DeSlypere, J. P., Dehuyzere, M., Robbrecht, J., Wieme, R., & Vermeulen, A. (1989). Normal reference values for creatine, creatinine, and carnitine are lower in vegetarians. *Clinical Chemistry*, *35*, 1802 – 1803.

DesJardins, M. (2002). Supplement use in the adolescent athlete. *Current Sports Medicine Reports*, *1*, 369 – 373.

DeSouza, M. J., Miller, B. E., Loucks, A. B., Luciano, A. A., Pescatello, L. S., Campbell, C. G. *et al.* (1998). High frequency of luteal phase deficiency and anovulation in recreational women runners: Blunted elevation in follicle-stimulating hormone observed during luteal-follicular transition. *Journal of Clinical Endocrinology and Metabolism*, *83*, 4220 – 4232.

Ekblom, B. (1997). Micronutrients: Effects of variation in [Hb] and iron deficiency on physical performance. In A. P. Simopoulos & K. N. Pavlou (Eds.), *Nutrition and fitness: Metabolic and behavioral aspects in health and disease* (pp. 122 – 130). Basel: Karger.

Fallon, K. E. (2004). Utility of haematological and iron-related screening in elite athletes. *Clinical Journal of Sports Medicine*, *14*, 145 – 152.

FIFA (2005). *FIFA laws of the game 2005/2006* (available at http://dps.twiihosting.net/USSF/doc; accessed 10 August 2005).

Fogelholm, M. (1994). Vitamins, minerals and supplementation in soccer. *Journal of Sports Sciences*, *12*, S23 – S27.

Fogelholm, M., Kukkonen-Harjula, T. K., Taipale, S. A., Sievanen, H. T., Oja, P., & Vuori, I. M. (1995). Resting metabolic rate and energy intake in female gymnasts, figure skaters, and soccer players. *International Journal of Sports Medicine*, *16*, 551 – 556.

Hespel, P., Maughan, R. J., & Greenhaff, P. L. (2006). Dietary supplements for soccer. *Journal of Sports Sciences*, *24*, 749 – 761.

Hinton, P. S., Sanford, T. C., Davidson, M. M., Yakushko, O. F., & Beck, N. C. (2004). Nutrient intakes and dietary behaviors of male and female collegiate athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *14*, 389 – 405.

Iglesias-Gutierrez, E., Garcia-Roves, P. M., Rodriguez, C., Braga, S., Garcia-Zapico, P., & Patterson, A. M. (2005). Food habits and nutritional status assessment of adolescent soccer players: A necessary and accurate approach. *Canadian Journal of Applied Physiology*, *30*, 18 – 32.

Institute of Medicine (2002). *Dietary reference intakes for energy, carbohydrates, fiber, fat, protein, and amino acids (macronutrients)*. Washington, DC: National Academy Press (available at: http://www.nap.edu/books; accessed 26 July 2005).

Kirkendall, D. T. (2000). Physiology of soccer. In W. E. Garrett & D. T. Kirkendall (Eds.), *Exercise and sport science* (pp. 875 – 884). Philadelphia, PA: Lippincott Williams & Wilkins.

Kirkendall, D. T. (2004). Creatine, carbs, and fluids: How important in soccer nutrition? *Sports Science Exchange*, *17*, 1 – 6.

Larson-Meyer, D. E., Hunter, G. R., Trowbridge, C. A., Turk, J. C., Ernest, J. M., Torman, S. L. *et al.* (2000). The effect of creatine supplementation on muscle strength and body composition during off-season training in female soccer players. *Journal of Strength and Conditioning Research*, *14*, 434 – 442.

Lemon, P. W. R. (1994). Protein requirements of soccer. *Journal of Sports Sciences*, *12*, S17 – S22.

Loucks, A. B. (2004). Energy balance and body composition in sports and exercise. *Journal of Sports Sciences*, *22*, 1 – 14.

Malm, C., Ekblom, O., & Ekblom, B. (2004). Immune system alteration in response to two consecutive soccer games. *Acta Physiologica Scandinavica*, *180*, 143 – 155.

Manore, M. M. (2000). Effect of physical activity on thiamine, riboflavin, and vitamin B-6 requirements. *American Journal of Clinical Nutrition*, *72*, 598S – 606S.

Maughan, R. J., & Leiper, J. B. (1994). Fluid replacement requirements in soccer. *Journal of Sports Sciences*, *12*, S29 – S34.

Metzl, J. D. (2002). Performance-enhancing drug use in the young athlete. *Pediatric Annals*, *31*, 27 – 32.

Metzl, J. D., Small, E., Levine, S. R., & Gershel, J. C. (2001). Creatine use among young athletes. *Pediatrics*, *108*, 421 – 425.

Millward, D. J. (2004). Protein and amino acid requirements of athletes. *Journal of Sports Sciences*, *22*, 143 – 145.

M'Kaouar, H., Peronnet, F., Massicotte, D., & Lavoie, C. (2004). Gender difference in metabolic response to prolonged exercise with [^{13}C] glucose ingestion. *European Journal of Applied Physiology*, *92*, 462–469.

Mullinix, M. C., Jonnalagadda, S. S., Rosenbloom, C. A., Thompson, W. R., & Kicklighter, J. A. (2003). Dietary intake of female U.S. soccer players. *Nutrition Research*, *23*, 585–593.

National Sporting Goods Association (2004a). *Women's participation – ranked by total female participation* (available at: www.nsga.org; accessed 10 July 2005).

National Sporting Goods Association (2004b). *Youth participation in selected sports with comparisons to 1994* (available at: www.nsga.org; accessed 10 July 2005).

Ostojic, S. J. (2004). Creatine supplementation in young soccer players. *International Journal of Sport Nutrition and Exercise Metabolism*, *14*, 95–103.

Pettersson, U., Nordstrom, P., Alfredson, H., Henriksson-Larsen, K., & Lorentzon, R. (2000). Effect of high impact activity on bone mass and size in adolescent females: A comparative study between two different types of sports. *Calcified Tissue International*, *67*, 207–214.

Petrie, H. J., Stover, E. A., & Horswill, C. A. (2004). Nutritional concerns for the child and adolescent competitor. *Nutrition*, *20*, 620–631.

Reilly, T. (1997). Energetics of high-intensity exercise (soccer) with particular reference to fatigue. *Journal of Sports Sciences*, *15*, 257–263.

Rico-Sanz, J., Frontera, W. R., Rivera, M. A., Rivera-Brown, A., Mole, P. A., & Meredith, C. N. (1996). Effects of hyperhydration on total body water, temperature regulation and performance of elite young soccer players in a warm climate. *International Journal of Sports Medicine*, *17*, 85–91.

Riddell, M. C., Partington, S. L., Stupka, N., Armstrong, D., Rennie, C., & Tarnopolsky, M. A. (2003). Substrate utilization during exercise performed with and without glucose ingestion in female and male endurance-trained athletes. *International Journal of Sport Nutrition and Exercise Metabolism*, *13*, 407–421.

Roepstorff, C., Steffensen, C. H., Madsen, M., Stallknecht, B., Kanstrup, I., Richter, E. A. *et al.* (2002). Gender differences in substrate utilization during submaximal exercise in endurance-trained subjects. *American Journal of Physiology: Endocrinology and Metabolism*, *282*, E435–E447.

Rowland, T. W. (2000). Exercise and the child athlete. In W. E. Garrett & D. T. Kirkendall (Eds.), *Exercise and sport science* (pp. 339–349). Philadelphia, PA: Lippincott Williams & Wilkins.

Ruiz, F., Irazusta, A., Gil, S., Irazusta, J., Casis, L., & Gil, J. (2005). Nutritional intake in soccer players of different ages. *Journal of Sports Sciences*, *23*, 235–242.

Shirreffs, S. M., Armstrong, L. E., & Cheuvoront, S. N. (2004). Fluid and electrolyte needs for training, competition, preparation and recovery. *Journal of Sports Sciences*, *22*, 57–63.

Soderman, K., Bergstrom, E., Lorentzon, R., & Alfredson, H. (2000). Bone mass and muscle strength in young female soccer players. *Calcified Tissue International*, *67*, 297–303.

Tarnopolsky, M. A., Atkinson, S. A., Phillips, S. M., & MacDougall, J. D. (1995). Carbohydrate loading and metabolism during exercise in men and women. *Journal of Applied Physiology*, *78*, 1360–1388.

Tarnopolsky, M. A., Parise, G., Yardley, N. J., Ballantyne, C. S., Olatunji, S., & Phillips, S. M. (2001b). Creatine-dextrose and protein-dextrose induce similar strength gains during training. *Medicine and Science in Sports and Exercise*, *33*, 2040–2052.

Tarnopolsky, M. A., Zwada, C., Richmond, L. B., Carter, S., Shearer, J., Graham, T. *et al.* (2001a). Gender differences in carbohydrate loading are related to energy intake. *Journal of Applied Physiology*, *91*, 225–230.

The Football Association (2002). *A brief history: Women's football* (available at: http://www.thefa.com/Womens/EnglandSenior/History; accessed 3 August 2002).

The Football Association (2003). *Participation figures* (available at: http://wwwthefa.com/Womens/Reference-FAQ/Posting/2003/11/Participation+Figures.htm; accessed 1 August 2005).

The Football Association (2005). *Studying the game* (available at: http://www.thefa.com/Womens/EnglandSenior/NewsAndFeatures; accessed 1 August 2005).

Timmons, B. W., Bar-Or, O., & Riddell, M. C. (2003). Oxidation rate of exogenous carbohydrate during exercise is higher in boys than men. *Journal of Applied Physiology*, *94*, 278–284.

Tipton, K. D., & Wolfe, R. R. (2004). Protein and amino acids for athletes. *Journal of Sports Sciences*, *22*, 65–79.

US Soccer Federation (2002). *Youth soccer heat stress guidelines* (available at: www.ussoccer.com; accessed 3 July 2005).

Volek, J. S., & Kraemer, W. J. (1996). Creatine supplementation: Its effect on human muscular performance and body composition. *Journal of Strength and Conditioning Research*, *10*, 200–210.