Journal of Combat Sports and Martial Arts
© MEDSPORTPRESS, 2010; 2(2); Vol. 1, 85-90

Iron metabolism assessment with reference to selected anthropometric parameters and food-stuffs consumption National Taekwondo Team competitors

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Key words: iron deficiency, ferritin, soluble transferrin receptor, sport, iron bioavailability, food consumption

Summary

Introduction. Iron deficiency can lead to loss of exercise potential. A proper diet plays a key role in iron supplementation. The goal of the study was the assessment of selected anthropometric parameters as related to blood biochemical parameters reflecting iron concentration.

Material and methods. The sample included National Taekwondo Team competitors (15 males and 15 females). Body mass and body composition were determined based on anthropometric measurements. Iron levels were measured by iron, ferritin, transferrine and transferrin receptor assay. Using a calibrated FFQ questionnaire, information was obtained from the subjects on their nutritional habits.

Results. One male subject had his blood iron level elevated; in the remaining subjects, the biomarkers of iron levels were normal. Among the females, 3 had normal iron level biomarkers, 8 were diagnosed with 1st degree iron deficiency and 4 – with 2nd degree iron deficiency. The female subjects with decreased body mass had significantly higher blood content of ferritin and significantly lower content of transferrin. No significant differences were found in consumption of products being the main source of iron. The males were found to consume more high processed grain products and less coffee and tea then their female counterparts. The females with disturbed iron metabolism were found to consume significantly less meat and smoked poultry, coffee and tea than the females with normal iron levels.

Conclusions. The results suggest the need of iron and nutritional status monitoring in female athletes. Modification of nutritional habits may significantly contribute to improvement of blood biochemical parameters.

Introduction

Iron deficiency is commonly diagnosed in athletes, particularly those involved in endurance sports Iron deficiency may amount to 10% in male athletes and even 20% in female ones [1]. Short-term iron deficiency may not lead to anemia if hemoglobin level does not drop below the normal values defined for the gender and age groups [2].

Healthy individuals usually have iron reserves, acting as a buffer against deficiency and utilised when the dietary content of iron is insufficient to meet the body demand for this element. Deficiency is a status when the body runs out of iron or the reserves are insufficient and the tissues that need iron (blood, cerebral tissue and muscles) are still able to maintain normal physiological functions [3].

Iron metabolism is an exceptional process as it is controlled by absorption and not by excretion. Males and the females who do not menstruate lose approximately 1 mg of iron daily through the loss of blood or dead cells. The women who menstruate lose significantly more iron. Additionally, there are multiple underlying mechanism acting during exertion: hemolysis, hematuria, perspiration and bleeding within the gastrointestinal system [2,4,5,6].

Iron absorption, which takes place mainly in the small intestine, amounts to 5-15% in individuals with normal homeostasis [7]. Overdosing leads to absorption decrease and deficiency – to its threefold to fivefold increase. The dietary content of iron has a vast influence on iron metabolism, as well as the products containing iron and the nutrients that may additionally increase iron absorption.

Stores of iron in the body are measured by determining serum ferritin levels provided no infection is present. Otherwise, ferritin levels may increase even though the stores of iron are low. Then, with frequent infections, it may be difficult to find the reason of high ferritin levels [5]. Additionally, ferritin concentration is closely related to training load [8,9]. It increases immediately following exertion and can mask iron deficiency. Serum ferritin levels below 30 mg/l are indicative of deficiency and the levels below 12 mg/l indicate running out of iron reserves in the body [10,11].

Transferrin receptor concentration in blood serum also reflects the intensity of erythropoiesis and body demand for iron. Concentration of this receptor increases with progressive anemia due to iron deficiency. Clinical studies indicate that the results based on serum transferrin receptor content are less affected by inflammatory conditions than the results based on ferritin concentration [12]. Transferrin receptor is a stable indicator of iron status with high training load. Unlike ferritin, it does not change due to physical load applied the day before [11,12].

As a functional element of hemoglobin and myoglobin, iron is a fundamental nutrient in oxygen transport to body tissues. Moreover, it is found in the centres of active mitochondria and cytochromes participating in energy production [13]. Iron deficiency was found to affect health [14,15,16] and well-being [19] and to result in loss of body exercise potential [17,18,19].

Despite the knowledge of the significance of iron, numerous reports [20,21,22], indicate that in individuals performing regular physical exercise, iron dietary content is frequently insufficient and even marginal.

The goal of the study was to assess the effect of selected anthropometric parameters, nutrient consumption and slimming on blood biochemical parameters indicating iron status in National Team Taekwondo competitors.

Material and methods

The study was carried out in Polish National Taekwondo Senior team competitors in 2009, including 30 athletes participating in the training organised by Polish Olympic Taekwondo Association. The sample comprised 15 females and 15 males aged 17-26 years.

To evaluate the subjects' nutritional status using anthropometric methods, the following parameters were measured: body mass [kg], body height [cm] and four skin-fat folds [cm]. Based on the obtained results, body nutritional status was determined using body mass index (BMI) and body fat content using Durnin and Womersley's method [23].

To evaluate iron metabolism, serum iron levels were determined as well as the levels of ferritin, transferrin and transferrin receptor. Table 1 presents reference values of these paramaters.

The subjects were next divided into groups (A, B and C) according to the degree of iron deficiency (Table 2). The classification of iron deficiency proposed by Peeling et al. [14] was used: I – iron deficiency: decreased iron stores in bone marrow, liver and spleen; II – disturbed erythropoiesis: limited erythropoiesis due to the decreased iron transport potential; III – anemia with iron deficiency: decrease in hemoglobin production.

Evaluation of the nutritional habits in the studied sample was made using a calibrated Food Frequency Questionnaire (FFQ) [24]. The questions pertained to the frequency of consumption of 165 products and meals and the amounts consumed. The frequency of consumption was defined based on habitual daily, weekly, monthly and yearly consumption. The consumed amounts of food products were expressed in grams and pieces. The sizes of food portions were determined according to the "Photo Album of Nutritional Products and meals" [25].

The results were next subjected to statistic analysis using StatSoft STATISTICA 9 program. The analysis was based on Student-t test and one-factor variance analysis ANOVA) at the level $p<=0.05$.

Results

Table 3 presents general characteristics of the studied population and the mean values of iron biomarker status. Statistically significant between-gender differences were found in

Tab. 1. Ranges of normal values for athletes according to the Warsaw Institute of Sport

Parameter	Range of normal values
iron [μg/100 ml]	37-160
ferritin [μg/l]	>30
transferrin [g/l]	2.0-3.6
transferrin receptor [μg/ml]	2.9-8.3

Tab. 2. Classification of iron metabolism disorders

Group	Degree of deficiency	Fr[1] [μg/l]	sTfR[2] [μg/ml]
A	normal parameters of iron status	>30	<8.3
B	**I** – iron reserve deficiency	<30	<8.3
C	**II** – running out/no iron reserve decreased erythropoiesis	<12	>8.3

[1] Fr – blood ferritin level
[2] sTfR – serum transferrin receptor level

Tab. 3. Basic anthropometric and biochemical parameters in the studied male and female population[1]

	Range of normal values	Women (n=15)[2]	Men (n=15)	p
Age		20.4±2.5	22.1±1.8	-
Height [cm]		169.7±7	179.3±10.2	-
Body mass [kg]		60.6±8.3	72.7±13.3	≤0.**01**[3]
BMI [kg/m^2]		21±1.7	22.4±2	≤0.**05**[4]
Adipose tissue [%]		25.7±4	13.6±3	≤0.**001**[5]
Iron [mg/dl]	37-160	110.5±76.6	107.2±37.7	Ns[6]
Ferritin [µg/l]	>30	20.6±15.3	60.2±17.17	≤0.**001**
Transferrin [mg/dl]	2.0-3.6	2.83±0.39	2.22±0.17	≤0.**001**
sTfR[7] [µg/ml]	2.9-8.3	7.25±7.16	4.20±0.81	ns

[1] $\bar{x} \pm SD$ – mean values and standard deviation
[2] n – number of subjects
[3] ≤0.01 – differences statistically significant at p≤0.01
[4] ≤0.05 – differences statistically significant at p≤0.05
[5] ≤0.001 – differences statistically significant at p≤0.001
[6] ns – differences statistically insignificant
[7] sTfR – serum transferrin receptor level

Tab. 4. BMI values and the level of iron status markers and body content of adipose tissue[1]

	Range of normal values	**BMI**≤19,9 [kg/m^2]	**BMI=20÷24,9** [kg/m^2]	**BMI>25** [kg/m^2]	p
WOMEN		(n=5)[1]	(n=10)	(n=0)	
Adipose tissue [%]		22.8±1.5	27.1±4.1	-	≤0.**05**[2]
Iron [mg/dl]	37-160	114±96	109±71	-	Ns[1]
Ferrytyna [µg/l] Ferritin	>30	10±9	26±15	-	≤0.**05**
p≤0.05					
Transferrin [g/l]	2.0-3.6	3.1±0.1	2.7±0.4	-	≤0.**05**
sTfR[3] [µg/ml] Transferrin	2.9-8.3	11.9±11.6	4.9±1.4	-	ns
MEN		(n=2)	(n=12)	(n=1)	
Adipose tissue [%]		11.2±2.5	14.2±3	10.6	ns
Iron [mg/dl]	37-160	86±19	110±39	104	ns
Ferritin [µg/l]	> 30	57±13	61±18	56	ns
Transferrin [g/l]	2.0-3.6	2.2±0.4	2.2±0.2	2.1	ns
sTfR [µg/ml]	2.9-8.3	4.4±2.1	4.2±0.6	4.6	ns

[1] n – number of subjects
[2] ≤0.05 – differences statistically significant at
[3] ns – differences statistically insignificant

ferritin and transferrin levels. Mean ferritin concentration in the females was below normal values (<30 µg/l). Analysis of population distribution according to the degree of iron deficiency revealed abnormal ferritin concentration in 12 females, I degree iron deficiency in 8 females (Fr<30 µg/l, sTfR<8.3 µg/ml) and II degree deficiency in 4 females (Fr<12 µg/l, sTfR>8.3 µg/ml). Two female subjects with II degree deficiency had also their blood iron levels decreased (<60 mg/dl). Elevated iron levels (>170 mg/dl) were noted in 2 female and 1 male subject. 3 female and 14 male subjects were found to have normal parameters.

Analysis of anthropometric parameters revealed a decreased body mass (BMI<19.9 kg/m^2) in 5 females and 2 males (Table 4). Increased body mass index (BMI>25 kg/m^2) was found in one male, although it did not indicate obesity, but well developed muscle tissue (as indicated by the results of body composition measurement). Significant differences in blood biochemical parameters were noted between the females with normal and decreased body mass. The latter had significantly lower ferritin levels and significantly higher transferrin levels. The subjects who reported slimming that lasted more than two weeks during the year preceding the study were characterised by lower body mass and fat content than other subjects. The differences, however, were statistically insignificant (Table 5). As for the males, the between-group difference in body mass was statistically significant. Among the markers of iron status, a higher level of transferrin receptor was noted in the women being on slimming diet as compared to the remaining female subjects. Again, the difference was statistically insignificant and the values did not exceed the accepted norms. The males who were not slimming had higher transferrin levels than their slimming counterparts, however the values were normal and the difference statistically insignificant (Table 5).

Table 6 presents the comparison of average consumption of nutritional products, rich in iron and containing nutrients positively affecting iron absorption from food, as related to iron body status. The females were found to consume significantly more coffee and tea. They also reported higher consumption of offal, red meat and juices rich in vitamin C, whole-

Tab. 5. The mean value of antropometric and biochemical parameters of iron consumption and the intended body mass reduction

	Range of normal values	Slimming		p
		NO	YES	
WOMEN		(n=5)[2]	(n=10)	
BMI [kg/m^2]		21.3±2.2	20.8±1.6	ns[3]
Adipose tissue [%]		28±5.4	24.5±2.8	ns
Iron [mg/dl]	37-160	110±17	111±95	ns
Ferritin [µg/l]	>30	21±18	20±15	ns
Transferrin [g/l]	2.0-3.6	2.7±0.4	2.9±0.4	ns
sTfR[4] [µg/ml]	2.9-8.3	5.4±2	8.2±8.7	ns
MEN		(n=7)	(n=8)	
BMI [kg/m^2]		23.5±1.8	21.5±1.7	≤0.**05**[5]
Adipose tissue [%]		14.7±3	12.6±3	ns
Iron [mg/dl]	37-160	103±23	111±48	ns
Ferrytyna [µg/l]	>30	64±22	57±13	ns
Transferyna [g/l]	2.0-3.6	2.9±0.4	2.2±0.2	ns
sTfR [µg/ml]	2.9-8.3	4.4±0.6	4.1±1	ns

[1] $\bar{x} \pm SD$ – mean values and standard deviation
[2] n – number of subjects
[3] ns – differences statistically insignificant
[4] sTfR – serum transferrin receptor level
[5] ≤0.05 – differences statistically significant at p≤0.05

Tab. 6. Consumption of food products depending on the degree of iron deficiency[1]

Products	Classification according to iron deficiency			p
	A	B	C	
WOMEN	(n=3)[2]	(n=8)	(n=4)	
Offal [g]	4±3	6±7	4±1	ns[3]
Red meat [g]	56±42	64±48	94±43	ns
Smoked meat and sausages [g]	28±22	46±35	143±235	ns
Dark poultry [g]	5±7	4±6	5±8	ns
White and smoked poultry [g]	134±66	71±67	36±11	≤0.**05** (AC)[4]
Vegetables and fruit rich in vitamin C [g]	1173±93	1099±165	1051±71	ns
Juices rich in vitamin C [ml]	593±955	129±87	175±211	ns
Highly processed grians [g]	30±18	64±47	175±158	ns
Low processed grains and cereals [g]	70±46	92±86	59±50	ns
Pulses [g]	15±6	20±36	8±6	ns
Tea and coffee [ml]	888±250	400±304	323±176	≤0.**05** (AB) (AC)
Dairy [g]	813±719	452±291	392±175	ns
Potatoes and potato meals [g]	29±21	32±33	68±49	ns
MEN	(n=15)	(n=0)	(n=0)	
Offal [g]	6±8	-	-	-
Red meat [g]	61±35	-	-	-
Smoked meat and sausages [g]	70±53	-	-	-
Dark poultry [g]	15±44	-	-	-
White and smoked poultry [g]	109±93	-	-	-
Vegatables and fruit rich in vitamin C [g]	1113±285	-	-	-
Juices rich in vitamin C [ml]	114±89	-	-	-
Highly processed grains [g]	176±130	-	-	-
Low processed grains and cereals [g]	69±49	-	-	-
Pulses [g]	8±18	-	-	-
Tea and coffee [ml]	199±180	-	-	-
Dairy [g]	463±336	-	-	-
Potatoes and potato meals [g]	70±52	-	-	-

[1] $\bar{x} \pm SD$ – mean values and standard deviation
[2] n – number of subjects
[3] ns – differences statistically insignificant
[4] ≤0.05 (AB)(AC) – differences statistically significant at p≤0.05 between groups A and B and A and C

meal products, pulses or dairy products, the differences however, were insignificant. The males were found to consume significantly more highly processed grains as compared to the females. They also reported higher consumption of smoked meat and sausages, poultry, vegetables and fruit rich in vitamin C, potatoes and potato meals, but again, the differences were insignificant.

The females with 2nd degree iron deficiency (C) were found to consume significantly smaller amounts of poultry including smoked products, tea and coffee than the females having normal blood parameters (A). The lower consumption of vegetables and fruit rich in vitamin C and dairy products turned out insignificant. The consumption of red meat, smoked meat, highly processed grains and potatoes was the highest in the subjects with 2nd degree iron deficiency (C) and the lowest in the subjects with normal blood parameters (A) (Table 6).

Discussion

The study results were similar to the results of other studies [11,24] reporting that iron deficiency among athletes concerns mainly women. Low values of ferritin concentration, below the norms in 8 studied femeles indicate limited iron reserves. Ferritin concentration below the critical limit in 4 females indicates limited iron reserves and additionally, elevated level of transferrin receptor with disordered erythropoiesis, leading to anemia. Abnormal iron balance was connected with the reduced body mass in 33% of the female subjects. Taekwondo is a combat sport with weight categories and it was probably the reason of body mass reduction in 60% of the studied sample (10 females and 8 males) during the year preceding the study.

Such behaviours were probably due to the competitors' desire to gain prevalence over their opponents in terms of strength and body height, which proves favourable with the system of higher scores obtained from blows in the head and electronic sensors of blow strength. This phenomenon probably affected mean body mass of the competitors. Body fat content was high even in the subjects with body mass deficits, particularly among the females. This may indicate inadequate methods of body mass reduction, adversely affecting muscle tissue. The diet was probably inadequately balanced and contained inadequate proportions of food products. Numerous papers [27,28,29] report that the methods of body mass reduction used by athletes, particularly these involved in combat sports, are rarely controlled by nutritionists and often consist in fasting and body dehydration.

Energy deficits, limited food consumption and inadequately balanced diets result in nutrient deficiency. The studied females with normal body mass (BMI=20÷24.9 kg/m^2) were found to have higher iron status parameters (significantly higher ferritin levels and significantly lower transferrin levels) as compared to those with lower body mass (BMI≤19.9 kg/m^2). The mean value of transferrin receptor was higher in the females with reduced body mass than the range of normal values, indicating disordered erythropoiesis. The females who were not on slimming diets had noticeably lower transferring levels than their slimming counterparts, which may indicate increased demand for iron and inadequate supply.

Iron is present in food products in two forms: hem iron (in animal products) and non-hem iron (in vegetables and dairy products). Hem iron is more easily absorbed and its absorption is not disturbed by other nutrient components or body nutritional status. Non-hem iron acts with dietary elements [10]. The main sources of iron in the diet of the study subjects were grains, next smoked meat and red meat. Thus, it was partly non-hem iron. Bio-availability of non-hem iron increases depending on the content of such nutrients and foods as: ascorbate, meat, seafood, organic acids (citric, lactic, malic and tartaric). The inhibitors present in diet decrease iron absorption. These include: phytates present in grain products, phenol iron binding tea, coffee, red wine, some vegatable, herb, nut and pulse components, as well as calcium, fibre and soy proteins [6,30] and the medicines increasing pH level in the alimentary tract (e.g. antacids, H2 histamine receptor blockers, proton-pump inhibitors) [31,32]. Iron absorption in the studied female competitors might have been impaired by lower, compared to that of the males, consumption of grain products, pulses, dairy and significantly lower consumption of tea and coffee. Higher consumption of vegetables and fruit rich in vitamin C and poultry as well as significantly higher consumption of highly processed grains also might have contributed to higher absorption of the consumed iron.

The females with normal iron metabilism (A) consumed significantly higher amounts of poultry including smoked products than in the females with 2nd degree iron deficiency (C). Protein contained in these products might have had a positive influence on non-hem iron absorption. This group also reported significantly higher consumption of coffee and tea.

There is confirmed evidence that tea inhibits non-hem iron absorption. On the other hand, studies on populations reveal different correlations between tea consumption and iron status. The potential absorption inhibition of tea probably reduces poor iron balance during periods of increased demand or inadequate supply of iron [9]. Although there is no evidence, it is believed that the negative effect of tea consumption on iron status is connected with drinking tea with meals. Moderate tea consumption at different times of the day does not seem to have an adverse effect on iron status. Moreover, the inhibitory effect of tea on iron absorption may be partly overcome by simultaneous consumption of animal tissues and vitamin C [9].

Conclusions

Normal parameters of nutritional status were found only in 3 females; 8 females were diagnosed with 1st degree iron deficiency and 4 females were diagnosed with 2nd degree iron deficiency.

Among the studied males, only one subject was found to have elevated blood iron level; the remaining 14 subjects had normal iron parameters.

In the group of females with normal iron metabolism, poultry consumption as well as tea and coffee consumption was higher than in the females with iron metabolism disorders.

Statistically significant differences in blood biochemical parameters were found between the females with normal and reduced body mass. Those with reduced body mass had significantly lower ferritin levels and significantly higher transferrin levels. The mean level of transferrin receptor was higher than normal values.

The study results indicate that iron metabolism and diet of the female athletes have to be monitored. Modification of nutritional habits may significantly improve blood biochemical parameters and contribute to optimal physical fitness and athletic performance.

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Received: 12.02.2010
Accepted: 11.05.2010