Asia Pac J Clin Nutr 2009;18 (3):344-350

Original Article

Nutrient intake and blood iron status of male collegiate soccer players

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The purpose of this study was: 1) to collect baseline data on nutrient intake in order to advise athletes about nutrition practices that might enhance performance, and 2) to evaluate the dietary iron intake and blood iron status of Japanese collegiate soccer players. The subjects were 31 soccer players and 15 controls. Dietary information was obtained with a food frequency questionnaire. The mean carbohydrate (6.9 g•kg^{-1} BW) and protein (1.3 g/kg) intakes of the soccer players were marginal in comparisons with recommended targets. The mean intakes of calcium, magnesium, vitamin A, B_1, B_2, and C were lower than the respective Japanese recommended dietary allowances (RDAs) or adequate dietary intakes in the soccer players. The mean intakes of green and other vegetables, milk and dairy products, fruits, and eggs were lower than the recommended targets. Thus, we recommended athletes to increase the intake of these foodstuffs along with slight increase in carbohydrate and lean meat. The mean intake of iron was higher than the respective RDA in the soccer players. A high prevalence of hemolysis (71%) in the soccer players was found. None of the soccer players and controls had anemia. Two soccer players had iron depletion, while none was found in the controls. In those players who had iron deficiency, the training load need to be lowered and/or iron intake may be increased.

Key Words: dietary assessment, serum ferritin, hemolysis, iron deficiency, anemia

INTRODUCTION

Good performance in soccer consists of many factors, including excellence in games skills, cognitive abilities to make correct decisions within the game, moderate to high aerobic and anaerobic power.[1] One study investigated the effects of specific aerobic training on performance during soccer match and soccer specific tests.[2] The results showed that enhanced aerobic endurance in soccer players improved soccer performance by increasing the distance covered, enhancing work intensity, and increasing the number of sprints and involvements with the ball during a match. Because running plays an essential role in soccer training, soccer players have risk factors for iron depletion, which include hemolysis caused by repeated foot strikes and physical contact, iron loss through gastrointestinal and urinary tracts, and sweating.

Many studies related to the iron nutritional status in athletes have been performed on female long distance runners and/or endurance athletes,[3,4] while studies on iron intake[5-10] and blood iron status[11-14] of soccer players are limited. Furthermore, many of these studies have been reported from Western countries. The diet of the Japanese population is quite different from that of the population living in Europe and the Americas in general. Japanese dietary habits are characterized by a high carbohydrates intake, along with low protein and fat.[15] Because net depletion of glycogen depots have been observed after soccer matches,[9] it is recommended for players to ingest a well-balanced diet particularly rich in carbohydrates. Furthermore, it has been stated that young soccer players undertaking intense training require adequate amounts of calories, high-quality protein, vitamins, and minerals.[16,17] The purpose of this study was: 1) to collect baseline data on nutrient intake in order to advise athletes about nutrition practices that might enhance performance, and 2) to evaluate the dietary iron intake and blood iron status of Japanese collegiate soccer players.

MATERIAL AND METHODS

Subjects

Two groups comprising 31 well-trained male collegiate soccer players and 15 sedentary controls matched with

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Manuscript received 15 December 2008. Initial review completed 17 June 2009. Revision accepted 2 July 2009.

regard to age were studied. The soccer players, who were maintaining their training schedule that consisted of aerobic and anaerobic exercises all year round (at least 6 days per week and 2 training hours per day) for more than 4 years, volunteered from the K university to participate in this study. The mean (±SD) soccer experience of the players were 10.3±2.7 years. Although the athletes were recruited from nationally competitive senior high-school teams, the K university team was locally competitive at the time of the study because only 15 months have been passed since the foundation of the team. The university employed 2 professional soccer players as coaches for the team. All data were obtained within the same two weeks in June 2008, which was considered representative of their physiologic status during pre-season training. Because almost all students belonged to sport clubs at the K university, the controls were solicited for participation through 2 other universities. They had been sedentary, except participating in a physical education class once a week, for at least 1 year. The subjects were all non-smokers. The study protocol was approved by the Ethics Committee of the Nakamura Gakuen University. Informed consent was obtained from each subject.

Measurements and dietary Information

Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. The body mass index (BMI) was calculated as weight/height^2 (kg/m^2).

All subjects were interviewed by experienced dietitians using a food frequency questionnaire (FFQ), which was developed for the Japanese and based on 29 food groups and 10 types of cooking methods, for energy and nutrient intake estimation during the past 1 to 2 months.[18] The FFQ was validated by a comparison with weighed dietary records for 7 continuous days.[19] From the FFQ, the mean daily nutrient intake was calculated according to the Tables of the Japanese Foodstuff Composition.[20] Each player was also questioned by the investigators as to whether or not he was using nutrient supplement or on a diet.

Blood Analysis

The participants reported to the laboratory in the morning. Physical exercise and beverages other than water were not allowed 24 hours prior to blood sampling. Fasting (12 hour) blood samples were drawn from the antecubital vein after each subject had been seated quietly for at least 30 min. Samples were analyzed by a local commercial laboratory (SRL Inc, Tokyo, Japan). All measurements were duplicated, and the results were reported within 2 weeks. Red blood cell (RBC), hemoglobin (Hb), and hematocrit (Ht) were measured by automated blood cell analyzer.[21] Mean corpuscular volume (MCV) was calculated by Ht/RBC×10, mean corpuscular hemoglobin (MCH) was calculated by Hb/RBC×10, mean corpuscular hemoglobin concentration (MCHC) was calculated by Hb/Ht×100. Serum ferritin was measured by chemiluminescent enzyme immunoassay.[22] Serum iron, total iron-binding capacity (TIBC) and unsaturated iron binding capacity were measured by the Nitroso-PSAP method.[23] Serum transferrin was measured by the turbidimetric immunoassay method[24] and serum haptoglobin by the nephelometry method.[25] Percentage of saturated transferrin was calculated by serum iron/TIBC×100.

Anemia was defined as a Hb level below 13 g/dL. Iron depletion was defined as a ferritin level below 20 μg/L.[26] Hemolysis was defined as serum haptoglobin lower than the standard values reported by the commercial laboratory (SRL Inc., Tokyo, Japan). .

Statistical Analysis

The SPSS statistical software 10.0J (Chicago, IL) was used to analyze the data. Descriptive statistics included means and SD. Differences in mean values between 2 groups were analyzed by 2-tailed t-test. A two-sided $p<0.05$ was considered to be statistically significant.

RESULTS

The characteristics of the subjects are shown in Table 1. The soccer players showed significantly higher mean body weight and BMI than the controls.

The nutrient intakes of the subjects are shown in Table 2; in which nutrient intakes of general population aged 20 to 29 years from the results of the Japanese National Nutrition Survey 2007 were also included.[27] In comparison with the general population, the controls showed very similar values in energy and many other nutrient intakes. None of the subjects were on standard or non-standard diet such as the vegetarian diet. Of the soccer players, 3 were occasionally taking protein and/or multi-vitamin and mineral supplements. Because including the supplements did not alter the results, the results were presented without the supplements. The soccer players showed significantly higher energy and many other nutrient intakes than the controls. However, iron intake did not differ between the 2 groups.

The micronutrient intakes expressed as percentages of the Japanese dietary allowances (RDAs) or adequate dietary intakes (ADIs) are shown in Table 3. The mean intakes of calcium, magnesium, vitamin A, B_1, B_2, and C were lower than RDAs or ADIs in the soccer players, while all micronutrients, except potassium, were lower than the respective RDAs or ADIs in the controls.

The foodstuff intake is shown in Table 4. The soccer players consumed significantly more rice, beverages, fat and oil and less fish than the controls.

The hematological parameters are shown in Table 5. The soccer players showed significantly lower mean Hb and MCHC and higher MCV than the controls. Twenty two out of 31 soccer players (71%) and 4 out of 15 controls (27%) had evidence of hemolysis. None of the soccer players and controls had anemia. Two soccer player had iron depletion, while none of the controls had iron depletion.

Table 1. Characteristics of the study subjects

	Soccer players (n=31)	Sedentary (n=15)
Age (years)	19 ± 1	19 ± 1
Weight (Kg)	66.2 ± 6.2	59.3 ± 6.**
Height (cm)	171.7 ± 5.7	168.6 ± 5.3
BMI (Kg/m2)	22.4 ± 1.6	20.9 ± 1.9*

mean±SD. BMI= body mass index.
$^*p<0.05$, $^{**}p<0.01$.

Table 2. Nutrient intake of the subjects

	Soccer players (n=31)	Sedentary (n=15)	Population[27]
Energy (kcal)	3006 ± 1052	2044 ± 483**	2183
(kcal/kg)	45.6 ± 15.5	34.6 ± 7.7*	
Protein (g)	83.0 ± 30.7	69.4 ± 16.5	76.7
(g/kg)	1.3 ± 0.4	1.2 ± 0.3	
(%E)	11.0 ± 1.3	13.6 ± 1.4***	
Fat (g)	88.7 ± 36.3	71.4 ± 16.9*	66.3
(%E)	26.3 ± 4.3	31.6 ± 3.4***	26.9
Carbohydrate (g)	451.7 ± 162.2	267.4 ± 73.0***	300.2
(g/kg)	6.9 ± 2.4	4.5 ± 1.2**	
(%E)	62.7 ± 5.2	54.8 ± 4.5***	58.9
Potassium (mg)	2822 ± 1451	2167 ± 496*	2181
Calcium (mg)	746 ± 523	498 ± 170*	474
Magnesium (mg)	312 ± 146	220 ± 54**	241
Phosphorus (mg)	1293 ± 600	996 ± 221*	1030
Iron (mg)	8.0 ± 3.3	6.5 ± 1.9	7.8
Heme iron	0.5 ± 0.2	0.6 ± 0.2	
Nonhem iron	7.6 ± 3.2	6.0 ± 1.8	
V.A (μgRE)	507 ± 280	477 ± 125	603
V.B_1 (mg/1000 kcal)	0.38 ± 0.06	0.46 ± 0.06***	0.46
V.B_2 (mg/1000 kcal)	0.46 ± 0.13	0.56 ± 0.11*	0.56
V.C (mg)	71 ± 41	59 ± 21	87

Mean±SD. V= vitamin. *p<0.05, **p<0.01, ***p<0.001.

Table 3. Micronutrient intakes expressed as percentages of the recommended dietary allowances (RDAs), and adequate dietary intakes (ADIs)

			Soccer players (n=31) %	Sedentary (n=15) %
Potassium (mg)	ADI	2000	141.1 ± 72.5	108.3 ± 24.8
Calcium (mg)	ADI	900	82.8 ± 58.1	55.3 ± 18.9
Magnesium (mg)	RDA	340	91.8 ± 43.1	64.8 ± 15.8
Phosphorus (mg)	ADI	1050	123.2 ± 57.1	94.8 ± 21.0
Iron (mg)	RDA	7.5	107.1 ± 43.6	87.0 ± 25.8
V.A (μgRE)	RDA	750	67.6 ± 37.3	63.6 ± 16.7
V.B_1 (mg/1000 kcal)	RDA	0.54	71.1 ± 27.1	67.1 ± 16.9
V.B_2 (mg/1000 kcal)	RDA	0.60	80.4 ± 45.1	70.4 ± 16.5
V.C (mg)	RDA	100	71.3 ± 41.1	58.7 ± 20.9

Mean±SD. V= vitamin.

Table 4. Foodstuff intake of subjects (g)

	Soccer players (n=31)	Sedentary (n=15)
Rice	632.8 ± 291.5	312.2 ± 111.5***
Breads	46.9 ± 42.5	40.9 ± 43.5
Noodles	72.0 ± 56.6	73.7 ± 58.2
Potatos	19.0 ± 20.2	28.1 ± 27.2
Green vegetables	69.8 ± 95.8	82.0 ± 60.5
Other vegetables	109.5 ± 47.1	85.7 ± 54.6
Seaweeds	3.5 ± 3.5	3.7 ± 3.8
Soybeans & soybean products	55.6 ± 71.4	30.7 ± 26.3
Fish (raw & processed)	20.6 ± 21.2	49.0 ± 30.0**
Meat (raw & processed)	113.8 ± 49.1	113.1 ± 46.4
Eggs	33.1 ± 18.0	39.3 ± 16.9
Milk & dairy products	272.9 ± 358.2	170.3 ± 159.2
Fruits	51.6 ± 84.4	27.9 ± 31.1
Beverages	418.8 ± 423.2	184.9 ± 174.7*
Sugars	4.7 ± 5.1	5.0 ± 3.9
Fats & oils	20.6 ± 13.3	15.2 ± 4.0*

Mean±SD. *p<0.05, **p<0.01, **p<0.001.

Table 5. Hematological parameters

	Soccer Players (n=31)	Sedentary (n=15)
Ferritin (ng/mL)	60.6 ± 27.4	61.5 ± 32.9
Transferrin (mg/dL)	256 ± 23	243 ± 35
Serum iron (μg/dL)	104 ± 39	97 ± 29
TIBC (μg/dL)	332 ± 28	318 ± 44
UIBC (μg/dL)	228 ± 41	221 ± 53
Red blood cell (×10000/μL)	508 ± 40	520 ± 34
Hemoglobin (g/dL)	15.3 ± 0.9	16.0 ± 1.0*
Hematocrit (%)	49.9 ± 3.0	48.6 ± 3.0
MCV (fL)	98.5 ± 4.2	93.4 ± 2.4**
MCH (pg)	30.3 ± 1.2	30.8 ± 0.8
MCHC (%)	30.8 ± 0.7	32.9 ± 0.7**
Platelet (×10000/μL)	22.8 ± 4.5	24.8 ± 3.1
Haptoglobin (mg/dL)	66 ± 47	91 ± 48
Tf %	31.3 ± 11.2	31.1 ± 10.2

Mean±SD. TIBC= total iron binding capacity, UIBC= unsaturated iron binding capacity,
MCV= mean corpuscular volume, MCH= mean corpuscular hemoglobin,
MCHC= mean corpuscular hemoglobin concentration, Tf %= saturated transferrin.
*$p<0.05$, **$p<0.001$.

DISCUSSION

Nutrient Intake

The average daily energy intake of the soccer players in the present study (3,006 kcal) was approximately 1.5 times higher than the controls. It was similar to elite Spanish junior players (3,003 kcal)[8] but was lower than the intakes of Puerto Rican Olympic players (3,952 kcal),[10] Italian professionals (3,650 kcal),[7] elite Swedish (4,929 kcal),[9] and Danish players (3,738 kcal).[5] The divergent results obtained among these studies could be due to the differences in body size, training status, skill levels and methods of collecting information on dietary intake.

An adequate carbohydrate intake is important because 1) the high exercise demand nature of soccer, 2) enhanced running performance in soccer players who supplemented their diets with carbohydrate has been reported,[5] and 3) significant glycogen depletion has been observed after soccer matches.[9] In the present study, the mean percentage of energy from carbohydrate for the players (62.7%) was higher than Italian professionals (55.8%),[7] elite Spanish junior players (45%),[8] Puerto Rican Olympic players (53.2%),[10] elite Swedish (47%)[9] and Danish players (46.3%).[5] However, the absolute amount of carbohydrate consumed by the players in the present study was 6.9 g/kg$^-$ body weight (BW). American College of Sports Medicine, American Dietetic Association, and Dietetics of Canada (ACSM, ADA, & DC)[28] stated that a diet providing 500 to 600 g of carbohydrate (approximately 7 to 8 g/kg BW for a 70-kg athlete) is adequate to sustain muscle glycogen stores during training and competition. According to these standards, the mean carbohydrate intake of soccer players in the present study was marginal.

The ACSM, ADA, and DC[28] recommended a protein consumption of 1.2 to 1.4 g/kg/day for endurance athletes and 1.6 to 1.7 g/kg/day for resistance and strength-trained athletes. Tarnopolsky et al.,[29] using the leucine kinetic and nitrogen balance methods, investigated the dietary protein requirements of strength athletes compared with sedentary subjects. They reported that the protein intake for zero nitrogen balance for sedentary subjects was 0.69 g/kg/day and for strength athletes was 1.41 g/kg/day; with a safety margin of ±1 SD, the suggested recommended intake were 0.89 and 1.76 g/kg/day, respectively. Because soccer is a high-intensity, intermittent activity which requires aspects of both strength and endurance over a period of 90 min, Lemon[16] recommended 1.4 to1.7 g/kg/day of protein intake for soccer players. From this assumption, the mean protein intake of soccer players in the present study was marginal (1.3 g/kg/day).

In the present study, the mean intakes in terms of calcium, magnesium, vitamin A, B_1, B_2, and C of the soccer players were lower than the respective Japanese RDAs or ADIs. The mean intakes below RDAs or ADIs in terms of vitamin A, B_1, and B_2, iron, calcium, phosphorus and/or magnesium has been reported in Japanese collegiate karate players.[30, 31] To increase mineral and vitamin intakes, the Ministry of Health, Labour, and Welfare in Japan[32] recommends the consumption of 120 g of green vegetables and 230 g of other vegetables. The consumption of 400 g of milk and dairy products, 200 g of fruits, 50 g of eggs is also recommended for very active men of similar age.[33] The mean intakes of these foodstuffs in both groups in the present study were lower than the recommendations. Consequently, both groups showed inadequacy of micronutrient intakes. Thus, we recommended athletes to increase the intake of these foodstuffs along with slight increase in carbohydrate and lean meat. In addition, written information on foodstuffs which are good sources of calcium, iron, other minerals, vitamins, and/or proteins, such as algae, broccoli, soybean and soybean products, poultry, legumes, nuts, liver, shell fish were given to the subjects.

Two limitations of our study need to be mentioned. First, although the controls were solicited for participation through 2 universities, we could only recruit 15 subjects. However, the nutrient intakes of the control group were very similar to the nutrient intakes of the general population. Thus, we consider the control group as representative of the general population in the same age group. Intakes of many micronutrients below the RDA/ADI are common in the general young Japanese population. Second, in the present study, FFQ was used to estimate energy and nutrient intake of each subject during the past one to two months.[19] Because FFQ was developed to determine the most common food items at the population level, its applicability for assessing the nutrient intakes of people whose eating patterns deviate considerably from those of the mainstream is largely limited. It is stated that FFQ may overestimate at low energy intakes and underestimate at high energy intakes.[34] Thus, the applicability for assessing the nutrient intakes of some of the players, especially players who show much higher or lower energy intake than general population, may possibly be limited. It has been stated that a 7-day dietary record increases the reliability of collected data.[34] However, in the present study, FFQ was chosen because it is much less burdensome than the 7-day dietary record with the busy schedule of the subjects' soccer training and academic studies. Even with this limitation taken into consideration, it seemed worthwhile to collect dietary assessments of these athletes because soccer is becoming one of the most popular sports in Asia and trends in Japanese competitive soccer players' dietary habits, which considerably differ from Western countries, could be shared with others interested in sports nutrition in the region.

Hematological status, dietary iron intake, and blood iron status

Although the mean Hb in the soccer players (15.3 g/dL) was above the accepted standard value (13 g/dL), the soccer players showed significantly lower Hb than the controls. This might be due to the expansion of plasma volume associated with endurance training. Schmidt et al.[35] reported that plasma volume increased during the course of 3 weeks of ergometer training 5 times a week for 45 min at 70% $\dot{V}O_2max$. The soccer players showed significantly lower MCHC and higher MCV than the controls. The higher MCV might be due to increased young red cell.[36]

Some studies reported mean dietary iron intake without measuring blood iron status. Clark et al.[6] reported that members of a US collegiate Division I female soccer players had mean iron intakes of 17.3±4.7 mg/day for preseason and 12.2±5.2 mg/day for post-season. Leblanc et al.[37] reported that 13-16 year old French male elite players had mean intakes ranging from 12±2 to 18±3 mg/day, depending on the different groups divided by their skill level. Iglesias-Gutiérrez et al.[8] reported that Spanish youth players had intakes of about 150% of the RDA. In the present study, the mean dietary iron intake of the soccer players (8±3.3 mg/day) was slightly higher than the respective Japanese RDA but was much lower than the values obtained in the above mentioned studies.

Two studies obtained both iron intake and blood iron status.[11, 14] Douglas [11] reported that sports anemia was not present in 30 female collegiate soccer and field hockey players. On the other hand, Resina et al.[14] examined 19 male professional players and found that 17 of the 19 players' haptoglobin levels were below normal range although the mean iron intake of these players seemed to cover iron losses sufficiently (19 mg/day). In the present study, a high prevalence of hemolysis in the soccer players was also found.

Iron deficiency reduces oxygen transport capacity and oxidative capacity at the cellular level, which develops rapidly or very slowly depending on the balance between iron intake and iron requirements.[38] The estimated basal iron loss and dietary iron absorption for Japanese reference men aged 18 to 29 years are 0.91 mg/day and 15%, respectively.[32] The dietary iron intake of the soccer players (8 mg/day) would cover the basal iron loss. For the endurance-trained athletes, the total iron loses from feces, urine, and sweat have been estimated at about 1.75 mg/day.[39] Although, calculated iron absorption (8 mg/day × 0.15 = 1.2 mg/day) for the soccer players in the present study appears to be lower than the estimated total iron losses for the endurance-trained athletes, iron status of the athletes were very normal in the present study. Because we collected the data during pre-training period, the future study should obtain data throughout the season. Escanero et al.[12] examined iron stores in 9 male professional soccer players. They obtained blood samples at the beginning, in the middle, and at the end of the season and reported that seum ferritin reduced significantly at the end of the season.

Soccer players have risk factors for iron depletion, which include poor iron intake, hemolysis caused by repeated foot strikes and physical contact, iron loss through gastrointestinal and urinary tracts, and sweating. Robinson et al.[40] suggested possible reasons of intravascular hemolysis, namely: intramuscular destruction, osmotic stress, and membrane lipid peroxidation caused by free radicals released by active leukocytes. They also stated that intravascular hemolysis can even be regarded as physiological means to provide heme and proteins for muscle growth.

In conclusion, we recommended athletes to increase the intake of green and other vegetables, milk and dairy products, fruits, and eggs along with slight increase in carbohydrate and lean meat. Although a high prevalence of hemolysis (71%) in the soccer players was found, none of the subjects had anemia. Two soccer players had iron depletion, while none of the controls had iron depletion. In those players who had iron deficiency, the training load need to be lowered and/or iron intake may be increased.

AUTHOR DISCLOSURES

This study was supported by grants from the Nakamura Gakuen University and Nakamura Gakuen University Graduate School. Yuka Noda, Kazuhide Iide, Reika Masuda, Reina Kishida, Atsumi Nagata, Fumiko Hirakawa, Yoshitaka Yoshimura, and Hiroyuki Imamura, no conflicts of interest.

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Original Article

Nutrient intake and blood iron status of male collegiate soccer players

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大學的男性足球員營養素攝取與血液中鐵狀況

此研究目的共有兩個 1. 收集運動員營養攝取基本資料，以便提出營養建議，可能有助運動表現；2. 評估日本大學足球員，飲食鐵攝取與血液中鐵狀況。受試者共有 31 位足球員及 15 位控制組人員，經由食物頻率問卷獲得飲食資料。足球運動員醣類及蛋白質攝取平均數（6.9 g•kg^{-1} BW 及 1.3 g/kg）皆在建議目標邊緣；然而鈣、鎂、維生素 A、B_1、B_2 及 C 皆低於日本每日營養素建議攝取量（RDAs）及足夠膳食攝取量。綠色蔬菜及其他種類蔬菜、奶類、奶類製品、水果及蛋攝取皆低於建議目標。因此建議運動員增加攝取這些食品，並且些微增加醣類及瘦肉攝取量。足球員鐵平均攝取量高於 RDA。在足球運動員中發現高比例溶血現象（71％）。足球運動員及控制組皆未發現有貧血，其中有兩位足球運動員有鐵耗盡情形，而在控制組中均未發現此情形。發現鐵缺乏的運動員，必須降低負荷訓練或是增加鐵的攝取量。

關鍵字：膳食評估、血清鐵蛋白、溶血、鐵缺乏、貧血