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Body Composition and Nutritional Assessments in Soccer

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This review summarizes results from studies investigating the physical characteristics, daily energy expenditures, diets, and effects of nutritional supplements to the habitual diets of soccer players. The results show that players fall within a wide range of stature and body weight, and they are classified as mesomorphs. The body fat of male players is about 10% of body weight, whereas the average for females is about 21%. Energy expenditure for males is about 4,000 kcal on training days and 3,800 kcal on match day, while energy intake reported in other studies is on the order of 3,700 kcal. Carbohydrate (CHO), fat, and protein intakes are about 53, 30, and 14% of energy intake, respectively, the remaining being from alcohol intake. There are indications that CHO supplements might be beneficial during soccer performance. However, more research is needed to clarify the importance of branched-chain amino acid and creatine supplementation in soccer.

Soccer scientists have used skinfold thickness, underwater weighing, and bioelectrical impedance to estimate the composition of soccer players' bodies (7–9, 13, 16, 17, 31, 33, 40, 45, 49). Players' energy expenditures and weight loss during training and competition have been estimated from physiological measurements in soccer matches and in laboratory conditions (4, 14, 22, 28, 35, 41, 42, 44). Daily activity records have been used to estimate energy output, and dietary records have been used to assess players' energy intake and the quality of their diets during training and competition (4, 8, 17, 20, 24, 35, 39, 40, 47, 48). Carbohydrates (CHO), branched-chain amino acids (BCAA), creatine (Cr), and water have also been added to players' habitual diets to evaluate the effect of these items on physiological parameters and performance (4, 23, 24, 27, 34, 41, 45, 51). This review summarizes studies that assessed the physical characteristics, daily energy expenditures, and diets of soccer players, and it evaluates the effects of nutritional supplements that may enhance soccer performance.

Anthropometric Characteristics

The average age of elite senior soccer players is about 25 years for males and about 23.5 years for females (see Tables 1 and 2). The male soccer players' average height

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and weight are about 179 cm and 76 kg, respectively (Table 1). Goalkeepers and central defenders are usually taller and heavier than the rest of the team (13). Body fat (BF) assessment by skinfold thickness shows that the average percentage BF of outfield players is about 10% of body weight (Table 1). Hydrostatic weighing has shown the BF percentage of a group of American professional (n = 18) and college (n = 17) players to be 9.6 and 9.8% (33, unpublished observations), respectively, and that of under-18 Canadian elite players (n = 17) to be 8.0% (25). There appears to be little difference in BF percentage and distribution among the different outfield positions, although midfielders tend to have lower fat content (5, 13, 31, 33). However, goalkeepers appear to have larger BF percentage compared to defenders, midfielders, and forwards (5, 13). BF of professional goalkeepers is about 13% of body weight, whereas that of college goalkeepers is about 17% (5, 13). The very few data available for 36 female soccer players reveal that their average BF is on the order of 21% (Table 2).

The somatotype rating, which includes three components (endomorph, mesomorph, ectomorph), has also been used to describe soccer players. Somatotype ratings obtained for European college (n = 61), European Champion Portuguese junior team (under-16), professional (n = 17), and World Cup–caliber (n = 18) players showed a large mesomorphy estimate (1, 5, 16, 32, 50), with no differences between starters and substitutes (32). However, goalkeepers had significantly higher values for endomorphy and mesomorphy than outfield players.

Daily Energy Expenditure

The daily energy expenditures of amateur (n = 8, age = 20 ± 1 [*SD*] years) and professional (n = 23, age = 23 ± 3) soccer players during daily activities, including training and competition, have been estimated (35, 40). On average, the daily amounts of time spent lying down (sleeping included) and sitting were 10.5 and 7.5 hr, respectively. Other daily activities such as driving, standing still, and walking accounted for 3 to 4 hr of daily activity. The duration of training sessions varied from 45 min to slightly over 2 hr. The estimated energy demand for a training session was about 12 kcal $\cdot$ min^{-1}, and the estimated energy expenditure during a match was about of 16.7 kcal $\cdot$ min^{-1} for outfield players and 4.8 kcal $\cdot$ min^{-1} for goalkeepers (35). The estimated mean daily energy expenditure was, on average, about 3,550 kcal, and it ranged from 3,100 to 4,050 kcal for the lightest and heaviest players, respectively. The heaviest training day and match day were estimated to require, on average, 4,050 (range 2,850–5,250) and 3,800 (range 3,350–4,750) kcal, respectively.

Dietary Habits

The nutritional habits of elite soccer players have been evaluated in several studies (4, 8, 17, 20, 24, 40, 47, 48) (see Table 3). In these studies (n = 104 males, age range = 16–35 years), the daily energy intake averaged 3,525 kcal and ranged from 2,650 to 4,925 kcal for the groups. In one study, the day-to-day variability in energy intake was approximately 26% for 8 elite players during 2 weeks of intense training (40).

Macronutrient Intake

Soccer players' CHO intake is reported to be about 53% of their total energy intake, while protein and fat intakes are reported to be 15% and 30%, respectively (4, 8, 17,

Table 1 Anthropometric Characteristics (Means ± *SD*) of Senior Soccer Players From Different Countries

Nationality	Reference	*N*	Age (years)	Height (cm)	Weight (kg)	Body fat (%)
Czechoslovakian	7	15	24.8 ± 3.4	182.6 ± 5.5	78.7 ± 6.2	8.1
Finnish[a]	31	31		180.4 ± 4.3	76.0 ± 7.3	12.4
English	12	122	23.8 ± 4.4		77.1 ± 5.6	10.5
Dutch	49	78	26.8	179.6	76.6	11.8
American[a]	22	12	22.5	178.6	76.2	9.9
Australian[a]	22	12	23.8	178.6	75.8	10.8
Greek	46	99	25.4 ± 3.3	178.2 ± 5.1	74.5 ± 5.5	9.2
Portuguese	30	21	27.6	178.1	73.8	11.0
Italian	8	33	26.3 ± 3.8	178.0 ± 5	75.7 ± 5.9	11.7
Hong-Kong[a]	9	24	26.3 ± 4.2	173.4 ± 4.6	67.7 ± 5.0	7.3
Kuwaiti[a]	32	18				8.9
Total		465	25.3 ± 1.3	178.6 ± 1.8	75.6 ± 2.2	10.4 ± 1.3

Note. Body fat was estimated from skinfold thickness.
[a]National Team.

Table 2 Anthropometric Characteristics (Means ± *SD*) of Junior and Female Soccer Players From Different Countries

Nationality	Reference	*N*	Age (years)	Height (cm)	Weight (kg)	Body fat (%)
Junior						
Finnish[a]	31	25	U-18 + 17	178.6 ± 6.3	71.3 ± 6.8	12.1
American[a]	22	19	17.5	178.3	72.3	9.4
Finnish[a]	31	21	U-16	177.1 ± 7.4	66.7 ± 6.8	10.8
Canadian[a]	25	9	U-18	175.8 ± 4.4	69.1 ± 3.4	8.2
Finnish[a]	31	29	U-15	174.7 ± 5.1	62.5 ± 6.5	10.2
Canadian[a]	25	8	15.4 ± 0.5	171.1 ± 4.3	62.7 ± 2.8	7.8
Puerto Rican[a]	40	8	17.0	169.8	63.4	7.6
Total		119	14-18	176.0 ± 2.7	67.2 ± 4.0	10.1 ± 1.4
Female						
Danish[a]	21	10	24.7	169	62.2	22.3
English[a]	11	14	25.4	166.0 ± 6.5	59.6 ± 2.7	21.1
Canadian	38	12	20.3	164.8	59.5	19.7
Total		36	23.5 ± 2.3	166.4 ± 1.7	60.3 ± 1.2	21.0 ± 1.0

Note. Body fat was estimated from skinfold thickness.
[a]National Team.

Table 3 Means for Energy Intake; Amounts of Carbohydrate (CHO), Fat, and Protein; and Their Percentage Contribution to Total Energy Intake in the Habitual Diets of Soccer Players

Nationality	Reference	*N*	Energy (kcal)	CHO (g)	CHO (%)	Fat (g)	Fat (%)	Protein (g)	Protein (%)
Senior									
Swedish	20	15	4,929	596	47.0	217	29.2	170	13.6
Danish	4	7	3,738	426	46.3	152	38.0	144	15.7
Italian	8	33	3,066	485	56.0	101	28.0	138	14.0
Italian	17	20	3,650	509	55.8	115	28.3	145	15.9
Junior									
Canadian[a]	24	5	3,619	397	48.0	156	39.0	103	13.0
Puerto Rican[a]	40	8	3,952	526	53.2	142	32.4	142	14.4
Total		88	3,682	503	52.9	135	30.1	144	14.5

[a]National Team.

20, 24, 40; see Table 3), the remaining being the contribution from alcohol intake. Thus, relative CHO intake is generally below the recommended intake (10) for players in training and competition. However, some players within a team may have an adequate CHO intake. In one study, the day-to-day variation in relative CHO intake was 20% (40).

Micronutrient Intake

Some deficiencies of vitamin A, vitamin B_6, vitamin D, vitamin E, folacin, calcium, zinc, and potassium have been observed in soccer players' diets (4, 40, 48). Hematological status has also been assessed, revealing little evidence of anemia in elite young and professional players (6, 40). Further, a study on an Italian First division team showed that the players were not prone to iron deficiency based on values of serum iron, total iron-binding capacity, and serum ferritin (37). However, a recent study of 20 Italian professionals showed that iron levels in blood and hemoglobin decreased throughout a soccer season but iron supplementation prevented the decrease of both iron and hemoglobin levels in another season (15).

In another study on professional Italian players, the levels of circulating ceruloplasmin and the enzymatic activity of protein were lower than in control subjects; however, copper levels were comparable (36). The authors concluded that the reduced enzymatic activity might be related to impaired antioxidant defenses against damaging free radicals produced during intense physical activity. In general, the small degree of micronutrient deficiencies do not seem to merit concern, since the RDA is designed to exceed most individuals' actual requirements. Nevertheless, it might be advisable to assess players' diets regularly to prevent accumulated seasonal deficiencies such as those observed with iron.

Fluid Balance

The hydration status of professional and Olympic players was assessed in two studies (8, 41) using bioelectrical impedance and a D_2O dilution method. The average body water contents were 62.5% and 65.8% of body weight. In one of these studies (41), the voluntary fluid intake of the players was 2.7 L $\cdot$ day^{-1}, which included water and beverages as well as water in the foods consumed. The urine output was about 1.1 L $\cdot$ day^{-1}.

During continuous intense training and playing, voluntary rehydration may not be sufficient to offset the water losses due to metabolic heat generated during physical activities and by environmental conditions. During a match, players lose, on average, 1 to 2 kg when performing in temperatures and humidity levels between 5 and 33 °C and 7 and 69%, respectively, but some players may lose up to 4 kg while playing in warm, humid conditions (26 °C, 78–81% relative humidity) (14, 23, 28, 41, 44, 51). However, despite water loss via evaporation to cool the body, individual core temperatures as high as 41 °C have been observed in soccer players during a match (41). More dramatically, a recent report revealed that 34 players collapsed of heat exhaustion during a youth soccer tournament held in Blaine, MN, in early July, when wet bulb globe temperatures (WBGT) exceeded the ACSM-recommended maximum of 27.8 °C (23). Thus, it is clear that players' level of hydration must be seriously considered to prevent heat illness during training or competition.

Dietary Supplementation

Carbohydrate

The implications of a low-CHO diet were exemplified in a Swedish study which showed that players with the lowest glycogen values had lower average speed and ran less distance during the second half of the match (42). In a more controlled performance test, designed to simulate the intensity of playing a soccer match, 7 professional Danish players were observed after a 2-day diet modification period, during which the composition of the experimental diet was 65% (602 g) CHO and 14% protein, compared to their typical diet of 39% (355 g) CHO and 16% protein (4). The experiment showed that running distance in the test was longer with the high-CHO diet.

The effects of acute CHO loading just prior to or during a soccer match on players' metabolic responses during the match have been observed by several researchers (26, 43, 44, 51). In these studies, blood glucose levels were maintained during the match (on average, 4.3–6.1 mmol · L^{-1} before the match and 5.1–6.6 mmol · L^{-1} after the match). However, plasma lactate concentrations did not seem to be affected by the ingestion of a short-chain glucose polymer before a match and at halftime (51). Very likely, the exogenous sugar contributes to the energy demands and the sparing of glycogen at the end of a match (43, 44). However, in one study, plasma free fatty acid levels did not differ from the nonsupplemented condition and glycerol levels were higher in the polycose-supplemented players, which in the authors' interpretation might have been due to a reduction in hepatic gluconeogenesis (43). Also, after subjects were supplied exogenous sugar, levels of cortisol and growth hormone were lower than when sugars were not supplied, suggesting a reduced synthesis of glucose from amino acids and lipids (26). In another study, players in the youth squad of a top First Division English team were monitored throughout training sessions, during which they ingested 200 ml of a maltodextrin solution (150 g dissolved in 1 L of water) every 20 min (27). After the sessions in which maltodextrin was provided, the players reported being less physically and mentally tired and the coaches reported that the players worked harder. This is contrary to the subjective experience of Canadian players who did not perceive a match to be easier after polycose supplementation (43). Also, in one recent study, ingestion of a glucose polymer before the match and at halftime did not affect several parameters of soccer motor skill proficiency (51).

Fifteen players of a top Swedish soccer team were evaluated after a regular season match to determine whether glycogen stores would be replenished prior to the next match (20). The glycogen levels following the match were 46 mmol · $kgwwt^{-1}$, on average, and after players followed their habitual diets, their intramuscular glycogen only increased by 27 mmol · $kgwwt^{-1}$ after 2 days. Intramuscular glycogen levels 2 days after the match were lower than those usually found in sedentary subjects. The daily quantity of CHO consumed was 596 g, on average, which is the largest reported in soccer players. Thus, in general, the amount of CHO intake of soccer players might be insufficient to replenish the glycogen stores. In another study, players of the Canadian national youth team drank 2.5 L of a 7% glucose polymer solution during 19 hr following the match (24). The total energy provided by the diet and the supplement was 3,450 kcal and the percentage contributions of CHO, protein, and fat were 65, 11, and 26%, respectively; the percentage contributions of macronutrients for the control group of players were 48% CHO, 13% protein, and 39% fat. Interestingly, the resynthesis of glycogen for the experimental group was not enhanced. The investigators concluded that the relatively high muscle glycogen levels after the soccer match may have caused this slow resynthesis. One likely reason for the diversity in glycogen degradation between these two experiments is the different playing intensities of the subjects during the matches.

Amino Acid

Compared to CHO supplementation, less emphasis has been placed on the study of amino acid supplementation in soccer players. In one study, the ratio of free tryptophan to BCAA in blood increased after a soccer match (11). Depletion of glycogen and increased uptake of BCAA by muscle might increase the rate of entry of tryptophan into the brain, thus increasing the neurotransmitter 5-hydroxytryptamine and resulting in mental fatigue (11, 29). There is preliminary evidence that BCAA supplementation can enhance physical and mental performance in marathon runners, cross-country skiers, and soccer players (11, 29). However, only one study to date has tested the effects of long-term BCAA supplementation on soccer players. In that study, the youth players of a top Italian professional club were examined prior to and after 1 and 2 months of BCAA supplementation (45). The players' postmatch plasma levels of ammonia and glucagon were not significantly increased after supplementation compared to without BCAA supplementation, although plasma alanine was increased after play in the supplemented players. The authors used this increase in alanine to conclude that BCAA might induce a better substrate availability. However, based on these findings, it is premature to conclude that soccer performance might be enhanced by BCAA supplementation.

Creatine

Creatine supplementation has recently gained popular attention among athletes. Recent experiments using repeated exercise models have provided insight into the potential effects of additional dietary Cr on the muscle metabolic response in soccer players (2, 3, 18, 19, 34, 39). Balsom et al. (3) reported lower phosphocreatine (PCr) breakdown and lower lactate accumulation at the end of a series of supramaximal intermittent exercise bouts, while Greenhaff et al. (18) showed an increased amount of PCr resynthesized during recovery from an intense ischemic exercise bout after Cr supplementation. This led to the hypothesis that Cr positively affects performance during intense intermittent exercise by enhancing PCr resynthesis rate on the recovery periods. However, in a study on soccer players, Cr did not enhance the velocity in repeated 60-m sprints separated by 2 min of rest (34).

Rico-Sanz et al. (39) used nuclear magnetic resonance (^{31}P-NMR) to show that, following Cr supplementation, the amount of net PCr utilized was lower and muscle pH decreased less during periods of long-term, high-intensity, intermittent exercise when oxygen availability was not severely compromised. In addition, the rate constant of PCr resynthesis during the recovery periods was not altered by Cr independent of the exercise intensity (39). These findings provided evidence that additional Cr might enhance the contribution of aerobic sources to the total energy requirement during exercise, which might have a larger influence on soccer players when performing continuously during a soccer match (i.e., 90 min).

Water Intake

Few investigators have assessed hydration levels and effects of hyperhydration in soccer players. In one study, in which water replacement was allowed during training sessions, players felt that training was easier and reported they were less physically tired compared to no water replacement (27). To examine whether the body compartments would be able to uptake more water, in another study players were asked to follow a regimen of hyperhydration for 1 week prior to a soccer match (41). Total body water increased by 1.1 L after the hyperhydration regimen, indicating that the subjects' body water reserves were not refilled by voluntary hydration. Measurements of rectal temperature, prior to and after the match, showed that the increased body water levels reduced thermal stress placed on the players during the match, which was played in a warm, humid environment. Although water alone did not influence the performance decrement observed by the end of a soccer match (41), it is possible that in more stressful weather conditions this may not be the case.

Summary

Soccer players fall within a wide range of stature and body weight, and they are generally classified as mesomorphs. Body composition assessments by skinfolds and hydrostatic weighing reveal that the BF of male soccer players is, on average, 10% of body weight; the average for females is about 21%. Nutritional assessment of soccer players indicates that CHO intake is lower than desirable, and slight deficiencies in some vitamins and minerals have been observed. There are indications that manipulating players' diets in order to increase the muscle glycogen levels of some amino acids, total Cr, and water contents might be beneficial in soccer performance. Individual nutritional counseling may help soccer players break habits imposed by the cultural environment and adopt new ones that are more in accordance with the consensus on dietary requirements for their sport. More research is needed on the nutritional habits of male and particularly female players from different levels (youth, collegiate, semiprofessional, professional, masters) and the effects that nutritional modifications and supplementations may have on players' performance and body composition.

References

1. Apor, P. Successful formulae for fitness training. In *Science and Football,* T. Reilly, A. Lees, K. Davids, and W.J. Murphy (Eds.). London: E. and F.N. Spon, 1988, pp. 95-107.
2. Balsom, P.D., B. Ekblom, K. Söderlund, B. Sjödin, and E. Hultman. Creatine supplementation and dynamic high-intensity intermittent exercise. *Scand. J. Med. Sci. Sports* 3:143-149, 1993.
3. Balsom, P.D., K. Söderlund, B. Sjödin, and B. Ekblom. Skeletal muscle metabolism during short duration high intensity exercise: Influence of creatine supplementation. *Acta Physiol. Scand.* 154:303-310, 1995.
4. Bangsbo, J., L. Norregaard, and F. Thorsoe. The effect of carbohydrate diet on intermittent exercise performance. *Int. J. Sports Med.* 13:152-157, 1992.
5. Bell, W., and G. Rhodes. The morphological characteristics of the association football player. *Brit. J. Sports Med.* 9:196-200, 1975.

6. Biancotti, P.P., A. Caropresso, G.C. Di Vincenzo, G. Canzit, and C.G. Gribaudo. Hematological status in a group of male athletes of different sports. *J. Sports Med. Phys. Fitness* 32:70-75, 1992.
7. Bunc, V., J. Heller, and L. Prochazka. Physiological characteristics of Czech top football players. In *Abstract Book of the Second World Congress on Science and Football* (Veldhoven, The Netherlands), 1991.
8. Caldarone, C., G.C. Tranquilli, and M. Giampietro. Assessment of the nutritional state of top level football players. In *Sports Medicine Applied to Football,* G. Santilli (Ed.). Rome: Istituto di Scienza dello Sport del C.O.N.I., 1990, pp. 133-141.
9. Chin, M.K., Y.S.A. Lo, C.T. Li, and C.H. So. Physiological profiles of Hong Kong elite soccer players. *Brit. J. Sports Med.* 26:262-266, 1992.
10. Clark, K. Nutritional guidance to soccer players for training and competition. *J. Sports Sci.* 12:S43-S50, 1994.
11. Davis, J.M. Carbohydrates, branched-chain amino acids, and endurance: The central fatigue hypothesis. *Int. J. Sports Nutr.* 5:S29-S38, 1995.
12. Davis, J.A., and J. Brewer. Physiological characteristics of an international female soccer squad. In *Abstract Book of the Second World Congress on Science and Football* (Veldhoven, The Netherlands), 1991.
13. Davis, J.A., J. Brewer, and D. Atkin. Preseason physiological characteristics of English first and second division soccer players. *J. Sports Sci.* 10:541-547, 1992.
14. Ekblom, B. Applied physiology of soccer. *Sports Med.* 3:50-60, 1986.
15. Galanti, G., L., Gatteschi, G. Diricatti, M. Manzuoli, and S. Mininni. Iron supplementation in soccer players. *Med. Sport* 49:79-84, 1996.
16. Garganta, J., J. Maia, and J. Pinto. Somatotype, body composition and physical performance capacities of elite young soccer players. In *Science and Football II*, T. Reilly, J. Clarysand, and A. Stibbe (Eds.). London: E. and F.N. Spon, 1993, pp. 292-294.
17. Giada, F., G. Zuliani, G. Baldo-Enzi, E. Palmieri, S. Volpato, E. Vitale, D. Magnanini, A. Colozzi, L. Vecchiet, and R. Fellin. Lipoprotein profile, diet and body composition in athletes practicing mixed and anaerobic activities. *J. Sports Med. Phys. Fitness* 36:211-216, 1996.
18. Greenhaff, P.L., K. Bodin, K. Söderlund, and E. Hultman. Effect of oral creatine supplementation on skeletal muscle phosphocreatine resynthesis. *Am. J. Physiol.* 266:E725-E730, 1994.
19. Greenhaff, P.L., A. Casey, A.H. Short, R. Harris, K. Söderlund, and E. Hultman. Influence of oral creatine supplementation on muscle torque during repeated bouts of maximal voluntary exercise in man. *Clin. Sci.* 84:565-571, 1993.
20. Jacobs, I., N. Westlin, J. Karlsson, M. Rasmusson, and B. Houghton. Muscle glycogen and diet in elite soccer players. *Eur. J. Appl. Physiol.* 48:297-302, 1982.
21. Jensen, K., and B. Larsson. Variations in physical capacity in a period including supplemental training of the National Danish Soccer Team for Women. In *Science and Football II*, T. Reilly, J. Clarysand, and A. Stibbe (Eds.). London: E. and F.N. Spon, 1993, pp. 114-117.
22. Kirkendall, D.T. The applied sport science of soccer. *Physician Sportsmed.* 13:53-59, 1985.
23. Kirkendall, D.T. Effects of nutrition on performance in soccer. *Med. Sci. Sports Exerc.* 25:1370-1374, 1993.
24. Leatt, P.B., and I. Jacobs. Effect of a liquid glucose supplement on muscle glycogen resynthesis after a soccer match. In *Science and Football*, T. Reilly, A. Lees, K. Davids, and W.J. Murphy (Eds.). London: E. and F.N. Spon, 1988, pp. 42-47.

25. Leatt, P.B., R.J. Shephard, and M.J. Plyley. Specific muscular development in under-18 soccer players. *J. Sports Sci.* 5:165-175, 1987.
26. Mangoni, Di S., G. Stefano, M. Ruggiero, E. Marmo, and E. Acampora. Physiological evaluation of athletic performance: A hematological approach. In *Proceedings of the 1st International Congress on Sports Medicine Applied to Football*, L Vecchiet (Ed.). Rome: D. Guanillo, 1980, pp. 817-827.
27. Miles, A., D. Maclaren, and T. Reilly. The efficacy of a new energy drink—A training study. *Science and Football* 6:4-7, 1992.
28. Mustafa, K.Y., and Nasr El-DinAhmed Mahmoud. Evaporative water loss in African soccer players. *J. Sports Med. Phys. Fitness* 19:181-183, 1979.
29. Newsholme, E.A., E. Blomstrand, P. Hassmenn, and B. Ekblom. Physical and mental fatigue: Do changes in plasma amino acids play a role? *Biochem. Soc. Trans.* 19:358-362, 1991.
30. Puga, N., J. Ramos, J. Agostinho, I. Lomba, O. Costa, and F. de Freitas. Physical profile of a first division Portuguese professional soccer team. In *Science and Football II*, T. Reilly, J. Clarysand, and A. Stibbe (Eds.). London: E. and F.N. Spon, 1993, pp. 40-46.
31. Rahkila, P., and P. Luhtanen. Physical fitness profile of Finnish national soccer teams candidates. *Science and Football* 5:30-34, 1991.
32. Ramadan, J., and R. Byrd. Physical characteristics of elite soccer players. *J. Sports Med. Phys. Fitness* 27:424-428, 1987.
33. Raven, P., L. Gettman, M. Pollock, and K. Cooper. A physiological evaluation of professional soccer players. *Brit. J. Sports Med.* 109:209-216, 1976.
34. Redondo, D.R., E.A. Dowling, B.L. Graham, A.L. Almada, and M.H. Williams. The effect of oral creatine monohydrate supplementation on running velocity. *Int. J. Sport Nutr.* 6:213-221, 1996.
35. Reilly, T., and V. Thomas. Estimated daily energy expenditure of professional association footballers. *Ergonomics* 22:541-548, 1979.
36. Resina, A., L. Gatteschi, M.G. Rubenni, M.A. Giamberardino, and F. Imreh. Comparison of some serum copper parameters in trained professional soccer players and control subjects. *J. Sports Med. Phys. Fitness* 31:413-416, 1991.
37. Resina, A., L. Gatteschi, M.G. Rubenni, and L. Vecchiet. The role-related differences of some serum iron parameters in top level soccer players. In *Science and Football II*, T. Reilly, J. Clarysand, and A. Stibbe (Eds.). London: E. and F.N. Spon, 1993, pp. 135-139.
38. Rhodes, E.C., and R.E. Mosher. Aerobic and anaerobic characteristics of elite female university soccer players. In *Abstract Book of the Second World Congress on Science and Football* (Veldhoven, The Netherlands), 1991.
39. Rico-Sanz, J. Muscle energetics during repeated intense exercise as evaluated biochemically and by ^{31}P-NMR. Unpublished doctoral dissertation, University of Copenhagen, Denmark, 1995.
40. Rico-Sanz, J., W.R. Frontera, P.A. Molé, M.A. Rivera, A. Rivera-Brown, and C.N. Meredith. Dietary and performance assessment of elite soccer players during a period of intense training. *Int. J. Sports Nutr.* (in press).
41. Rico-Sanz, J., W.R. Frontera, M.A. Rivera, A. Rivera-Brown, P.A. Molé, and C.N. Meredith. Effects of hyperhydration on total body water, temperature regulation and performance of elite young soccer players in a warm climate. *Int. J. Sports Med.* 17(2):83-89, 1996.
42. Saltin, B. Metabolic fundamentals in exercise. *Med. Sci. Sports* 5:137-146, 1973.
43. Shephard, R.J., and P. Leatt. Carbohydrate and fluid needs of the soccer player. *Sports Med.* 4:164-176, 1987.

44. Smaros, G. Energy usage during football match. In *Proceedings of the 1st International Congress on Sports Medicine Applied to Football*, L. Vecchiet (Ed.). Rome: D. Guanillo, 1980, pp. 795-801.
45. Tavana, R., T. Sacco, R. Bernardi, G. Buccino, and R. Parravicini. BCAA supplementation reduces hyperammonemia and hyperglucagonemia induced by exercise in a group of soccer players. In *Abstract Book of the Second World Congress on Science and Football* (Veldhoven, The Netherlands), 1991.
46. Tokmakidis, S.P., A. Tsopanakis, E. Tsarouchas, T. Kioussis, and S. Hadjikonstantinou. A physiological profile of Greek professional soccer players. In *Abstract Book of the Second World Congress on Science and Football* (Veldhoven, the Netherlands), 1991.
47. Van Erp-Baart, A.M.J., W.M.H. Saris, R.A. Binkhorst, J.A. Vos, and J.W.H. Elvers. Nationwide survey on nutritional habits in elite athletes. Part I. Energy, carbohydrate, protein and fat intake. *Int. J. Sports Med.* 10:S3-S10, 1989.
48. Van Erp-Baart, A.M.J., W.M.H. Saris, R.A. Binkhorst, J.A. Vos, and J.W.H. Elvers. Nationwide survey on nutritional habits in elite athletes. Part II. Mineral and vitamin intake. *Int. J. Sports Med.* 10:S11-S16, 1989.
49. Vos, J.A. Physiological comparison between Dutch soccer players and other teamsport men. In *Proceedings of the 1st International Congress on Sports Medicine Applied to Football*, L. Vecchiet (Ed.). Rome: D. Guanillo, 1980, pp. 695-701.
50. White, J.E., T.M. Emery, J.E. Kane, R. Groves, and A.B. Risman. Preseason fitness profiles of professional soccer players. In *Science and Football*, T. Reilly, A. Lees, K. Davids, and W.J. Murphy (Eds.). London: E. and F.N. Spon, 1988, pp. 164-171.
51. Zeederberg, C., L. Leach, E.V. Lambert, T.D. Noakes, S.C. Dennis, and J.A. Hawley. The effect of carbohydrate ingestion on the motor skill proficiency of soccer players. *Int. J. Sports Nutr.* 6(4):348-355, 1996.

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