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Dietary and Performance Assessment of Elite Soccer Players During a Period of Intense Training

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This study examined the nutritional and performance status of elite soccer players during intense training. Eight male players (age 17 ± 2 years) of the Puerto Rican Olympic Team recorded daily activities and food intake over 12 days. Daily energy expenditure was 3,833 ± 571 (SD) kcal, and energy intake was 3,952 ± 1,071 kcal, of which 53.2 ± 6.2% (8.3 g · kg BW^{-1}) was from carbohydrates (CHO), 32.4 ± 4.0% from fat, and 14.4 ± 2.3% from protein. With the exception of calcium, all micronutrients examined were in accordance with dietary guidelines. Body fat was 7.6 ± 1.1% of body weight. Time to completion of three runs of the soccer-specific test was 37.65 ± 0.62 s, and peak torques of the knee flexors and extensors at 60° · s^{-1} were 139 ± 6 and 225 ± 9 N · m, respectively. Players' absolute amounts of CHO seemed to be above the minimum recommended intake to maximize glycogen storage, but calcium intakes were below recommended. Their body fat was unremarkable, and they had a comparatively good capacity to endure repeated bouts of intense soccer-specific exercise and to exert force with their knee extensors and flexors.

Key Words: carbohydrates, energy expenditure, energy intake, body fat, intermittent exercise

Nutrition, training, and overall health are important aspects of successful sports performance. Soccer participants are challenged to run randomly at various speeds and execute technical skills during a match. The energetic demands of training and competition at the elite level require that participants ingest a well-balanced

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diet particularly rich in carbohydrates, since net depletion of glycogen depots has been observed after soccer matches (12, 16, 30). Furthermore, the degree of depletion has been correlated with a lower speed and distance run at the end of a match (30), and improvements in running performance have been observed after CHO supplementation in soccer players (2, 10, 15). In addition to adequate CHO, young soccer players undertaking intense training require adequate amounts of calories, high-quality protein, vitamins, and minerals (9, 18).

Although nutritional recommendations have been established for soccer players (6), it is not known whether young participants comply during intense training. Young athletes usually live with their families where there often is little choice in food selection, and thus their diets may not be optimal for training and performance. Therefore, there is a need to evaluate nutrient intakes of free-living young athletes. The present study was designed to assess nutrient intake in young elite athletes during a period of intense soccer training. Hematological parameters, percent body fat, and specific performance were also determined during this period and compared to values reported for other groups of soccer players (13, 17, 23, 24, 27, 37).

Methods

Subjects

Eight male soccer players of the Puerto Rico Olympic Team volunteered to participate in this study. Players gave their written consent after an introductory meeting in which the purpose of the experiment was explained. The study was approved by the Human Subjects Review Committee of the University of California at Davis and of the Medical Sciences Campus of the University of Puerto Rico.

Data Collection and Recording

Anthropometry. Skinfold thickness was measured by standard techniques (19) using a Lange caliper. Six sites on the right side of the body were used (triceps, subscapular, suprailiac, abdomen, pectoralis, and thigh), and the average of three measurements was used as the representative skinfold thickness for a given site. Percent body fat (%BF) was estimated from a regression equation that incorporates the sum of the six skinfolds and the subject's age (11).

Diet and Activity Records. For 12 days in a 2-week period of training 1 month before Olympic qualifying matches, players recorded their daily activities and food intakes. Before the study began, players spent 2 days at the Puerto Rico Olympic Training Center for instruction in recording daily activities and food intakes. With respect to daily activities, the subjects were instructed to record every activity to the nearest 5 min. Players were asked to carry with them at all times a notebook containing daily activity forms, so they could more easily recall and record their activities at regular intervals during the day. Daily activities were divided into lying down (including sleeping, lying at ease), sitting (including sitting at ease, writing, eating, driving), standing (including washing, toilet, dressing, making bed, tidying room), walking, and training. Subjects were asked to review their records during the meal hours. We estimated the total energy spent from the daily activity records assuming conversion factors as used by Reilly and Thomas (26) and considering each player's weight.

With respect to the dietary intake records, the players were instructed to write down the amount of each food eaten using sizes (e.g., small, medium, or large apple), pieces (e.g., fast food menus, breads), spoons (e.g., tablespoons olive oil), cups (e.g., cooked rice), and weights in grams (e.g., grams of beefsteak) as measuring units. Players were also given a bottle of known volume to measure the volume of milk and juices consumed. Beverages consumed were recorded as the volume specified by the manufacturer's label. Every day before training, daily activity and food intake records were evaluated for completeness and accuracy. Data were stored using a Macintosh computer system and analyzed for foods consumed using the Food Processor Nutrition Program (Salem, Oregon). On Day 7 of the study prior to a training match performed in the evening, approximately 24 hr after the last training session and 3 hr since the last meal, a blood sample was taken from an antecubital vein after the subject had been seated for approximately 5 min. Samples were later analyzed for hematological parameters using a Coulter Counter (Model S-Plus JR).

Performance Measurements. A few days before the 12-day dietary recall period began, a soccer-specific test was performed on a regular grass soccer field on a marked portion of the penalty area as described by Zelenka et al. (37). Prior to the test, subjects performed a standard warm-up for 20 min. In addition, subjects were taken through the Zelenka circuit (37) two times before the first run in order to become familiar with and warm-up for the specific movements required for the test. The test was repeated three times separated by 3-min resting intervals; the same procedures were repeated on the following day to examine reproducibility of results. The heat stress index was 24.7 ± 0.5 and 24.2 ± 0.5 °C on Day 1 and Day 2, respectively. The environmental conditions during the 12-day period remained similar to these values.

Players wore heart rate monitors (Polar heart rate monitor, Stamford, CT) during this soccer-specific test. The monitor was programmed to provide one reading every 15 s. The stored values for heart rate were later downloaded into an IBM PC using an interface (Polar, Stamford, CT). The time to complete each round was measured using a stopwatch (Polar, Stamford, CT). On another day, during the afternoon hours also prior to the commencement of the dietary recall period, peak torque, angle at peak torque, average power, and total work of knee extensors and flexors were measured on a Cybex 340 dynamometer at an angular velocity of $60° \cdot s^{-1}$. The test consisted of 30 repetitions of knee extension and flexion. Measurements were taken in the late afternoon.

Statistics

All data are presented as means ± standard deviation (*SD*). Energy, macronutrient, and micronutrient intakes were compared to the Recommended Dietary Allowances (RDAs; 22) and to values reported for other groups of soccer players (2, 5, 12, 14, 16). Energy expenditure, %BF, hematological parameters, and performance were compared to other values reported for soccer players (13, 17, 23–27, 32, 33, 37). To evaluate significant differences among the three exercise bouts in every soccer-specific testing session, we used a repeated-measures analysis of variance (ANOVA). A paired *t* test was used to test the reproducibility of the test on the next day. For all comparisons, $p < .05$ was used. Data were analyzed using Statview 512+ (Brain Power, Inc., Calabasas, CA).

Results

The mean age of the soccer players was 17 ± 2 years. Body height was 169.8 ± 6.5 cm and body weight 63.4 ± 3.1 kg. Body fat was 7.6 ± 3.1% of body weight. Daily activity assessment for 12 days revealed that players spent, on average, 10 hr 30 min lying down, 7 hr 20 min sitting, 2 hr 50 min standing, 1 hr 30 min walking, and 2 hr 10 min training. Figure 1 shows the pattern of daily activities for the 8 players. From the players' daily activity records, the total daily energy expenditure was estimated to be 3,833 ± 571 kcal.

Table 1 shows the average daily energy intake and amounts of carbohydrate, fat, and protein in the soccer players' diets. The amounts of dietary micronutrients (Tables 2 and 3), with the exception of calcium and vitamin A, were, on average, in accordance with dietary recommended guidelines (22).

An assessment of blood constituents revealed that the average red blood cell count was 4.55 ± 0.59 million cells per microliter of blood, which was slightly below the low range for normal values (Table 4). On the other hand, lymphocyte count (3.62 ± 0.42 thousand cells per microliter of blood) was slightly above the upper range for normal values. Other hematological parameters were within normal values.

Subjects' average times to complete the soccer-specific test are shown in Table 5. The times to complete the test for the first, second, and third runs were not significantly different from each other. Also, there were no differences in the time to completion among the three runs on the second day and between the 2 days for each run. Heart rates before the tests were on the order of 120 beats · min^{-1} and increased to about 180 beats · min^{-1} at the end of the three runs. Table 6 shows the isokinetic data for the knee flexors and extensors.

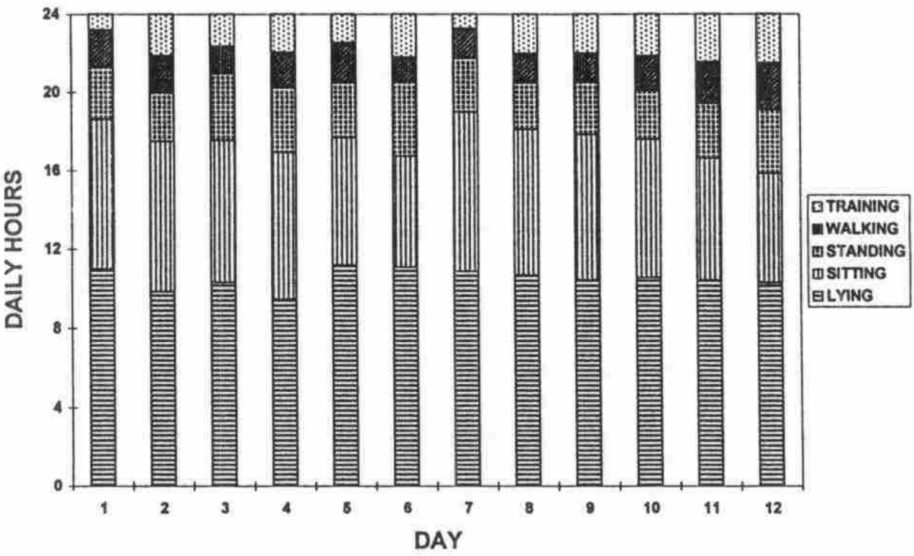

Figure 1 — Daily time spent in training, walking, standing, sitting, and lying down for the players during 12 days of intense training.

Table 1 Energy Intake, Amounts of Carbohydrate (CHO), Fat, and Protein, and Percentage Contribution of These Macronutrients to the Total Energy Intake in the Habitual Diets of 8 Elite Soccer Players

	Average	*SD*
Energy expenditure (kcal·day^{-1})	3,833	571
Energy intake (kcal·day^{-1})	3,952	1,071
Energy intake (kcal·kg BW^{-1})	62	12
CHO (g·day^{-1})	526	62
Fat (g·day^{-1})	142	17
Protein (g·day^{-1})	142	23
CHO (%)	53.2	6.2
Fat (%)	32.4	4.0
Protein (%)	14.4	2.3

Note. Values are the average (±*SD*) of 12 days for the 8 soccer players.

Table 2 Daily Amounts of Vitamins in the Habitual Diets of 8 Elite Soccer Players

	Average	*SD*	% of RDA
Vitamin A (RE)	934	1,021	93
Vitamin B_1 (mg)	3.91	0.88	261
Vitamin B_2 (mg)	2.48	0.56	146
Niacin (mg)	35.1	6.7	185
Vitamin B_6 (mg)	3.30	0.74	165
Vitamin B_{12} (μg)	10.7	9.2	535
Folacin (μg)	905	286	452
Panthothenic acid (mg)	8.77	1.85	125
Vitamin C (mg)	520	173	867
Vitamin E (mg)	46.0	22.0	460

Note. Values are the average (±*SD*) intake during the 12 days for the 8 soccer players.

Discussion

The main aim of this study was to assess the nutritional and performance status of elite soccer players during a period of intense training. The results showed that the players' estimate of energy expenditure was within the range reported for elite soccer players (2, 5, 12, 16) and their body fat was similar to other young elite players (13, 17, 24, 37). Their dietary habits revealed that absolute amounts of CHO intake were satisfactory according to recommended values to maximize muscle glycogen stores (4) but, on average, the amounts of dietary vitamin A and calcium

Table 3 Daily Amounts of Minerals in the Habitual Diets of 8 Elite Soccer Players

	Average	*SD*	% of RDA
Calcium (mg)	1,072	246	89
Copper (mg)	2.41	0.66	100[a]
Iron (mg)	22.0	5.5	220
Magnesium (mg)	500	115	143
Phosphorus (mg)	2,113	460	176
Potassium (mg)	5,725	1,318	102
Selenium (μg)	184	45	263
Sodium (mg)	2,721	588	100[b]
Zinc (mg)	19.7	4.6	131

Note. Values are the average (±*SD*) intake of 12 days for the 8 soccer players.
[a]RDA range = 1.5–3.0. [b]RDA range = 1,100–3,300

Table 4 Hematological Parameters

Blood cell		*M*	*SD*	Normal values
Red	(10^6 cells·μL^{-1})	4.6	0.6	4.7–6.1
Hemoglobin	(g·dl^{-1})	14.2	0.8	14.0–18.0
Hematocrit	(%)	40.5	4.9	42.0–52.0
White	(10^3 cells·μL^{-1})	6.0	1.7	4.8–10.8
Lymphocyte	(10^3 cells·μL^{-1})	3.6	0.4	1.2–3.4
Mononuclear	(10^3 cells·μL^{-1})	0.5	0.2	0.1–0.6
Granulocyte	(10^3 cells·μL^{-1})	1.6	1.7	1.4–6.5
Lymphocyte percent	(%)	60.8	15.6	20.5–51.1
Mononuclear percent	(%)	10.2	5.9	1.7–9.3
Granulocyte percent	(%)	24.8	19.1	42.2–75.2
Platelet	(10^3 cells·μL^{-1})	273.8	84.5	130.0–400

were slightly below the RDA (22). Hematological parameters were within normal values (Coulter Counter manual, Model S-Plus JR) with the exception of the number of red blood cells, which on average was slightly below normal. Performance results indicated that players were able to repeat intense soccer-specific bouts without a deterioration in velocity and the strength of their knee extensors was similar to other young elite players (17, 32, 33).

The subjects' calculated average daily energy expenditure (3,833 kcal) was slightly higher than the average value (3,429 kcal) but within the range (3,024–4,119

Table 5 Performance Assessment on a Soccer-Specific Test (34)

	Day 1		Day 2	
	M	*SD*	*M*	*SD*
Time to completion (s)				
Run 1	37.27	1.41	36.71	1.24
Run 2	37.15	1.50	38.44	1.75
Run 3	38.25	2.38	38.06	1.22

Table 6 Performance Assessment on a Strength Test of the Knee Flexors and Extensors

	Flexors		Extensors	
	M	*SD*	*M*	*SD*
Peak torque (N·m)	139	17	225	25
Angle at peak torque (°)	33	17	56	8
Average power (W)	105	14	158	20
Total work (J)	156	25	236	34

kcal) observed for professional English players (26) who were involved in intense training and competition in the English first division. The longer training session and increased mobility during the day are the likely reasons for our subjects' larger daily energy expenditure.

The average daily energy intake of the players in this study (3,952 kcal) was similar to intakes of Danish (3,738 kcal) and Canadian youth (3,619 kcal) but considerably larger than the intake of Italian professionals (3,048 kcal) (2, 5, 16). On the other hand, Swedish elite players during training and competition had an average daily energy intake on the order of 5,000 kcal (12), considerably larger than our subjects' energy intake. Differences in body size, levels of occupational activity, computer programs used to estimate the quantity of dietary macronutrients, and the quality of the subjects' dietary records contribute to the variations in energy intake among the groups. The length of the dietary evaluation period is also relevant, since we have observed a 26% between-day variation in energy intake. It is likely that the differences in energy intake among the groups from different countries result from all of these factors.

A low body fat will reduce players' energy demands during training and competition, as a negative correlation has been observed between percent body fat and performance in activities where the body mass must be moved against gravity (36). The players' percent body fat was lower than values for elite Finish U-18 (12.1%), U-16 (10.8%), and U-15 players (10.2%) and Czechoslovakian players (11.6%) (24, 36). However, the 7.6% body fat of the players in the present study compared well with the body fat values obtained in Canadian elite U-16 (7.8%) and

U-18 players (8.2%), while a slightly higher value was found for an American junior team (9.1%) (13, 17). Thus, the players in the present study had a comparatively satisfactory body composition, which would help reduce the physiological load imposed when training and playing (36).

An adequate CHO intake is important in soccer because intramuscular glycogen can be depleted by halftime of a soccer match, and its depletion might be related to decrements in speed and distance run in the second half (30). This is supported by enhanced physical performance in soccer players who supplemented their diets with CHO (2, 10, 15). The relative CHO intake of the players in the present study (53.2%) was slightly higher than intakes reported for Swedish (47.0%), Danish (46.3%), Canadian (48.0%), and American college players (48.0%) (2, 12, 14, 16) but lower than the average 56% of a group of Italian first division players (5). The average relative CHO intake was also lower than the level recommended for soccer players: between 55 and 65% of the total calorie intake (6). However, due to the large daily energy intake, the absolute amount of CHO consumed was $8.3\ g \cdot kg\ BW^{-1}$, which was between values reported (4) to maximize glycogen stores in muscle.

The average protein intake of the players in this study was $2.3 \pm 0.6\ g \cdot kg^{-1} \cdot day^{-1}$, which was more than twice the RDA and it was in excess of the recommended $1.4–1.7\ g \cdot kg^{-1} \cdot day^{-1}$ for soccer players (18). It has been suggested that the RDA for protein intake is perhaps low for endurance athletes (21), as amino acid oxidation occurs particularly during endurance exercise (34). The recommended range might also be low for strength-trained subjects (8), because protein intake as high as $3.3\ g \cdot kg^{-1} \cdot day^{-1}$ has been shown to enhance lean body weight (8). However, an intake of $2.4\ g \cdot kg^{-1} \cdot day^{-1}$ did not increase lean body deposition beyond the increased protein synthesis level observed with an intake of $1.4\ g \cdot kg^{-1} \cdot day^{-1}$, although it increased amino acid oxidation (31). The branched-chain amino acids (BCAAs) are the primary amino acids oxidized in muscle, and the circulating levels have been suggested to modulate tryptophan entry into the brain and consequently serotonin synthesis (3). However, BCAA oxidation occurs primarily in the glycogen-depleted state. This situation could be delayed by having players increase their CHO intake by $75\ g \cdot day^{-1}$ or more on average and reduce their fat intake to about $100\ g \cdot day^{-1}$. Considering that these players were still growing and under a high muscular stress, their elevated protein intake was probably being used also for contractile or enzymatic unit development.

The players' micronutrient intake was satisfactory with the exception of slight deficiencies of vitamin A and calcium. Although the most commonly recognized function of vitamin A involves the visual system, vitamin A is also involved in growth and tissue maintenance and other metabolic processes. The slightly low intake of vitamin A does not merit concern, since vitamin A is very unevenly distributed in foods and it is easy to get a false low from dietary histories. All water-soluble vitamins (vitamin B complex and vitamin C) were well in excess of the RDA, ensuring that these essential cofactors were available for metabolic reactions during fat, carbohydrate, and protein breakdown. Also, vitamin E was well above the RDA, which could enhance protection against oxidative stress that might occur during intense training (7). On the other hand, calcium was slightly low, which can compromise its main function in bone development; in addition, abnormally low amounts of calcium can compromise the activation of several important enzymes and the regulation of muscle relaxation and contraction (35). Thus, players may need to be cautioned about a long-term effect of accumulated calcium deficiency. Therefore, with regard to micronutrient intake, only the low amount of calcium intake might be problematic, because it might limit adequate bone development in these players, who were still growing (20).

Blood hematological analysis revealed that the soccer players' red blood cell counts were slightly below the low range, which might be explained as an adaptation to aerobic training, which can increase plasma volume (20). Also, hemoglobin concentration (14.2 g · dl^{-1}) was in the low end of the normal range (20, Coulter Counter manual, Model S-Plus JR), but it was similar to values reported for Italian (14.3 g · dl^{-1}) and American professional players (14.6 g · dl^{-1}) (25, 27). Because the players' iron intake was well above the RDA (see Table 3), the oxygen-carrying and extraction capacity in these players was probably not compromised, since their average maximum oxygen uptake was 69.2 ml · kg^{-1} · min^{-1} (29), indicating unremarkable adaptation to the intense training and no evidence of anemia. The lymphocyte count was slightly above the upper range of normal values (Coulter Counter manual, Model S-Plus JR), indicating that the players also had sufficient circulating defenses to combat infection.

The performance measurements showed that players were able to sustain repeated bouts of all-out efforts similar to those performed during a soccer match. The time to complete the circuit was lower than for a group of young Czechoslovakian players (37) and for players from an Australian soccer league (23). During this type of performance, energy for muscle contraction is supported mainly by phosphocreatine (PCr) splitting and glycogen breakdown. With repeated bouts, there appears to be an increased relative contribution from aerobic energy sources; an investigation on the muscle energetic responses of soccer players using ^{31}P-NMR revealed that, during the first bout, muscle PCr and pH decreased considerably more than during the following exercise bouts (28). A large oxidative capacity also enables a fast resynthesis of PCr during the recovery periods, thus replenishing high-energy compounds for subsequent performance. For instance, PCr in the gastrocnemius of soccer players returns to resting levels with a half-time of about 20 s after intense exercise, producing a 70% drop in PCr (28). Thus, it is likely that the players in the present study were able to maintain a high rate of oxidative energy delivery, during exercise and recovery, to replenish part of the PCr used in previous bouts and maintain a high velocity without performance deterioration in repeated bouts of the soccer-specific test.

Anaerobic power also is needed in soccer for kicking the ball, jumping, rapidly accelerating and decelerating, and changing direction. A close correlation has been found between strength of the knee extensors and ball speed in kicking (1). The peak isokinetic torque of the knee extensors at 60° · s^{-1} for the players in this study was similar to the peak torques of players from the youth Japanese team (237 ± 33 N · m) and Australian elite players (233 ± 34 N · m) (32, 33). However, lower values (150 ± 25 N · m) were reported for players of the U-18 Canadian National team (17). The peak isokinetic torque of the knee flexors was also larger for the players in the present study than that of players on the youth Canadian team, whose average peak torque was 107 (17). Thus, comparatively, the players in the present study had well-developed strength in muscles directly involved in soccer performance.

During rigorous training, these eight soccer players showed a good tolerance for high-intensity intermittent exercise, consistent with their aerobic capacity, strength, and lean physique. According to current thought (4), their CHO intake was adequate to maximize glycogen stores in muscle. However, an increase intake of calcium would be advisable to ensure optimal bone development in these young subjects.

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