



Dietary Iron Intake and Hemoglobin Concentration in College Athletes in Different Sports

Takako Fujii^{1,2*}, Yuka Okumura³, Etsuko Maeshima^{3,4} and Koji Okamura²

¹Japanese Center for Research on Women in Sports, Juntendo University, Japan

²Graduate School of Sport Science, Osaka University of Health and Sport Sciences, Japan

³Department of Health and Sport Management, Osaka University of Health and Sport Sciences, Japan

⁴Third Department of Internal Medicine, Wakayama Medical University, Japan

***Corresponding author:** Takako Fujii, Japanese Center for Research on Women in Sports, Juntendo University, Graduate School of Sport Science, Hiragagakuendai, Inzai, Chiba 270-1695, Japan, E-mail: takako519@gmail.com

Abstract

Iron-deficiency anemia is relatively prevalent among endurance athletes. It is therefore recommended that athletes consume a greater amount of iron. Resistance exercise has been shown to alleviate anemic symptoms, suggesting that the prevalence of anemia may vary among athletes that participate in different sporting events and that their iron requirements may differ according to their sports. The present study investigated the relationship between iron intake and anemia in college athletes in different sports. A total of 97 college athletes who participated in various sports including sprinting, throwing, jumping, middle and long distance running, judo, gymnastics and American football were evaluated. Fifty-eight of 70 (83%) male athletes consumed more iron than the recommended daily allowance (RDA), while 3 of 70 (4%) consumed less iron than the estimated average requirement (EAR). In contrast, only 4 of 27 (15%) of female athletes consumed more iron than the RDA, while 19 of 27 (83%) consumed less iron than the EAR. The hemoglobin (Hb) concentration was within the normal range in all participants; thus none of the athletes was anemic, while the Hb concentration was significantly higher in the throwing group than in the middle and long distance running group among males. Although female athletes showed a similar trend to the males, the Hb concentration did not differ to statistically significant extent. These results suggest that iron requirements may differ depending on the type of sport, and that athletes may not always need to adhere to the currently recommended practice of consuming large amounts of iron.

Keywords

Type of exercise, Blood analyses, Diet survey

Introduction

Athletes such as long distance runners, whose routine training consumes a great deal of energy, demonstrate a relatively high prevalence of iron-deficiency anemia [1]. It has been proposed that iron deficiency results from several factors such as a low iron intake [2], gastrointestinal hemorrhage [1] and hemolysis within the micro vessels of the foot during running [3]. The hemoglobin concentration

is low in some athletes due to the expansion of the plasma volume, which is known as pseudo anemia [4]. Thus, endurance sports are often considered to cause iron-deficiency anemia. Consequently, it has been recommended that athletes consume more iron than the general population. The reference intake of iron for athletes in Japan is 20-30 mg [5], which is approximately two to three times the recommended daily allowance (RDA; 7.0 mg/day for male, 10.5 mg/day for female) [6]. It has been reported that mild resistance exercise improves the iron status of young females with non-anemic iron deficiency without iron supplementation [7]. In a rat model in which climbing exercises were used to model resistance exercise, rats displayed enhanced bone marrow heme biosynthesis after performing resistance exercise training for 3 weeks, regardless of their dietary iron content [8]. This effect was stronger than that induced by aerobic exercise [9]. In addition, the activity of bone marrow δ -aminolevulinic acid dehydratase (ALAD), the key enzyme involved in Hb synthesis, has been shown to increase after resistance exercise and to decrease over time [10], while the basal ALAD activity in the bone marrow is maintained at a high level after routine resistance exercise training in comparison to that in sedentary rats [11,12].

Exercise has been demonstrated to cause decreased iron absorption [13-15]. Ruckman et al. reported that swimming increased fecal iron excretion and decreased apparent iron absorption and that the iron content was increased in the skeletal muscles and decreased in the liver and spleen by swimming exercises [14]. The authors suggested that the decrease in the iron content in the liver and spleen may be associated with an increase in the Hb level and that exercise influences the distribution and reuse of iron in the body. We observed an increase in the fecal excretion of iron in iron-deficient rats which performed resistance exercises in comparison to sedentary iron-deficient rats [15]; however, there was no significant difference between the exercised and sedentary rats in their blood iron status and tissue iron content. This observation suggests that the resistance exercise-induced improvement in iron status does not occur due to an increase in iron absorption. Rather, it is caused by an increase in the recycling of iron within the body. Thus, the effects of exercise on iron

Citation: Fujii T, Okumura Y, Maeshima E, Okamura K (2015) Dietary Iron Intake and Hemoglobin Concentration in College Athletes in Different Sports. Int J Sports Exerc Med 1:029

Received: September 30, 2015: **Accepted:** December 09., 2015: **Published:** December 11., 2015

Copyright: © 2015 Fujii T, et al. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.

status differ according to the type of exercise. Thus, the present study investigated the relationship between iron intake and the prevalence of anemia in athletes engaged in various sports.

Materials and Methods

Subjects

A total of 97 healthy college athletes (age: 20-21 years) who belonged to exercise clubs in a university majoring in sport sciences and who performed exercise on a daily basis were studied. The participants engaged in various sports, including sprinting (18 males and 4 females), throwing (8 males and 6 females), jumping (6 males and 2 females), middle and long distance running (8 males and 5 females), judo (7 males and 7 females), gymnastics (6 males and 3 females) and American football (17 males). Prior to the study, informed consent was obtained from each participant after a detailed explanation of the experimental procedures. The protocol of this study was approved by the Experimental Human Committee of Osaka University of Health and Sport Sciences.

Body composition analysis

Body weight (BW), body fat and lean tissue mass were measured using an electronic scale (ITO-InBody370; ITO Co., Ltd. Tokyo, Japan) under fasting conditions in the morning. The impedance method was employed for the measurement of body fat and lean tissue mass. Body height was measured using a stadiometer (U-well2; MST Inc., Kyoto, Japan). The body mass index (BMI) was calculated by dividing the BW in kilograms by the square of the height in meters (kg/m^2). The demographic and physiological characteristics of the subjects are shown in **table 1**.

Diet survey

A diet survey was conducted with a food frequency questionnaire, Excel Eiyokun FFQg Ver.3.5 (Kenpakuhsa, Tokyo, Japan). The use of

dietary supplements, including the name of the items, the amounts consumed and the frequency of their use and their nutrient values were analyzed using a nutrient calculation software program (Excel Eiyokun Ver. 6.0 [Kenpakuhsa, Tokyo, Japan]). The diet survey was performed by registered dieticians. Menstrual abnormalities and the use of oral contraceptives were also investigated with the questionnaire in the females.

Blood analyses

Venous blood samples were obtained under fasting condition in the morning to measure the subjects' red blood cell (RBC), hemoglobin (Hb), hematocrit (Hct), mean cell volume (MCV), mean corpuscular hemoglobin (MCH) and mean cell hemoglobin concentration (MCHC) values. Hb was determined by the SLS-Hb assay. RBC, Hct, MCV, MCH and MCHC were determined by the sheath flow DC detection method (XE2100D; Sysmex Co., Hyogo, Japan). All analyses were conducted at a clinical laboratory (Koseikai Medical Corporation, Osaka, Japan). Anemia was defined, according to the criteria of the World Health Organization (WHO), as an Hb concentration of $< 13 \text{ g/dL}$ for males and $< 12 \text{ g/dL}$ for females [16].

Statistics

A Steel-Dwass test was used to identify differences among the groups for which a significant result was identified by a Kruskal-Wallis test. P values of < 0.05 were considered to be statistically significant. The results for females in the jumping group only represent the mean values and were excluded from the statistical analysis because there were only two participants.

Results

The RBC, Hb, Hct, MCV, MCH and MCHC values are shown in **table 2**. No participants were anemic, as the Hb concentrations were $> 13 \text{ g/dL}$ in all males and $> 12 \text{ g/dL}$ in all females.

Table 1: The results of body composition measurements.

			Sprinting	Throwing	Jumping	Middle and long distance running	Judo	Gymnastics	American football
	Male / Female		n = 18 / n = 4	n = 8 / n = 6	n = 6 / n = 2	n = 8 / n = 5	n = 7 / n = 7	n = 6 / n = 4	n = 17
Male	Height	cm	172.0 \pm 4.8	173.3 \pm 6.0	176.8 \pm 5.0	171.1 \pm 6.5	172.6 \pm 6.2	166.1 \pm 4.2	170.9 \pm 4.7
	Body weight	kg	62.8 \pm 6.3 ^b	79.5 \pm 6.3 ^a	61.6 \pm 4.8 ^b	57.1 \pm 5.7 ^b	100.8 \pm 28.5 ^a	60.2 \pm 2.9 ^{ab}	80.2 \pm 12.2 ^a
	BMI	kg/m ²	21.2 \pm 1.5 ^{bc}	26.6 \pm 2.8 ^{ab}	19.7 \pm 1.3 ^c	19.5 \pm 0.7 ^c	33.6 \pm 8.2 ^a	21.8 \pm 1.0 ^{bc}	27.4 \pm 3.6 ^a
	Body fat	%	11.5 \pm 1.7 ^b	19.9 \pm 6.2 ^a	9.0 \pm 1.6 ^b	11.1 \pm 2.4 ^b	27.5 \pm 8.9 ^a	9.3 \pm 2.3 ^b	22.3 \pm 6.6 ^a
	Lean tissue mass	kg	55.5 \pm 5.1 ^b	63.5 \pm 5.1 ^a	56.0 \pm 4.2 ^{ab}	50.7 \pm 4.8 ^b	71.1 \pm 12.4 ^{ab}	54.6 \pm 3.6 ^{ab}	61.7 \pm 5.3 ^a
Female	Height	cm	162 \pm 4.7	162.6 \pm 3.6	155.2	160.8 \pm 4.8	164.1 \pm 7.2	155.7 \pm 4.5	
	Body weight	kg	53.4 \pm 4.3 ^{ab}	67.7 \pm 1.8 ^a	49.6	49.9 \pm 6.7 ^b	68.4 \pm 8.9 ^{ab}	50.4 \pm 2.6 ^{ab}	
	BMI	kg/m ²	20.3 \pm 1.4 ^{ab}	25.6 \pm 1.3 ^a	20.6	19.2 \pm 1.8 ^b	24.8 \pm 1.9 ^{ab}	20.8 \pm 0.4 ^{ab}	
	Body fat	%	16.9 \pm 2.7	26.2 \pm 1.6	19.7	21.1 \pm 3.9	23.3 \pm 3.8	18.2 \pm 1.2	
	Lean tissue mass	kg	44.3 \pm 3.6 ^{ab}	49.6 \pm 52.2 ^a	39.9	39.2 \pm 3.8 ^b	51.4 \pm 7.3 ^{ab}	41.3 \pm 2.7 ^{ab}	

The values are presented as the mean \pm SD. BMI, Body mass index. Values which do not share common superscript differ significantly ($P < 0.05$).

Table 2: The results of the blood analyses.

			Sprinting	Throwing	Jumping	Middle and long distance running	Judo	Gymnastics	American football
	Male / Female		n = 18 / n = 4	n = 8 / n = 6	n = 6 / n = 2	n = 8 / n = 5	n = 7 / n = 7	n = 6 / n = 4	n = 17
Male	RBC	$\times 10000/\mu\text{l}$	502.9 \pm 27.7 ^b	537.6 \pm 19.7 ^a	506.7 \pm 35.9 ^{ab}	467.9 \pm 32.5 ^b	525.7 \pm 23.1 ^{ab}	490.3 \pm 26.3 ^{ab}	515.5 \pm 29.6 ^{ab}
	Hb	mg/dl	15.7 \pm 0.8 ^{ab}	16.1 \pm 0.4 ^a	15.4 \pm 1.0 ^{ab}	14.8 \pm 0.7 ^b	15.6 \pm 0.9 ^{ab}	15.0 \pm 1.0 ^{ab}	15.7 \pm 0.9 ^{ab}
	Hct.	%	46.9 \pm 2.2	48.3 \pm 1.4	45.9 \pm 3.2	45.2 \pm 2.0	47.9 \pm 2.8	45.4 \pm 2.1	47.8 \pm 2.7
	MCV	fL	92.9 \pm 3.0	89.5 \pm 2.4	90.3 \pm 2.8	96.3 \pm 3.7	90.3 \pm 2.0	92.3 \pm 3.8	92.4 \pm 3.7
	MCH	pg	31.1 \pm 0.9	29.8 \pm 0.8	30.3 \pm 0.9	31.7 \pm 1.4	29.7 \pm 0.7	30.1 \pm 1.4	30.5 \pm 1.0
	MCHC	g/dl	33.3 \pm 0.7	33.2 \pm 0.4	33.4 \pm 0.7	32.7 \pm 0.6	32.6 \pm 0.6	32.9 \pm 1.1	32.9 \pm 0.9
Female	RBC	$\times 10000/\mu\text{l}$	446.0 \pm 20.6	463.5 \pm 26.8	467.0	416.6 \pm 17.6	450.7 \pm 31.6	466.3 \pm 37.4	
	Hb	mg/dl	13.6 \pm 0.2	13.9 \pm 0.9	15.3	13.0 \pm 0.6	13.5 \pm 0.7	13.9 \pm 0.9	
	Hct.	%	42.2 \pm 1.2	42.5 \pm 1.9	46.1	40.2 \pm 2.1	41.3 \pm 2.3	42.8 \pm 2.5	
	MCV	fL	94.0 \pm 1.8	94.2 \pm 3.6	95.5	96.0 \pm 4.2	91.6 \pm 2.8	92.0 \pm 1.7	
	MCH	pg	30.5 \pm 1.0	30.7 \pm 1.0	31.8	31.1 \pm 1.2	30.0 \pm 0.8	29.8 \pm 0.8	
	MCHC	g/dl	32.3 \pm 0.5	32.5 \pm 0.7	33.0	32.2 \pm 0.4	32.7 \pm 0.6	32.5 \pm 0.6	

The values are presented as the mean \pm SD. RBC: Red Blood Cell, Hb: Hemoglobin, Hct: Hematocrit, MCV: Mean Cell Volume, MCH: Mean Corpuscular Hemoglobin, MCHC: Mean Cell Hemoglobin Concentration. Values which do not share common superscript differ significantly ($P < 0.05$).

Among the males, the Hb concentration was highest in the throwing group and lowest in the middle and long distance running group; there was a significant difference between these two groups. The RBC showed similar results. The RBC, Hb, Hct, MCV, MCH, and MCHC values were all within the respective normal ranges.

The female subjects showed similar results to those observed in the male subjects; however, they did not reach statistical significance. The mean Hb level and RBC were highest in the throwing group, while the middle and long distance running group showed the lowest values. The RBC, Hb, Hct, MCV, MCH and MCHC values were within the respective normal ranges.

The results of the diet survey are shown in **table 3**.

The mean iron intake of the male subjects was 10.3 ± 3.8 mg/day, which is greater than the RDA (7.0 mg/day) and the estimated average requirement (EAR, 6.0 mg/day) [6]. Four subjects in the American football group and one subject in the middle and long distance running group consumed iron from supplements (1.0-5.7 mg/day and 6.8 mg/day, respectively). No subjects exceed the tolerable upper intake level of iron. All groups consumed more than 1.0 g/kg BW/day of protein. The energy ratio of protein, fat and carbohydrate did not differ among the groups. The meat protein ratio (approximately 50%) did not differ significantly among the groups.

The mean iron intake of the female subjects was 8.0 ± 3.1 mg/day, which was less than both the RDA (10.5 mg/day) and the EAR (8.5 mg/day) [6]. None of the female subjects consumed iron supplements. No subjects exceeded the tolerable upper intake level of iron. All groups consumed more than 1.0 g/kg BW/day of protein with the exception of the gymnastics group. The energy ratio of protein, fat and carbohydrate did not differ significantly among the groups. The meat protein ratio was approximately 50% in all of the groups.

Menstrual irregularities were noted in three of the six females in the gymnastics group and four of the six females in the middle and long distance running group.

The relationship between the daily iron intake and Hb concentration in the male and female athletes are shown in **figure 1** and **figure 2**, respectively. No correlation was observed between the iron intake and Hb concentration in either the males or the females.

Table 3: The results of diet survey.

		Sprinting	Throwing	Jumping	Middle and long distance running	Judo	Gymnastics	American football
Male / Female		n = 18 / n = 4	n = 8 / n = 6	n = 6 / n = 2	n = 8 / n = 5	n = 7 / n = 7	n = 6 / n = 4	n = 17
Male	Energy	kcal	2706.9 ± 404.1^c	4000.2 ± 1015.8^{abc}	3709.1 ± 873.6^{abc}	2848.5 ± 696.1^{bc}	5386.7 ± 1039.8^a	2800.2 ± 854.0^{abc}
	Protein	g	83.2 ± 15.2^c	120.2 ± 31.7^{abc}	126.5 ± 40.9^{abc}	98.3 ± 24.6^{abc}	155.1 ± 32.3^a	83.0 ± 24.2^{abc}
		g/kg BW	1.3 ± 0.3	1.5 ± 0.4	2.1 ± 0.6	1.7 ± 0.5	1.6 ± 5.0	1.4 ± 0.5
	Fat	g	85.8 ± 19.0^b	126.4 ± 34.3^{ab}	123.5 ± 46.0^{ab}	102.1 ± 32.5^{ab}	166.1 ± 40.2^a	85.1 ± 28.0^{ab}
	Carbohydrate	g	387.7 ± 72.3^c	568.0 ± 178.1^{abc}	505.0 ± 113.2^{abc}	338.5 ± 90.3^{bc}	784.1 ± 168.1^a	405.5 ± 125.8^{abc}
	Iron	mg	8.1 ± 1.9^b	11.7 ± 5.9^{ab}	12.2 ± 4.7^{ab}	10.3 ± 4.1^{ab}	14.4 ± 2.5^a	8.4 ± 2.7^{ab}
	Vitamin C	mg	112.5 ± 55.6^{ab}	207.2 ± 130.4^a	148.2 ± 71.03^{ab}	99.1 ± 34.6^{ab}	111.6 ± 41.4^{ab}	76.3 ± 25.3^b
	Protein energy	%	12.2 ± 1.4	12.1 ± 1.6	13.5 ± 1.8	13.5 ± 1.3	11.6 ± 1.5	11.9 ± 0.6
	Meat protein ratio	%	49.8 ± 11.1^{ab}	56.0 ± 13.5^{ab}	53.9 ± 11.4^{ab}	59.7 ± 3.2^a	50.2 ± 10.6^{ab}	49.5 ± 3.0^b
	Fat energy	%	28.6 ± 5.0	28.9 ± 5.4	29.5 ± 6.6	32.0 ± 4.0	27.7 ± 4.0	27.3 ± 4.1
	Carbohydrate energy	%	59.1 ± 5.9	59.0 ± 6.8	57.1 ± 8.2	54.5 ± 4.8	60.7 ± 4.9	60.8 ± 4.3
Female	Energy	kcal	1989.8 ± 424.6^{ab}	2143.2 ± 671.6^{ab}	2587.6	1795.5 ± 81.7^b	3195.3 ± 1016.0^a	1517.2 ± 187.1^{ab}
	Protein	g	62.2 ± 12.3	68.2 ± 22.5	93	62.0 ± 13.8	104.4 ± 46.4	50.4 ± 9.3
		g/kg BW	1.2 ± 0.2	1.0 ± 0.3	1.9	1.3 ± 3	1.5 ± 0.6	1.0 ± 0.2
	Fat	g	62.1 ± 12.6	81.1 ± 33.4	92.0	60.1 ± 8.2	117.2 ± 51.5	64.8 ± 17.3
	Carbohydrate	g	290.7 ± 77.6	277.1 ± 83.9	343.0	241.3 ± 12.4	411.4 ± 134.6	178.3 ± 18.0
	Iron	mg	6.6 ± 1	7.1 ± 2.4	12.6	7.1 ± 2.9	10.0 ± 3.3	5.4 ± 1.0
	Vitamin C	mg	103.9 ± 38.7	102 ± 56	149.2	87.1 ± 35.7	142.2 ± 72.4	66.7 ± 27.9
	Protein energy	%	12.5 ± 0.6	12.8 ± 1.3	14.3	13.8 ± 2.7	12.8 ± 1.8	13.3 ± 1.7
	Meat protein ratio	%	52.2 ± 6.3	56.0 ± 11.7	44.2	49.2 ± 3.5	55.8 ± 12.7	63.7 ± 9.7
	Fat energy	%	28.4 ± 4.8	33.7 ± 6.1	31.2	30.1 ± 3.5	32.9 ± 8.5	38.0 ± 6.2
	Carbohydrate energy	%	59.1 ± 4.9	53.5 ± 7.1	54.5	56.1 ± 5.3	54.3 ± 9.8	48.7 ± 7.2

The values are presented the mean \pm SD. Values which do not share common superscript differ significantly ($P < 0.05$).

Among the male athletes, the Hb concentrations ranged from 13.6 g/dl (American football group) to 17.1 g/dl (American football group), while the daily iron intake ranged from 4.6 mg (gymnastics group) to 24.6 mg (throwing group). Among the female athletes, the Hb concentrations ranged from 12.2 g/dl (middle and long distance running group) to 15.8 g/dl (jumping group), and the daily iron intake ranged from 3.6 mg (throwing group) to 16.0 mg (judo group).

The iron intake of 58 of 70 (83%) male athletes exceeded the RDA, while 3 of 70 (4%) consumed less iron than the EAR. In contrast, only 4 of 27 (15%) of females consumed more iron than the RDA, while 19 of 27 (83%) consumed less iron than the EAR.

Discussion

Endurance exercise, especially hard routine training, has been shown to be associated with anemia [1,17-19], while some forms of resistance exercise appear to ameliorate anemia [7-12,15], suggesting that the iron status of athletes varies according to the type of exercise

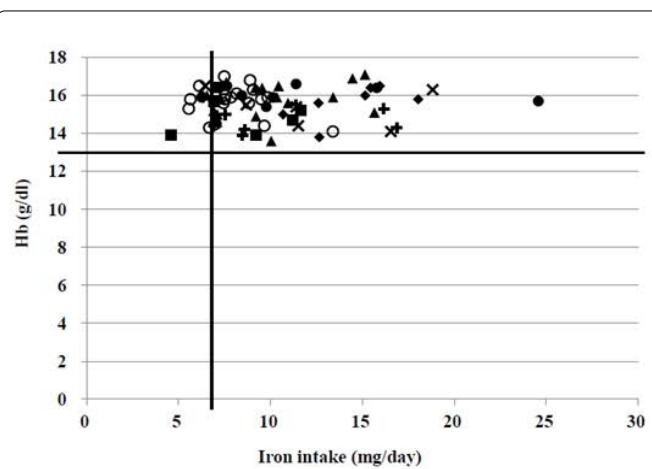


Figure 1: The relationship between the daily iron intake and hemoglobin concentration in males. ○: sprinting, ●: throwing, ✕: jumping, +: middle and long distance running, ♦: judo, ■: gymnastics, ▲: American football. The black transverse line indicates the cut-off value for the hemoglobin concentration. The black vertical line indicates the recommended dietary allowance (RDS) for males.

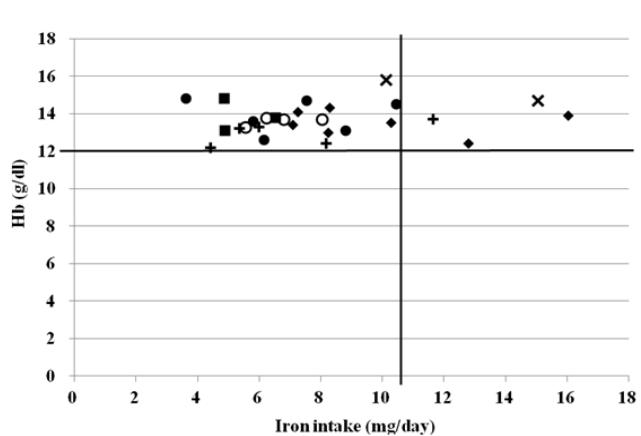


Figure 2: The relationship between the daily iron intake and hemoglobin concentration in females. ○: sprinting, ●: throwing, ✕: jumping, +: middle and long distance running, ♦: judo, ■: gymnastics. The black transverse line indicates the cutoff value for the hemoglobin concentration. The black vertical line indicates the recommended dietary allowance (RDA) for females.

that they perform. Thus, the present study investigated the relationship between iron intake and anemia in college athletes engaged in different sports. The results showed that the Hb and RBC levels in the subjects who were predominantly engaged in resistance exercise, such as throwing tended to be higher than those who predominantly engaged in endurance exercise such as middle and long distance running. The results also showed that quite a number of the subjects, especially females, consumed less iron than the RDA or even the EAR, whereas their Hb levels were not low. Likewise, some males did not meet the RDA of iron, but this was not reflected by low Hb levels.

The iron intake might be under- or overestimated because the intake was assessed with a food frequency questionnaire. The food frequency questionnaire is accepted as a tool for evaluating the nutrient intake of a subject over a period of one to two months [20,21]. Imamura et al. determined the nutritional intake of 34 male rugby players using a food frequency questionnaire [22] and showed a mean iron intake of 7.2-8.7 mg/day, without anemia. In addition, Taguchi et al. determined the nutrient intake of 93 female athletes based on a 9-day food record and photographic evidence and showed a mean iron intake of 8.5 ± 2.6 mg/day, without anemia [23]. As the results on iron intake in the present study were not significantly different to those of the studies by Imamura et al. [22] and Taguchi et al. [23], the iron intake reported in the present study was considered to be reliable.

In this study, the Hb concentrations were normal in all participants. However, there are some reported cases in which the serum ferritin level was low despite a normal Hb concentration. We were not able to evaluate the serum ferritin level in the present study, because we used the data of annual physical check-up that did not include the measurement of serum ferritin. Future studies that measure the serum ferritin level as well as other parameters to evaluate iron status such as iron-binding capacity, transferrin saturation and hepcidin concentration are needed to investigate the relationship between the iron intake and anemia in different sports.

The absorption of heme iron is higher than that of non-heme iron. Protein derived from meat sources promotes iron absorption and the consumption of meat results in a two-fold increase in the absorption of non-heme iron [24]. Lyle et al. reported that the daily consumption of one meat-containing meal was effective for maintaining serum ferritin levels in a prolonged study of subjects engaging in aerobic dance [25]. Tetens et al. reported that women of childbearing age who consumed a meat-based diet maintain their serum ferritin level, while this parameter decreased in those who consumed a vegetable-based diet [26]. In the current study, all of the participants, with the exception of the female gymnasts, consumed more than 1.0 g/kg BW/day of protein, and the proportion of consumption of animal-derived protein was approximately 50% in both males and females. These results suggest that sufficient meat consumption prevents the subjects from becoming anemic via increased iron absorption.

Resistance exercise has been reported to increase iron recycling in the body of rats [15]. Reinke et al. indicated that rowing, in which the most dominant physical factors for performance are power and endurance, mitigates the reduction of iron in comparison to soccer, which is dominated by speed and agility [27]. The routine training for sprinting, throwing, judo and American football, sports in which the Hb and RBC levels were higher than in middle and long distance running, includes a greater amount of resistance exercise than middle and long distance running. These observations suggest the possibility that iron recycling in the body is enhanced in athletes whose training predominantly includes resistance exercise training, which has been shown to prevent a decline in the Hb concentration.

The present study evaluated the relationship between iron intake and anemia in college athletes engaging in different sports. Some participants, especially the females of the present study did not meet the RDA or even EAR for iron; however, none of the participants were anemic. The required intake of iron appears to vary depending on factors such as the training method and intensity, and also the competition level. The results of the present study suggest that among athletes, the requirement might differ depending on the type of exercise that they perform and that athletes might not always need to consume large amounts of iron as is currently recommended.

Acknowledgements

This study was supported by grants from Osaka University of Health and Sport Sciences.

References

1. Ehn L, Carlmark B, Höglund S (1980) Iron status in athletes involved in intense physical activity. *Med Sci Sports Exerc* 12: 61-64.
2. Lukaski HC (2004) Vitamin and mineral status: effects on physical performance. *Nutrition* 20: 632-644.
3. Dufaux B, Hoederath A, Streitberger I, Hollmann W, Assmann G (1981) Serum ferritin, transferrin, haptoglobin, and iron in middle- and long-distance runners, elite rowers, and professional racing cyclists. *Int J Sports Med* 2: 43-46.
4. Eichner ER (1992) Sports anemia, iron supplements, and blood doping. *Med Sci Sports Exerc* 24: 315-318.
5. Nagamine S (1979) Sports and energy nutrition. In: *Meal composition and nutrient requirements of the athlete*, 216-229.
6. Japanese Nutritional Requirements-Meal Consumption Standards (2010-2015) Report of Ministry of Health, Welfare and Labour's.
7. Matsuo T, Suzuki M (2000) Dumbbell exercise improves non-anemic iron deficiency in young women without iron supplementation. *Health Sc* 16: 236-243.
8. Matsuo T (2004) Effects of resistance exercise on iron metabolism in iron-inadequate or iron-deficient rats. *The Korean Journal of Exercise Nutrition* 8:1-15.
9. Matsuo T, Suzuki H, Suzuki M (2000) Resistance Exercise Increases the Capacity of Heme Biosynthesis More Than Aerobic Exercise in Rats. *J Clin Biochem Nutr* 29: 19-27.
10. Fujii T, Matsuo T, Okamura K (2012) The effects of resistance exercise and post-exercise meal timing on the iron status in iron-deficient rats. *Biol Trace Elem Res* 147: 200-205.
11. Matsuo T, Kang HS, Suzuki H (2002) Voluntary Resistance Exercise Improves Blood Hemoglobin Concentration in Severely Iron-Deficient Rats. *J Nutr Sci Vitaminol* 48: 161-164.
12. Fujii T, Asai T, Matsuo T, Okamura K (2011) Effect of resistance exercise on iron status in moderately iron-deficient rats. *Biol Trace Elem Res* 144: 983-991.
13. Nachtigall D, Nielsen P, Fischer R, Engelhardt R, Gabbe EE (1996) Iron deficiency in distance runners. A reinvestigation using Fe-labelling and non-invasive liver iron quantification. *Int J Sports Med* 17: 473-479.
14. Ruckman KS, Sherman AR (1981) Effects of exercise on iron and copper metabolism in rats. *J Nutr* 111: 1593-1601.
15. Fujii T, Matsuo T, Okamura K (2014) Effects of resistance exercise on iron absorption and balance in iron-deficient rats. *Biol Trace Elem Res* 161:101-106.
16. (1968) Nutritional anaemias. Report of a WHO scientific group. *World Health Organ Tech Rep Ser* 405: 5-37.
17. Dressendorfer RH, Wade CE, Amsterdam EA (1981) Development of pseudoanemia in marathon runners during a 20-day road race. *JAMA* 246: 1215-1218.

18. Wijn JF, De Jongeste JL, Monsterveld W, Willebrand D (1971) Hemoglobin, packed cell volume, and iron binding capacity of selected athletes during training. *Nutr Metab* 13: 129-139.

19. Radomski MW, Sabiston BH, Isoard P (1980) Development of "sports anemia" in physically fit men after daily sustained submaximal exercise. *Aviat Space Environ Med* 51: 41-45.

20. Sone H, Yoshimura Y, Tanaka S, Iimuro S, Ohashi Y, et al. (2007) Cross-sectional association between BMI, glycemic control and energy intake in Japanese patients with type 2 diabetes. Analysis from the Japan Diabetes Complications Study. *Diabetes Res Clin Pract* 77: 23-29.

21. Umegaki H, Iimuro S, Araki A, Sakurai T, Iguchi A, et al. (2009) Association of higher carbohydrate intake with depressive mood in elderly diabetic women. *Nutr Neurosci* 12: 267-271.

22. Imamura H, Iide K, Yoshimura Y, Kumagai K, Oshikata R, et al. (2013) Nutrient intake, serum lipids and iron status of collegiate rugby players. *J Int Soc Sports Nutr* 10: 9.

23. Taguchi M, Ishikawa-Takata K, Tatsuta W, Katsuragi C, Usui C, et al. (2011) Resting energy expenditure can be assessed by fat-free mass in female athletes regardless of body size. *J Nutr Sci Vitaminol (Tokyo)* 57: 22-29.

24. Meehye K, Dong-Tae L, Yeon-Sook L (1995) Iron absorption and intestinal solubility in rats are influenced by dietary proteins. *Nutrition Research* 15: 1705-1716.

25. Lyle RM, Weaver CM, Sedlock DA, Rajaram S, Martin B, et al. (1992) Iron status in exercising women: the effect of oral iron therapy vs increased consumption of muscle foods. *Am J Clin Nutr* 56: 1049-1055.

26. Tetens I, Bendtsen KM, Henriksen M, Ersbøll AK, Milman N (2007) The impact of a meat- versus a vegetable-based diet on iron status in women of childbearing age with small iron stores. *Eur J Nutr* 46: 439-445.

27. Reinke S, Taylor WR, Duda GN, von Haehling S, Reinke P, et al. (2012) Absolute and functional iron deficiency in professional athletes during training and recovery. *Int J Cardiol* 156: 186-191.