PRELIMINARY REPORT

Nutritional Status, Iron-Deficiency–Related Indices, and Immunity of Female Athletes

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Nutritional status, iron-deficiency–related biochemical indices, and immunologic patterns of female Judo athletes and control subjects were evaluated. The subjects' 3-d food records showed that 41.0 kcal/kg of energy was consumed daily and the contributions of protein, fat, and carbohydrate to total energy intake were 12.5%, 29.2%, and 58.3%, respectively. The reported vitamin intakes of athletic subjects were above those of the recommended daily allowance, however, calcium and iron intakes were less than 100% of the recommended daily allowance. Intakes of energy, protein, phosphate, vitamin B1, and vitamin B2 were higher in the athletes than in the control subjects. Analysis using the Nutrient Adequacy Ratio and the Index of Nutritional Quality showed that athletic subjects had more desirable patterns than the control subjects. There was no any indication of anemia, which often occurs as a result of hemodilution in strenuously trained athletes. The subjects' immunologic patterns showed a slight immunosuppression. Iron, vitamin B1, niacin intakes were positively correlated with immunoglobulin (Ig) G levels in the athletes. The relation between nutrient intakes and the immune systems of endurance-trained athletes needs further investigation. *Nutrition* 2002;18:86–90. ©Elsevier Science Inc. 2002

KEY WORDS: nutritional status of female athletes, biochemical indices, immunologic status

INTRODUCTION

Athletes can undergo special demands because of enhanced metabolic process developed through extensive exercise. The repetitive training also makes them vulnerable to fatigue. In some sports, a repetitive cycle of food deprivation is common and might lead to a nutritionally undesirable state and dehydration problems. For good health, conditioning, and performance of athletes, appropriate nutrition becomes an important factor. In previous studies, overnutrition or imbalance of protein and fat and insufficient trace elements and vitamins were found in athletes.[1–3] Complete avoidance of foods high in animal fat reduces the intake of protein and several fat-soluble vitamins. In contrast, diets with very high carbohydrate content are usually achieved at the expense of protein. Plasma concentrations of copper, magnesium, and zinc in athletes have been found to be reduced.[4–6] In addition, nutritional problems related to micronutrients such as iron-deficiency anemia can occur.[7,8] In the previous investigations with Korean female athletes, calcium, iron, vitamin A, and vitamin C were found to be deficient.[9] In addition, there was a high prevalence of these athletes using micronutrient supplements.[10,11] Excessive intakes of micronutrients can cause toxicity problems. Deficiencies or excesses of various dietary components can have a substantial impact on immunosuppression often associated with heavy training loads. Various immune response parameters are suppressed by vigorous and heavy athletic training.[12–14] In this study, we investigated the nutritional status, dietary practices, and measures of nutritionally related blood biochemical indices of athletes versus those of sedentary control subjects. Of those biochemical indices, iron-deficiency–related blood parameters and immunologic characteristics were examined to establish a nutritional basis for the health and performance of athletes

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SUBJECTS AND METHODS

In this study, 18 female Judo athletes (mean age = 20.0 ± 0.0) were selected as the athletic subjects. Subjects exercised regularly for 6.0 h/d. Fifteen sedentary control subjects (female; mean age = 20.7 ± 0.2) were selected among their college mates and identified as individuals who did not engage in any regular exercise during their daily routines. The descriptive characteristics of both groups are shown in Table I. All subjects reported that they were nonsmokers, had no previous pregnancies or eating disorders, and were not taking supplements or drugs. Each subject completed a 3-d dietary record, and those records were processed with the Computer-Aided Nutritional Analysis (CAN) program (Korean Nutrition Society) to obtain the daily average intakes of nutrients. The dietary recommendations for Korean athletes were not available for comparison, so we used the recommended dietary allowances (RDAs) for normal Koreans. The nutrient adequacy ratio (NAR) was calculated from the subjects' daily average nutrient intakes according to the following equation, and values greater than 1 were expressed as 1 to identify individuals with lower intakes for each nutrient:

$$\text{NAR} = \frac{\text{one subject's daily intake of a specific nutrient}}{\text{Korean RDA of that nutrient}}$$

The average NAR value of all assessed nutrients was represented as the mean adequacy ratio. The Index of Nutritional Quality (INQ) indicates the quality of a nutrient in a diet relative to the recommended nutrient intake:

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TABLE I.

CHARACTERISTICS OF CONTROL AND ATHLETIC SUBJECTS*

	Controls	Athletes
Age (y)	20.0 ± 0.0	20.7 ± 0.2
Height (cm)	160.0 ± 1.3	165.9 ± 0.2‡
Weight (kg)	54.0 ± 1.7	65.1 ± 1.3‡
Body mass index	21.1 ± 0.8	23.5 ± 0.7†
Body fat (%)	25.8 ± 1.4	21.5 ± 0.6‡

* Values are shown as mean ± standard error of the mean.
† $P < 0.05$, significant difference between athletes and controls.
‡ $P < 0.01$, significant difference between athletes and controls.

$$\text{INQ} = \frac{\text{amount of nutrient in 1000 kcal of food}}{\text{allowance of nutrient/1000 kcal}}$$

Body mass index was calculated as weight (kg) divided by height (m^2). Estimates of subjects' body fat were determined by the bioelectric impedence method (Gil Woo Company, Seoul, Korea).

Blood samples were taken from an antecubital vein after a 12-h overnight fast. Whole blood was then centrifuged at 2000 rpm for 30 min to separate cells from serum. Serum samples were then stored at −70°C until analysis.

TABLE II.

AVERAGE DAILY INTAKES OF NUTRIENTS OF THE CONTROL AND ATHLETES STUDIED*

	Controls	Athletes	*t* test
Energy (kcal)	1680.4 ± 83.4	2667.3 ± 134.3	§
Protein (g)	60.5 ± 3.9	82.7 ± 5.1	‡
Animal	30.0 ± 3.3	45.0 ± 4.3	‡
Plant	30.0 ± 2.0	37.7 ± 1.9	‡
Fat (g)	45.4 ± 3.3	85.7 ± 6.7	§
Animal	22.3 ± 2.9	38.8 ± 3.9	‡
Plant	23.1 ± 2.0	46.9 ± 4.4	§
Carbohydrate (g)	257.8 ± 15.0	385.8 ± 15.9	§
NPC/N	148.55 ± 10.86	176.54 ± 13.95	‡
Calcium (mg)	428.5 ± 59.0	588.5 ± 62.3	
Animal	232.1 ± 53.0	359.7 ± 60.0	
Plant	196.4 ± 23.0	228.8 ± 11.9	
Phosphate (mg)	861.7 ± 57.0	1239.8 ± 83.6	§
Iron (mg)	10.2 ± 0.7	12.2 ± 1.8	
Animal	3.2 ± 0.5	3.1 ± 0.3	
Plant	7.0 ± 0.5	9.1 ± 1.7	
Sodium (mg)	3529.0 ± 335.6	4160.2 ± 275.2	
Potassium (mg)	2105.3 ± 190.6	2617.4 ± 138.0	†
Vitamin A (μg RE)	841.4 ± 273.8	820.7 ± 47.7	
Retinol	118.6 ± 35.3	258.5 ± 41.9	
Carotenoids	2689.0 ± 541.9	3289.4 ± 244.0	
Vitamin B1 (mg)	1.00 ± 0.07	1.34 ± 0.09	‡
Vitamin B2 (mg)	0.86 ± 0.11	1.36 ± 0.11	‡
Niacin (mg)	12.9 ± 1.1	15.0 ± 1.0	
Vitamin C (mg)	87.4 ± 15.4	75.5 ± 5.6	
Cholesterol (mg)	204.4 ± 25.9	325.6 ± 48.0	†

* Values are shown as mean ± standard error of the mean.
† $P < 0.05$, significant difference between controls and athletes.
‡ $P < 0.01$, significant difference between controls and athletes.
§ $P < 0.001$, significant difference between controls and athletes.
NPC/N, ratio of non-protein calories to nitrogen; RE, retinol equivalent.

TABLE III.

PERCENTAGE OF THE RECOMMENDED DIETARY ALLOWANCE IN AVERAGE DAILY NUTRIENT INTAKES OF CONTROL AND ATHLETIC SUBJECTS*

	Controls	Athletes	*t* test
Energy	84.0 ± 4.2	133.4 ± 6.7	‡
Protein	100.8 ± 6.6	137.8 ± 9.4	†
Calcium	61.2 ± 8.4	84.1 ± 8.9	
Phosphate	123.1 ± 8.1	177.1 ± 11.9	†
Iron	56.8 ± 3.8	67.7 ± 10.0	
Vitamin A	120.2 ± 39.1	117.2 ± 6.8	
Vitamin B1	100.0 ± 7.3	134.4 ± 9.3	†
Vitamin B2	70.8 ± 9.0	113.4 ± 8.9	†
Niacin	99.0 ± 8.8	115.2 ± 7.8	
Vitamin C	158.9 ± 28.0	131.9 ± 10.1	

* Values are shown as mean ± standard error of the mean.
† $P < 0.01$, significant difference between controls and athletes.
‡ $P < 0.00$, significant difference between controls and athletes.

Serum iron level and total iron-binding capacity were measured with a ferrozine colorimetric method that used reagent kits (Diagnostics kit 565, Sigma Chemical Co., St. Louis, MO, USA). Percentage of transferrin saturation was determined by computing the ratio of serum iron to the total iron-binding capacity. Serum ferritin level was measured with a ^{125}I-radioimmunoassay kit (Amersham International, Buckinghamshire, UK).

Serum levels of IgA, IgG, and IgM were measured according to the rate nephelometry method.[15]

The total leukocyte and neutrophil counts in whole blood were measured with a Coulter counter. Lymphocyte subsets were analyzed within 1 d with monoclonal antibodies. Antibodies of $CD3^+$ for T lymphocytes, $CD4^+$ for helper T cells, $CD8^+$ for suppressor T cells, $CD19^+$ for B lymphocytes, and $CD56^+$ for natural killer cells were added to portions of whole blood. After reactions between antibodies and lymphocytes, lysing solution was added and centrifuged to remove the red blood cells, and antibody-binding cells were counted with a flow cytometer (FACScan, Becton Dickinson, Mountain View, CA, USA). Lymphocyte subsets were expressed as percentages of specific antibody-binding cells per 10,000 lymphocytes. Statistical analysis was done with the Statistical Analysis System (SAS, Cary, NC, USA). Data were expressed as the mean with or without standard error, and statistically significant differences between subgroup means were evaluated primarily by unpaired Student's *t* test.

RESULTS

The demographic and basic physical characteristics of athletic and sedentary control subjects are presented in Table I. Mean height, weight, and body mass index were higher in the athletic group. Even though the mean body mass index of the athletic group was higher than that of the sedentary group, mean percentage of body fat was significantly lower than that of the sedentary group (21.5 ± 0.6 versus 25.8 ± 0.6). The mean values for dietary intake of nutrients and percentage RDA of average daily nutrient intakes of the control and athletic groups are shown in Tables II and III. The athletes' reported daily energy intake was 41.0 kcal/kg (2667.3 kcal/d), which was much higher than that of the sedentary controls (31.1 kcal/kg, 1680.4 kcal/d). The athletes consumed 133.4% of the Korean RDA, whereas sedentary controls consumed 16% below the Korean RDA. The contributions of protein, fat, and carbohydrate to total energy intake of the athletic group were

TABLE IV.

NAR AND INQ SCORES OF CONTROL AND ATHLETIC SUBJECTS*

	NAR		INQ	
	Controls	Athletes	Controls	Athletes
Energy	0.83 ± 0.04	1.00 ± 0.03‡		
Protein	0.90 ± 0.13	1.00 ± 0.04‡	1.19 ± 0.19	1.03 ± 0.14†
Calcium	0.60 ± 0.24	0.74 ± 0.24	0.73 ± 0.25	0.61 ± 0.18
Phosphate	0.96 ± 0.47	1.00 ± 0.00	1.46 ± 0.24	1.32 ± 0.18
Iron	0.57 ± 0.14	0.59 ± 0.25	0.70 ± 0.20	0.49 ± 0.23†
Vitamin A	0.75 ± 0.33	0.95 ± 0.10†	1.62 ± 2.04	0.89 ± 0.19
Vitamin B1	0.90 ± 0.16	0.96 ± 0.08	1.21 ± 0.25	1.01 ± 0.23†
Vitamin B2	0.67 ± 0.22	0.93 ± 0.23§	0.85 ± 0.09	0.84 ± 0.14
Niacin	0.86 ± 0.16	0.94 ± 0.13	1.17 ± 0.09	0.87 ± 0.21‡
Vitamin C	0.88 ± 0.18	0.94 ± 0.10	1.84 ± 0.31	1.03 ± 0.42‡
MAR	0.79 ± 0.14	0.89 ± 0.06‡		

* Values are shown as mean ± standard error of the mean.
† $P < 0.05$, significant difference between controls and athletes.
‡ $P < 0.01$, significant difference between controls and athletes.
§ $P < 0.001$, significant difference between controls and athletes.
INQ, Index of Nutritional Quality; MAR, mean adequacy ratio; NAR, nutrient adequacy ratio.

12.5%, 29.2%, and 58.3% respectively. For the sedentary controls, 14.4% of energy was derived from protein, 24.3% from fat, and 61.3% from carbohydrate. Athletic subjects' average daily intakes of animal protein and fat were 45.0 and 38.8 g, respectively. There was a trend toward a higher proportion of animal as opposed to plant protein and a lower proportion of animal as opposed to plant fat in the athletic subjects. The ratios of non-protein calories to nitrogen (NPC/N) were 176.54 in the athletes and 148.55 in the controls. Of the minerals studied, calcium and iron intakes were shown to be insufficient in both groups, whereas sodium and phosphate intakes were sufficient. The average intakes of calcium and iron in the athletes were not significantly different from those in the sedentary subjects. The vitamin intakes of the athletes were sufficient compared with the Korean RDAs. Of the vitamins, vitamin B1 and B2 intakes were higher in the althetes than in the sedentary control subjects. The control subjects consumed insufficient vitamin B1. The mean daily cholesterol intake of the athletic group was slightly higher than the recommended value (<300 mg) and that of the control group was within the normal range.

NAR and INQ values of the control and athletic groups are shown in Table IV. The NAR values for the athletes were significantly higher in energy, protein, vitamins A and B2, and mean adequacy ratio. The INQ analysis results showed that protein, vitamin B1, niacin, and vitamin C were higher in the athletic subjects, whereas iron was lower (0.70 ± 0.20 for controls versus 0.49 ± 0.23 for athletes).

The albumin and iron-deficiency–related blood parameters are shown in Table V. All mean values were within the normal range in both groups except for total iron-binding capacity in the control group, which was lower than the criterion for deficiency (>390 μg/dL). Even though serum iron levels of athletes were higher, serum ferritin levels were lower than those in control subjects.

White blood cell counts and lymphocyte subpopulation profiles of all subjects are shown in Table VI. There were no significant differences in the lymphocyte subpopulation cell numbers between the athletes and the controls. Table VII shows serum IgG, IgA, and IgM concentrations in all subjects. The concentrations of IgG and IgM were significantly lower in the athletic subjects than in the control subjects. The immunologic parameters correlated positively with some of the iron-deficiency–related blood parameters in both groups (Table VIII). There were significant correlations between IgG levels and iron, vitamin B1, and niacin in the athletic subjects but not in the control subjects (Table IX).

TABLE V.

IRON-DEFICIENCY–RELATED BLOOD PARAMETERS OF CONTROL AND ATHLETIC SUBJECTS*

	Controls	Athletes
Serum albumin (g/dL)	5.04 ± 0.06	4.84 ± 0.06†
Serum iron (μg/dL)	96.9 ± 9.0	125.7 ± 7.3†
TIBC (μg/dL)	373.0 ± 12.3	395.7 ± 12.4
Serum ferritin (μg/dL)	28.0 ± 4.3	25.4 ± 4.9
Transferrin (μg/dL)	317.6 ± 8.8	327.8 ± 10.2

* Values are shown as mean ± standard error of the mean.
† $P < 0.05$, significant difference between athletes and controls.
TIBC, total iron-binding capacity.

TABLE VI.

LYMPHOCYTE SUBSETS OF CONTROL AND ATHLETIC SUBJECTS*

Lymphocyte type	Controls	Athletes	*t* test
$CD3^+$	68.8 ± 1.8	64.3 ± 2.0	NS
$CD4^+$	34.5 ± 2.4	36.1 ± 2.3	NS
$CD8^+$	31.3 ± 1.7	29.1 ± 1.8	NS
$CD19^+$	14.3 ± 1.3	16.7 ± 1.8	NS
$CD56^+$	19.6 ± 1.9	20.5 ± 1.0	NS

* Values are shown as mean ± standard error of the mean.
NS, no significant difference between controls and athletes.

DISCUSSION

The average daily energy intake of the athletic group was 2667.3 kcal, or 133.4% of the RDA, and that of the control group was 1680.4 kcal, or only 84.0% of RDA. The reported energy intake of elite athletes averaged 2300 to 5900 kcal depending on the type of exercise.[16] The required energy intake of the athletes was estimated by multiplying the activity factor with the basal energy expenditure of Korean females 20 to 29 y old and then using the activity factor calculation data of the Korean Nutrition Society.

TABLE VII.

IMMUNOGLOBULIN G, A, AND M CONCENTRATIONS IN CONTROL AND ATHLETIC SUBJECTS*

Immunoglobulin (mg/dL)	Controls	Athletes	*t* test
G	1743.3 ± 58.1	1534.4 ± 73.9	†
A	168.5 ± 12.3	189.0 ± 13.2	NS
M	213.1 ± 22.0	166.4 ± 10.5	†

* Values are shown as mean ± standard error of the mean.
† $P < 0.05$, significant difference between controls and athletes.
NS, not significant.

TABLE VIII.

CORRELATION COEFFICIENTS BETWEEN IMMUNOLOGIC STATUS AND IRON-DEFICIENCY–RELATED BIOCHEMICAL INDICES OF ATHLETIC AND CONTROL SUBJECTS

		IgG	IgM	IgA	CD3^{+} cells	CD4^{+} cells	CD8^{+} cells	CD19^{+} cells	CD56^{+} cells
Serum iron	Athletes	0.3225	0.4981*	0.1839	−0.7745*	−0.3049	−0.3001	0.7387*	−0.0611
	Controls	−0.2259	0.1922	−0.1089	0.0126	0.0297	0.5749	−0.5281	0.1803
TIBC	Athletes	0.1509	−0.0853	−0.0154	−0.1234	0.0264	0.0093	0.1421	0.3132
	Controls	0.1799	0.5127	0.2740	0.2064	0.1877	−0.2469	0.1122	−0.2578
Ferritin	Athletes	−0.2360	−0.1815	0.0289	0.3267	0.3686	−0.0952	−0.1117	−0.0468
	Controls	−0.0954	0.2874	−0.0844	−0.7327*	−0.2129	0.2597	−0.0532	0.7784*
Transferrin	Athletes	0.1064	0.0129	−0.1814	0.3267	0.3686	−0.0959	−0.1117	−0.0468
	Controls	0.4699	0.6272*	0.3523	0.2636	0.3147	−0.6018	0.1439	−0.2616

* Significant correlation between the two parameters of rows on the left and columns on the right at $P < 0.05$.
IgA, IgG, IgM, immunoglobulins A, G, M; TIBC, total iron-binding capacity.

The activity factor was calculated as 2.11 according to the athletes' daily schedule, and the final estimated energy expenditure was 3065.7 kcal (data not shown). The resulting energy balance of the athletes was negative, so they needed approximately 398.4 kcal to meet their energy requirements.

The contributions of protein, fat, and carbohydrate to total energy intake in the athletic group were 12.5%, 29.2%, and 58.3% respectively. Compared with athletes in other studies,[17,18] the athletic subjects in this study appeared to derive less energy from fat and more from protein and carbohydrate. However, the proportion of carbohydrates in the diet can be modified for better performance based on the current theory of the connection between athletic performance and carbohydrate intake. For prolonged and strenuous endurance training, the relative contributions of specific nutrients might be altered so carbohydrates in particular would provide 60% to 70% of the total energy consumed.[19,20]

TABLE IX.

CORRELATION COEFFICIENT BETWEEN IMMUNOLOGIC STATUS AND NUTRIENT INTAKES OF ATHLETIC AND CONTROL SUBJECTS

		IgG	IgM	IgA	CD3^{+} cells	CD4^{+} cells	CD8^{+} cells	CD19^{+} cells	CD56^{+} cells
Energy	Athletes	0.3075	−0.2045	0.0926	0.2160	0.1435	0.3455	−0.6776*	0.4729
	Controls	−0.2190	0.0718	0.7010*	−0.3083	−0.4918	0.4832	0.5887	−0.2106
Protein	Athletes	0.3750	−0.0565	−0.0618	0.2378	0.2070	0.0345	−0.4727	0.5167
	Controls	−0.0168	−0.1867	−0.5827	−0.1522	−0.4129	0.2202	0.6173	−0.4753
Fat	Athletes	0.1000	−0.1529	0.0231	0.3145	0.1689	0.5016	−0.7593*	0.2442
	Controls	−0.5009	−0.2959	−0.5075	−0.0323	0.0286	0.2208	0.1384	−0.2481
CHO	Athletes	0.4036	−0.2731	0.2147	0.0604	0.0184	0.2859	−0.5431	0.6549*
	Controls	−0.1434	0.2839	0.6652*	−0.4310	−0.6259	0.5961	0.1023	−0.0423
Fiber	Athletes	0.5066	−0.0562	−0.0172	−0.3903	−0.1466	−0.1304	0.0028	0.3754
	Controls	0.1300	−0.4152	−0.1599	−0.2781	−0.6765*	0.0869	0.5910	−0.1127
Calcium	Athletes	0.2571	−0.2645	0.1429	0.3989	−0.1405	0.5982	−0.5819	0.4736
	Controls	−0.0663	−0.3155	−0.4758	−0.5448	−0.5367	0.1467	0.6456	−0.0050
Phosphate	Athletes	0.3309	−0.1550	0.0052	0.3538	0.0076	0.3589	0.5586	0.5806
	Controls	0.1265	−0.4330	−0.1227	−0.2523	−0.5240	0.1352	0.6586	−0.3193
Iron	Athletes	0.5057*	−0.3738	0.3855	0.0061	−0.1441	0.6913	−0.3823	0.6036
	Controls	0.1611	−0.4063	−0.5219	−0.2416	−0.4728	−0.0969	0.7114*	−0.3690
Vitamin A	Athletes	0.1957	−0.1421	0.1296	0.1486	−0.0664	0.5742	−0.3671	0.2504
	Controls	0.0725	0.0228	0.3765	−0.5757	−0.4074	0.2907	−0.0598	0.6665
Vitamin B1	Athletes	0.5235*	0.0741	0.0072	−0.2345	0.0282	−0.2397	−0.1645	0.5217
	Controls	−0.1360	−0.2750	−0.2670	0.0311	−0.1687	−0.0519	0.4235	−0.3168
Vitamin B2	Athletes	0.3507	−0.2169	0.1929	0.1434	−0.0286	0.3930	−0.6231	0.6047
	Controls	−0.0611	−0.3134	−0.3273	−0.5026	−0.5172	0.3320	0.6887*	−0.1538
Niacin	Athletes	0.4804*	0.0051	0.1486	0.0096	0.3417	−0.4163	−0.1931	0.4418
	Controls	0.1114	−0.2444	−0.2925	−0.0723	−0.3299	−0.0128	0.7059*	−0.3733
Vitamin C	Athletes	0.1158	0.1058	0.0368	0.6532*	−0.2106	−0.3066	0.1947	0.0242
	Controls	−0.4301	−0.2494	−0.5416	0.0864	−0.3555	0.1565	0.1530	−0.3257
MAR	Athletes	0.5615*	−0.0791	0.1960	0.0519	0.1782	0.0050	−0.4205	0.3779
	Controls	0.0185	−0.2683	−0.4814	−0.3007	−0.6426	0.1773	0.5795	−0.2350

* Significant correlation between the two parameters of rows on the left and columns on the right at $P < 0.05$.
CHO, carbohydrate; IgA, IgG, IgM, immunoglobulins A, G, M; MAR, mean adequacy ratio

Unlike the protein and fat intakes of most Western athletes, there was no indication of protein and fat overnutrition in our athletes. Based on research, intakes of 10% to 15% of protein, 30% to 35% of fat, and 50% to 60% of carbohydrate were suggested as daily dietary recommendations for athletes in Western countries.[16] The ratio of energy to protein in an athlete's diet needs attention. As the energy requirement of an athlete increases, the protein supply must be increased. In the present study. the net amount of energy and protein was higher in the athletic than in the control group, but the athletic group had a lower ratio of protein to energy, as shown in the NPC/N comparisons (176.54 for athletes versus 148.55 for controls). Even though the NPC/N values of the athletic subjects were in the optimal range of 150 to 200, their protein intake should have been higher, given their intensive exercise training.

The average intakes of calcium and iron in the athletes were lower than the RDAs at 84.4% and 67.7%, respectively. According to Woo et al.,[9] Korean female athletes consume less calcium (83.3%) and iron (57.0%). Calcium and iron deficiencies have been found in the nutrient intakes of female field-hockey players.[21] Low intakes of calcium and iron by aerobic athletes were observed.[22]

The vitamin intakes of our athletes were sufficient in relation to the Korean RDA, unlike other Korean female athletes' consumption of vitamins A (83.4%) and C (57.1%).[9] However, the vitamin recommendation for athletes probably differ from those of non-athletic people.[1]

Even though serum iron levels of athletes were higher, serum ferritin levels were lower than in control subjects. In a blood profile and physical activity study with 1743 Finnish men, the duration and frequency of physical activity were associated inversely with serum ferritin and blood hemoglobin. Further, Karmizrak et al.[23] reported that ferritin stores of athletes are about 30% less than normal, which might have occurred as a result of a shift in iron storage from reticuloendothelial cells to hepatocytes in athletes, rather than from a diminished total body iron supply.[24]

A heavy schedule of training and competition of athletes might lead to immunosuppression,[25] placing them at a greater risk for opportunistic infection. We found a slight immunosupression in the athletes, as indicated by their significantly low concentrations of IgG and IgM. Bishop et al.[14] discussed some of the major nutrition factors responsible for immunosuppression such as the decreased Ig concentrations usually found in athletes. Our study showed a strong correlation between nutrient intake and immune function in athletes. The imbalanced dietary regimen often adopted by athletes can cause immunologic depression. In addition, prolonged exercise likely depletes glycogen reserves, leading to keen competition among muscles and immune cells for major amino acids and/or an energy deficit that might reduce immunologic capacity.[12] Further, accelerated protein catabolism may have resulted in immunosuppression. The athletes in this study may need to increase their protein intake from 1.27 g/kg according to the suggestion[13] that 2.0 g/kg is more appropriate for athletes than the range of 0.7 to 1.0 g/kg for sedentary individuals. The effects of iron, vitamin B1, and niacin status on immunocompetence needs further investigation to establish the roles of these nutrients in exercise-induced immunosuppression.

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