JOURNAL OF NUTRITION FASTING AND HEALTH

The Effects of Iron Ion Solution Consumption and Aerobic Training on Hematologic Factors among Iron Deficiency Anemia Female Patients

Saeedeh Ansari Moghadam [1], Mohsen Aminaei [1*], Rohullah Nikoei[2]

1. Department of Sport Sciences, Shahid Bahonar University of Kerman, Kerman, Iran.
2. Department of Physical Education and Sport Sciences, Shahid Bahonar University of Kerman, Kerman, Iran.

ARTICLEINFO

Article type:
Research Paper

Article History:
Received: 07 Mar 2022
Accepted: 23 May 2022
Published: 30 Jun 2022

Keywords:
Aerobic exercise
Iron deficiency anemia
Ferritin
CBC

ABSTRACT

Introduction: Iron metabolism is important for maintaining body homeostasis, and aerobic exercise can enhance this process. This study aimed to evaluate the effects of iron Ion solution consumption on some hematologic factors and aerobic performance among iron deficiency anemia in female patients.

Methods: This experimental research was conducted on 30 women aged 20-30 years old with iron deficiency anemia, who referred to the medical centers of Kerman, Iran using a control group in pre- and post-test with primary care. The subjects were randomly divided into three equal groups. The ISAE=10 received Iron Supplement, while the AE=10 group received Aerobic Exercise, and the Control C=10 got neither. The aerobic exercises program included eight weeks and three sessions/week. The aerobic power was measured by Astrand aerobic bike test. The complete Blood Count (CBC) measurement included HCT, MCH, MCV, MCHC, RBC, HB, chemiluminescence and Ferritin in pre-test and post-test. The statistical method included the Kolmogorov-Smirnov test for normal distribution, the Levene test for homogeneity of variances, as well as one-way analysis of variance, and Scheffe post hoc tests.

Results: ISAE and AE significantly increased serum ferritin after eight weeks of aerobic training ($F= 3.160$; $p<0.05$ and aerobic power $F= 6.23$; $p<0.01$).

Conclusion: The results showed that aerobic power and iron ion solution consumption increased significantly between the two groups compared to the control. Other variables were not significantly different between groups. Exercise and iron ion solution consumption may play a significant role in improving serum ferritin index in female patients with anemia caused by iron deficiency.

► Please cite this paper as:
Ansari Moghadam S, Aminaei M, Nikoei R. The Effects of Iron Ion Solution Consumption and Aerobic Training on Hematologic Factors among Iron Deficiency Anemia Female Patients. J Nutr Fast Health. 2022; 10(2): 121-128. DOI: 10.22038/JNFH.2022.64238.1383.

Introduction

Iron metabolism is essential for maintaining body homeostasis. Anemia caused by iron deficiency is called Iron Deficiency Anemia (IDA) (1, 2). The reasons for IDA are the amount of iron consumption in the diet, iron requirements, and abnormal menstrual cycle. Athletes' performance can be negatively affected by iron depletion because it is required for oxygen transmission, mitochondrial respiratory chain enzymes, and oxidative enzymes (3). Iron is the main element in the total metabolism of living organisms, which plays a vital role in nutrition (4). Iron is found in hemoglobin, myoglobin, and cytochromes as well as in phytonutrients (5). The Heme iron, as functional iron, is responsible for connecting oxygen to red blood cells and transferring it into the tissue, as well as for transmitting electrons in the Krebs cycle and electron transport chain (6). Non-heme iron is a catalyzer, which converts beta-carotene to vitamin A (7), and synthesis the Purine to form the nuclide acid, remove blood lipids, and collagen synthesis (8), and produce antibody in the liver (9). The results of laboratory studies on animals with iron deficiency have indicated that most animal groups have the lowest aerobic capacity (10, 11). According to the results, iron deficiency affects mitochondrial enzymes and blood hemoglobin levels (12, 13). The findings show that iron deficiency reduces mitochondrial enzymes and hemoglobin levels, while iron supplementation increases the activity of cytochrome C (35%) and Krebs cycle enzymes (15%) (14, 15). Since energy production in mitochondria is affected by iron deficiency, metabolites accumulate, function decreases, and cell death occurs (16).

* *Corresponding author:* Mohsen Aminaei, Associate Professor, Department of Sport Sciences, Shahid Bahonar University of Kerman, Pajouhesh Square, Afzalipour Campus, Kerman, Iran. Tel: +983433257624, Email: maminai@uk.ac.ir.

IDA reduces capacity and aerobic power among athletes (17-20). Anemia treatment has included iron supplements, artificial iron fortification, biofortification, dietary modification, nutrition education, and antiparasitic treatment in recent years (21, 22). Iron deficiency is estimated to result in a loss of US $70 billion in the global economy each year in addition to the negative effects of supplement consumption. However, access to varied diets is neither affordable nor possible for many people, and supplements are expensive, not consistently available, and often culturally unacceptable (23).

The iron supplement is found in two forms of ferrous and ferric. The first type of iron absorbs better than the ferric form in the body. Second, sulfate can cause gastrointestinal distress, nausea, heartburn, diarrhea, and constipation. Fumarate, sulfate, and gluconate are forms of iron supplements that can be absorbed in the body properly, but their digestion can be problematic (24).

The iron-containing cookware could serve to reduce IDA, which is used among children. The potential advantages of iron-containing cookware include relative cost-effectiveness and complementary combination with other interventions (25).

Charles et al. (2011) indicated that the iron ingot in boiling water is another form, which has unique properties and is used as a supplement compared to the iron chemical drugs with high absorption without gastrointestinal effects. Natural iron is the most common form of iron in nature, so its structure is similar to iron in the body. However, further research was required to assess the quantity and bioavailability of iron leached from the ingot (26).

The iron reacts readily with oxygen and water to give brown to black hydrated iron oxides, commonly known as rust. Iron is a metal that reacts with water, so dipping molten iron in water results in releasing iron ions in the water, also called iron water (27, 28).

According to a report from the Laboratory of applied research in Shahid Bahonar University of Kerman, the iron ion dissolved in this solution is 5.3 ppm. Therefore, this study evaluated the effect of iron ion solution on iron deficiency anemia treatment among female patients. The iron ion solution may change Red Blood Cell (RBC), hemoglobin levels, Hematocrit (HCT), Mean Corpuscular Volume (MCV), Mean Corpuscular Hemoglobin (MCH), and Mean Corpuscular Hemoglobin Concentration (MCHC) of serum iron, and serum ferritin were also investigated.

Materials and Methods

This randomized controlled trial study was designed by pre-test and post-test with the control group and primary care. The consent form and health questionnaire were presented to control the detrimental nutritional factors. The statistical population was women aged 20 to 30 years old, who were the citizens of Kerman with iron deficiency anemia based on the results of two-factor of Iron and ferritin of serum. The leading indicators of anemia caused by iron deficiency were purposefully selected from the patients of Kerman health centers.

Table 1. Descriptive statistical analysis of variables

Characteristics		ISLE	AE	C
Age (yrs)		24.72 ± 1.01	26.72 ± 2.82	25.29 ± 1.84
Weight (kg)		59.61 ± 4.65	64.89 ± 6.31	60.88 ± 9.98
Height (cm)		161.67 ± 10.93	163.17 ± 13.75	167.65 ± 5.26
Aerobic capacity	pre	37.66 ± 1.34	34.49 ± 1.83	35.95 ± 1.48
(mL.kg.min)	post	44.28 ± 1.39	39.81 ± 1.46	36.96 ± 1.40
Hemoglobin	pre	14.66 ± 1.29	14.23 ± 1.62	13.99 ± 1.28
(g/dl)	post	15.70 ± 1.13	14.74 ± 1.17	14.61 ± 1.43
Hematocrit	pre	43.25 ± 0.74	42.01 ± 0.61	43.14 ± 1.01
	post	44.55 ± 0.49	43.82 ± 0.77	43.92 ± 0.37
MCV (fl)	pre	89.46 ± 1.82	89.33 ± 1.51	88.89 ± 1.20
	post	90.47 ± 1.09	89.66 ± 0.29	88.92 ± 0.33
MCH (Pg)	pre	28.31 ± 0.42	26.35 ± 0.75	26.54 ± 0.32
	post	29.03 ± 0.32	27.17 ± 0.12	26.92 ± 0.91
MCHC (g/dl)	pre	30.74 ± 0.25	31.28 ± 0.77	30.88 ± 0.84
	post	31.61 ± 0.14	32.99 ± 0.61	30.76 ± 0.93
Ferritin (g/dlμ)	pre	28.21±1.42	31.33±1/34	31.89±2.16
	post	39.01±2.76	39.66±1.29	33.92±4.33

Iron Supplement and Aerobic Exercise group (n=10) = ISAE, aerobic exercise group (n=10) = AE, Control group (n=10) = C

Subjects

The 75 patients in this study filled the 40-question questionnaire approved by domestic clinical experts. The exclusion criteria were laboratory, thalassemia, heart, respiratory problem, and vegetarian diet.

The patients were finally excluded from the study after the blood tests revealed that they had hematological problems. The blood tests determined the values of hemoglobin, hematocrit, MCV, MCH, and MCHC of serum ferritin in the laboratory, so the three groups were matched based on the results of ferritin levels (Table 1). The first group (n=10) received Iron Supplement and Aerobic Exercise (ISAE), the second group (n=10) got Aerobic Exercise (AE), and the third group (n=10) were control (C).

Aerobic Exercise Protocol

The aerobic exercises included three 10-15 minutes training sessions per week for eight weeks, including static stretching and dynamic warm-up. The main program was 20-35 minutes of continuous running on a fixed track with an intensity of 70-80% of the maximum heart rate for every subject. The overload program increased by 2 minutes in every session. The intensity of exercise was monitored by Polar heart rate. The cold down exercise was carried out with light jogging and stretching for 10-15 minutes. The total time was 40 minutes in the first and 60 minutes in the last session.

Measurements

The pre-test was performed by Complete Blood Count (CBC) test, which included HCT, MCH, MCV, MCHC, RBC, HB, by Symex (model: KX-21); chemiluminescence; Iron Ferozine kite; Auto Analyzer (Mindry, bs800), and Ferritin by Architect ferritin kite (7K59). The three groups were matched by ferritin levels. In addition, the aerobic power was measured by the six-minute Astrand aerobic bike tests (by Monark cycle ergometer E839). The ISAE group consumed 500 mg iron ion solution servings as 250 ml at 10 am and 250 ml at 10 pm during eight weeks of aerobic exercise protocol. AE and C groups received 500 mg of drinking water in two servings as 250 ml at 10 am and 250 ml at 10 pm as a placebo. The post-test administered the same variables after eight weeks.

Table 2. Analysis of covariance in post-test variables

	groups	Mean difference	F	P
Aerobic capacity (mL.kg.min)	ISAE	7.62	6.23	0.003*
	AE	6.32		
	C	1.1		
Hemoglobin (g/dl)	ISAE	1.4	0.301	0.892
	AE	0.51		
	C	0.62		
Hematocrit (%)	ISLE	1.30	1.24	0.287
	AE	1.82		
	C	0.150		
MCV (fl)	ISAE	1.01	1.632	0.240
	AE	0.33		
	C	0.03		
MCH (Pg)	ISAE	0.72	1.419	0.107
	AE	0.82		
	C	0.38		
MCHC (g/dl)	ISAE	0.87	1.421	0.210
	AE	0.67		
	C	0.96		
Ferritin (g/dlμ)	ISAE	10.8	3.160	0.021*
	AE	8.33		
	C	2.03		

* Significant at level p≥0.05.

Statistical Analysis

The data were analyzed by descriptive statistics, including mean, standard deviation, minimum, and maximum. The normality of variables was evaluated by the Shapiro-Wilk test. The differences in dependent variables were calculated in two pre-test and post-test stages (before and after supplementation) among three groups. The differences between groups were evaluated by the Analysis of Covariance

(ANCOVA), and the paired comparison of groups was analyzed by the Scheffe post hoc test.

Results

Table 1 present the descriptive statistical analysis variables. Consuming iron ion solution and aerobic training in the ISAE group affects aerobic capacity in female patients with IDA. The differences in aerobic power were calculated in pre and post-test (F= 6.23; p=0.003) among three groups (ISAE, AE, and C) and indicated in Tables 1 and 2.

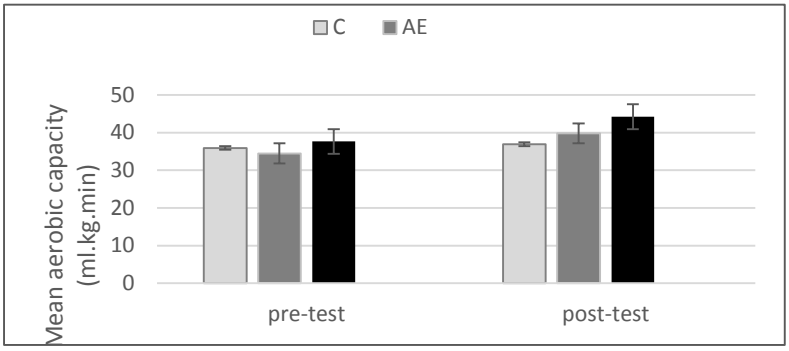

Figure 1. The alternation and comparison of aerobic capacity among groups in post-test. (C): Control group, (AE) aerobic exercise group, and (ISAE) Iron Supplement and Aerobic Exercise group. *Significant difference between groups

The Scheffe posthoc test revealed a significant difference between the ISAE group (44.28±1.39 mL.kg.min) and the C group (36.96±1.40 mL.kg.min). In addition, Figure 1 represents a significant difference between the AE (39.81±1.46 mL.kg.min) and C (36.96±1.40 mL.kg.min) groups. It means the iron ion solution and aerobic training effectively increase aerobic capacity in every group.

The supplementation of iron ion solution and aerobic training did not affect HB, HCT, MCV, MCH, and MCHC in female patients with IDA at the same time or aerobic exercise alone. No significant difference was found in HB (F= 0.301; p=0.892), HCT (F=1.24; p=0.287), MCV (F= 1.632; p=0.240), MCH (F= 1.419; p=0.107), and MCHC (F= 1.421; p=0.210) among ISAE, AE, and C groups in two stages of pre- and post-test (Table 1 and 2).

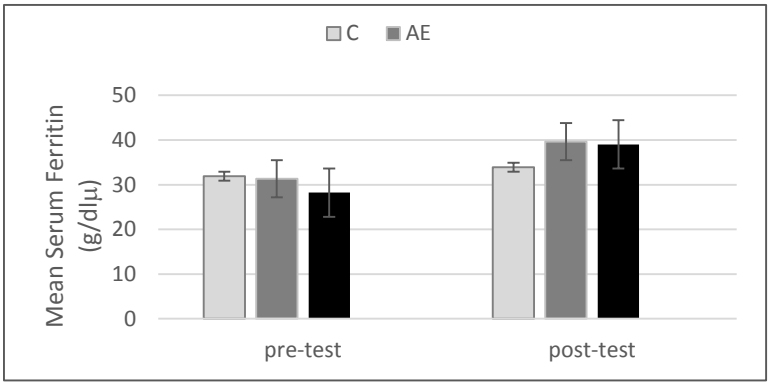

Figure 2. The alternation and comparison of serum ferritin among groups in post-test. (C): Control group, (AE) aerobic exercise group, and (ISAE) Iron Supplement and Aerobic Exercise group. *Significant difference between groups.

The iron ion solution supplement and aerobic exercise affect ferritin in female patients with IDA. There was a significant difference in serum ferritin among ISAE, AE, and C groups in pre- and post-test (F= 3.160; p=0.021). According to the Scheffe posthoc test, significant differences were observed between the ISAE and C groups, also AE and C groups. The ISAE and AE groups did not differ significantly (Figure 2). Therefore, the iron ion solution, along with aerobic training, is effective in increasing ferritin serum. In addition, aerobic training may affect ferritin serum alone.

Aerobic exercise is an essential factor in effect on Fe^2 serum (serum ferritin index).

Discussion

Iron is an essential factor in hemoglobin and myoglobin structure. Ion solution consumption and aerobic exercise affect aerobic capacity in female patients with IDA and improve iron status and endurance capacity in iron-deficient and non-anemic trained male and female subjects (29). The combination of iron in hemoglobin and aerobic exercise is fundamental to the success of athletes. Additionally, the better endurance performance of athletes in comparison with normal individuals is due to increased blood hemoglobin concentration. The function of iron in hemoglobin building increases the oxygen to the body because the prevailing system is powering through the aerobic system in endurance activities (5). Aerobic capacity may improve IDA lonely, but available cross-sectional and longitudinal studies indicate that the blood of endurance athletes is more dilute due to blood volume expansion, particularly plasma volume because of training. IDA reduces aerobic capacity, and the low hematocrit values in trained athletes represent a hydration condition rather than an iron store deficiency (30).

Biological mechanisms are sufficiently strong to justify interventions to improve iron status for the effect of IDA on aerobic capacity. Serum iron can improve exercise performance (17), and ID and IDA are common among young adolescent female athletes. Nevertheless, there was no difference between female athletes and nonathletes (19). The iron supplements may improve ventilation threshold and endurance capacity in men and women with iron deficiency (29). A few studies have reported that female endurance athletes should be screened using a serum ferritin cutoff between 20.0 and 25.0 μg/L to identify iron depletion to impair performance. Anemia or iron deficiency in athletes should be treated with supplemental and dietary guidance, as well as serial hemoglobin and serum ferritin measurements (17-20). The reduced functional observed in field studies is likely due to anemia and reduced oxygen transport. The biological mechanisms for the effect of IDA on work capacity are sufficiently strong to justify interventions to improve iron status for enhancing human capital (17).

In contrast, Garz et al. (1997) and Klingshirn et al. (1992) found that low ferritin did not affect endurance in women (31, 32). In addition, low serum iron cannot decrease endurance capacity without anemia (33). The results of these researches have not been consistent with the present study because the amount and type of supplements have differed probably.

In the present study, iron ion solution consumption and aerobic exercise did not affect blood hemoglobin in women with iron deficiency anemia. Some interfering factors, which may affect IDA, are altitude, menstrual bleeding, and renal disorder due to erythropoietin reduction and nutrition.

Hemoglobin comprises a protein section (globulin) and four granular pigments. Physical activity may cause many changes in the number, distribution, and proliferation of white blood cells. In addition, blood or hematology responses are not the same as any physical activity. Blood responses can be affected by factors such as time, intensity, duration of activities, and environmental conditions (7). Iron supplementation can raise serum ferritin levels and ferritin concentration, unaccompanied by increasing hemoglobin concentration and endurance performance (31). In addition, Zhu et al. (1997) reported that the difference in VO2max was significantly related to serum ferritin concentration, and hemoglobin value was not a significant confounder (33).

The consumption of iron ion solution and aerobic exercise did not affect blood hematocrit among female patients with iron deficiency anemia. Many factors affected blood hematocrits, such as stress, amenorrhea, climate, altitude, and activities. Drinking fluids increases blood volume and consequently decreases hematocrit. The activity in the hot environment reduces the volume of plasma serum, thereby increasing hematocrit. In general, the patients with iron deficiency anemia had normal blood factors. Aerobic training and consuming iron ion solution had no significant changes in their blood factors, especially hematocrit. The studies have indicated that the blood volume of endurance athletes is more dilute due to blood volume expansion, particularly plasma volume because of training (30).

The consumption of iron ion solution and aerobic training affected serum ferritin among female patients with iron deficiency anemia. Therefore,

using iron ion solution and aerobic training can increase serum blood ferritin. Concerning ferritin AE and ISAE groups were significantly different from the control group (placebo).

Zhu et al. (1997) indicated that the iron-sufficient group had significantly higher hemoglobin, transferrin saturation, serum ferritin values compared with the iron-depleted group with a significant greater tendency to use iron supplements (33). Garza et al. (1997) reported that screening involved in an endurance sport might be clinically useful for low iron stores at the start of a training program in female athletes given the high prevalence of iron depletion reported in this and other studies (31). In this study, iron-depleted rowers (serum Ferritin <20–25 μg/L) showed a decrease in performance time compared with normal iron stores. Bijeh et al. (2018) reported that there was a significant increase in mean platelet volume and a significant decrease in serum iron and ferritin levels in the experimental group after eight weeks of aerobic exercise (34). Eight-week moderate-intensity continuous aerobic exercises reduce Iron, hematocrit, and serum ferritin levels in the club soccer players (35). Submaximal exercise has no effect on plasma hepcidin concentration or iron metabolism immediately following exercise (36). This observation may be related to exercise duration and intensity.

The consumption of iron ion solution and aerobic exercise did not affect MCV in female patients with iron deficiency anemia. Bhatia et al. (2012) reported that MCV is unreliable as a screening parameter for the presumed diagnosis of macrocytic anemia associated with vitamin B12 deficiency (37), indicating different exercises affect MCV. A report observed that regular aerobic and strength exercises could positively influence sedentary women's body weight and BMI parameters. Additionally, a significant decrease was found in RBC, HCT, and MCV values of the strength exercise group compared to aerobic exercise (38). Although aerobic training of increasing intensity may be accompanied initially by decreases in HB, HCT, and RBC count in young women and an increase in MCV, these changes are transitory. A return to hematopoietic balance without RBC destruction or hemodilution may result in a draw upon body iron stores (39).

Consumption of iron ion solution and aerobic exercise does not affect the MCH and MCHC. The mean blood cell hemoglobin increased insignificantly since this increase was less than 1 mg/dl, so it is not worth much in all three groups. However, the consumption of ion solution and aerobic exercise had no effect on mean blood cell hemoglobin in women with iron deficiency anemia. Mousavizadeh (2009) showed that eight weeks of aerobic training decreased HCT, RBC, HB, serum iron, transferrin concentration, and serum ferritin in girls, which was consistent with the present study. However, there was no significant difference in MCH, MCV, MCHC, and TIBC among girls (40). Therefore, the changes in hematological indicators reduce result in endurance exercises due to the increase in plasma volume, which is a helpful mechanism concerning adaptation to endurance conditions. The young elite athletes with low serum ferritin and normal hemoglobin concentration and iron supplementation increased maximal aerobic performance capacity without an augmentation of RBV (41).

Conclusion

According to the results, iron supplementation increases aerobic capacity without significant changes in HCT, HB, MCH, MCV, and MCHC among young women with IDA. The iron ion supplements are easy to obtain, inexpensive, consistently available, and have adequate absorption by the body. This form of supplementation has no digestive problems and is often culturally acceptable. This study was performed without dietary restrictions, with a low number of subjects and in small groups, so it is suggested to research with at least four groups, more subjects, and a longtime protocol. The research interventions, including aerobic programs and iron supplementation, seemed to need a longer time to change.

Acknowledgments

We would like to express our appreciation to all the authors who participated, the medicine Clinic for participant recruitment, and the participants for their contribution and continuing interest in this research.

Conflict of Interest

This research received no specific grant from the public, commercial, or not-for-profit sectors funding agencies. The authors declare no conflict of interest.

References

1.Gozzelino R, Arosio P. Iron Homeostasis in Health and Disease. Int J Mol Sci. 2016;17(1).

2.Mu Q, Chen L, Gao X, Shen S, Sheng W, Min J, et al. The role of iron homeostasis in remodeling immune function and regulating inflammatory disease. Sci Bull. 2021.

3.DellaValle DM, Haas JD. Impact of iron depletion without anemia on performance in trained endurance athletes at the beginning of a training season: a study of female collegiate rowers. Int J Sport Nutr Exerc Metab. 2011;21(6):501-6.

4.Marchetti M, De Bei O, Bettati S, Campanini B, Kovachka S, Gianquinto E, et al. Iron metabolism at the interface between host and pathogen: From nutritional immunity to antibacterial development. Int J Mol Sci. 2020;21(6):2145.

5.Buratti P, Gammella E, Rybinska I, Cairo G, Recalcati S. Recent advances in iron metabolism: relevance for health, exercise, and performance. Med Sci Sports Exerc. 2015;47(8):1596-604.

6.Cairo G, Bernuzzi F, Recalcati S. A precious metal: Iron, an essential nutrient for all cells. Genes & Nutrition. 2006;1(1):25-39.

7.García-Casal MaN, Layrisse M, Solano L, Barón MaA, Arguello F, Llovera D, et al. Vitamin A and β-carotene can improve nonheme iron absorption from rice, wheat and corn by humans. J Nutr. 1998;128(3):646-50.

8.Gardi C, Arezzini B, Fortino V, Comporti M. Effect of free iron on collagen synthesis, cell proliferation and MMP-2 expression in rat hepatic stellate cells. Biochem Pharmacol. 2002;64(7):1139-45.

9.Anderson ER, Shah YM. Iron homeostasis in the liver. Compr Physiol. 2013;3(1):315.

10. McLane J, Fell R, McKay R, Winder W, Brown E, Holloszy J. Physiological and biochemical effects of iron deficiency on rat skeletal muscle. Am J Physiol Cell Physiol. 1981;241(1):C47-54.

11. Davies K, Donovan CM, Refino CJ, Brooks GA, Packer L, Dallman PR. Distinguishing effects of anemia and muscle iron deficiency on exercise bioenergetics in the rat. Am J Physiol Endocrinol Metab. 1984;246(6):E535-43.

12. Huang ML-H, Lane DJ, Richardson DR. Mitochondrial mayhem: the mitochondrion as a modulator of iron metabolism and its role in disease. Antioxid Redox Signal. 2011;15(12):3003-19.

13. Richardson DR, Lane DJ, Becker EM, Huang ML-H, Whitnall M, Rahmanto YS, et al. Mitochondrial iron trafficking and the integration of iron metabolism between the mitochondrion and cytosol. Proc Natl Acad Sci. 2010;107(24):10775-82.

14. Hentze M. Muckenthaler MU, and Andrews NC. Balancing acts: molecular control of mammalian iron metabolism Cell. 2004;117:285-97.

15. CAIRO G, Pietrangelo A. Iron regulatory proteins in pathobiology. Biochem J. 2000;352(2):241-50.

16. Bogdan AR, Miyazawa M, Hashimoto K, Tsuji Y. Regulators of iron homeostasis: new players in metabolism, cell death, and disease. Trends Biochem Sci. 2016;41(3):274-86.

17. Haas JD, Brownlie IV T. Iron deficiency and reduced work capacity: a critical review of the research to determine a causal relationship. J Nutr. 2001;131(2):676S-90S.

18. Pedlar CR, Brugnara C, Bruinvels G, Burden R. Iron balance and iron supplementation for the female athlete: a practical approach. Eur J Sport Sci. 2018;18(2):295-305.

19. Sandström G, Börjesson M, Rödjer S. Iron deficiency in adolescent female athletes—is iron status affected by regular sporting activity?. Clin *J Sport* Med. 2012;22(6):495-500.

20. DellaValle DM. Iron supplementation for female athletes: effects on iron status and performance outcomes. Curr *Sports Med* Rep. 2013;12(4):234-9.

21. Pasricha S-R, Drakesmith H, Black J, Hipgrave D, Biggs B-A. Control of iron deficiency anemia in low-and middle-income countries. Blood, The Journal of the American Society of Hematology. 2013;121(14):2607-17.

22. Koskenkorva-Frank TS, Weiss G, Koppenol WH, Burckhardt S. The complex interplay of iron metabolism, reactive oxygen species, and reactive nitrogen species: insights into the potential of various iron therapies to induce oxidative and nitrosative stress. Free Radic Biol Med. 2013;65:1174-94.

23. Armstrong GR. The Lucky Iron Fish: a simple solution for iron deficiency. Blood Adv. 2017;1(5):330.

24. Santiago P. Ferrous versus ferric oral iron formulations for the treatment of iron deficiency: a clinical overview. Sci World J. 2012;2012.

25. Alves C, Saleh A, Alaofè H. Iron-containing cookware for the reduction of iron deficiency anemia among children and females of reproductive age in low-and middle-income countries: A systematic review. PloS one. 2019;14(9):e0221094.

26. Charles CV, Dewey CE, Daniell WE, Summerlee AJ. Iron-deficiency anaemia in rural Cambodia: community trial of a novel iron supplementation technique. Eur J Public Health. 2011;21(1):43-8.

27. Martin WC, Musgrove A. Ground levels and ionization energies for the neutral atoms. 1998.

28. Ankersmith B, Griesser-Stermscheg M, Selwyn L, Sutherland S. Recognizing metals and their corrosion products. Canadian Conservation Institute, https://http://www cci-icc gc ca/caringforprendresoindes/articles/metals-metaux/indexeng aspx-int1. 2009.

29. Hinton P, Sinclair L. Iron supplementation maintains ventilatory threshold and improves energetic efficiency in iron-deficient nonanemic athletes. Eur J Clin Nutr. 2007;61(1):30-9.

30. El-Sayed MS, Ali N, Ali ZE-S. Haemorheology in exercise and training. Sports Med. 2005;35(8):649-70.

31. Garza D, Shrier I, Kohl 3rd H, Ford P, Brown M, Matheson GO. The clinical value of serum ferritin tests in endurance athletes. Clin *J Sport* Med. 1997;7(1):46-53.
32. Klingshirn LA, Pate RR, Bourque SP, Davis JM, Sargent RG. Effect of iron supplementation on endurance capacity in iron-depleted female runners. Med Sci Sports Exerc. 1992;24(7):819-24.
33. Zhu YI, Haas JD. Iron depletion without anemia and physical performance in young women. *Am J* Clin Nutr. 1997;66(2):334-41.
34. Bijeh N, Askari A, Ramezani S, Askari B. Effect of Eight Weeks of Aerobic Exercise on Iron Status and Coagulation and Immune Indices in Non-Athlete Females. Med Lab J. 2018;12(1):37-43.
35. Alikarami H, Nikbakht M, GHalavand A. Effect of 8 weeks of continuous moderate intensity aerobic training on iron status in club-level football players. The Horizon of Medical Sciences. 2017;23(2):129-33.
36. Afsari Kalashemi A, Shemshaki A, Hedayati M. The effect of one event of submaximal exercise on plasma hepcidin concentrations in male runners. Pathobiology Research. 2014;17(1):79-90.
37. Bhatia P, Kulkarni JD, Pai SA. Vitamin B12 deficiency in India: Mean corpuscular volume is an unreliable screening parameter. Natl Med J India. 2012;25(6):336-8.
38. Çiçek G. The Effects of Different Exercise Types on Hematological Parameters in Sedentary Women. Journal of Education and Training Studies. 2018;6(8):96-101.
39. Puhl JL, Runyan WS. Hematological variations during aerobic training of college women. Research Quarterly For Exercise And Sport. 1980;51(3):533-41.
40. Mousavizade M, Ebrahim K, Nikbakht H. Effect of one period of selective aerobic training on hematological indexes of girls. Blood. 2009;3(24):227-31.
41. Friedmann B, Weller E, Mairbaurl H, Bärtsch P. Effects of iron repletion on blood volume and performance capacity in young athletes. Medicine And Science In Sports And Exercise. 2001;33(5):741-6.