EUROPEAN JOURNAL OF BIOMEDICAL AND PHARMACEUTICAL SCIENCES
http://www.ejbps.com

ISSN 2349-8870
Volume: 12
Issue: 7
Year: 2025

LEVELS OF FERRITIN, PLASMA VISCOSITY AND SOME HAEMATOLOGICAL PARAMETERS IN SUBJECTS EXPOSED TO THREE WEEKS AEROBIC EXERCISE IN NNEWI NIGERIA

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Article Received on 13/05/2025 **Article Revised on 03/06/2025** **Article Published on 24/06/2025**

ABSTRACT
Hematological changes have been associated with physical activities and these changes have been found to involve the leucocytes, the thrombocytes and the erythrocytes and are dependent on the type, intensity and duration of the physical activities. Most individuals indulging in sports activities are ignorant of their haematological status and how stress affects their haematological profile. This pre-post study design evaluated the levels of Ferritin, plasma viscosity and some haematological parameters [red blood cell count (RBC), haemoglobin (HB), haematocrit (HCT)] in individuals exposed to 3 weeks of aerobic exercise (rope skipping). A total of 30 male and female participants aged 18-35 years were recruited for the study using simple random sampling method. The aerobic exercise involved skipping rope 30 minutes four times a week for three weeks (21days). Fasting venous blood samples were collected at baseline (pre-exercise samples; day 0) and after exercise (post-exercise samples; day 22) for determination of the levels of ferritin, plasma viscosity, RBC, HB, and HCT in the subjects using standard methods. Structured questionnaires were also used to obtain other relevant data of the participants including age, gender and body mass index (BMI). Results showed significant decreases in plasma viscosity **(**0.73±0.17 Vs 1.08±0.15; p = <0.001); RBC (4.17±.86 Vs 4.17±.86; p = 0.0004), HCT (0.37±0.07 Vs 0.40±0.05; p = 0.0006) and serum ferritin levels (64.94±54.24 Vs 93.30±104.04; p = 0.0497) post-exercise compared to their pre-exercise levels. However, BMI and HB level did not differ significantly compared before and after exercise (p >0.05). These alterations may be suggestive of the body's adaptive response in short-term aerobic exercise rather than pathological aetiology. Further longitudinal studies with larger sample size are needed to better understand the mechanisms behind the current findings.

KEYWORDS: Exercise, aerobic exercise, rope skipping, plasma viscosity, haematological parameters, ferritin, body mass index.

INTRODUCTION
The word exercise comes from the Latin word "Exercitium," which means to train. Exercise converts stored chemical energy into mechanical and thermal energy.[1] On the other hand, aerobic exercise is defined by the American College of Sports Medicine (ACSM) as any activity that is rhythmic, engages large muscular groups, and can be sustained over time.[2] Generally, the muscle groups that are engaged in this kind of exercise use aerobic metabolism to produce adenosine triphosphate (ATP), which is energy derived from amino acids, carbohydrates, and fatty acids.[3] Exercise is believed to be linked metabolic, physiological and hemodynamic changes which can impart either positively or negatively to the health of the exercising subjects by influencing various body functions.[1,4] It is generally known that both acute and chronic exercise induce several haematological changes in humans.[5] It has also been ascertained that exercise induced haematological changes are dependent on the type, intensity and duration of exercise[6]; also several factors like gender, age, environmental conditions and nutritional status of the subjects also play an important role.[5] Exercise training (Chronic exercise) and acute exercise are known to modulate red blood cell volume (RCV) and hematocrit (Hct)[7,8], While acute exercise increases Hct, exercise training usually decreases it, which may result in large blood viscosity changes.[9,10] Previous studies have shown alteration in RBC aggregation and hematocrit post-exercise.[11-13] These

hemorheological alterations could have a significant impact on oxygen transport and distribution to tissue during exercise because they can change cardiac output and vascular resistance.[13] In general, it can be concluded that an unhealthy, sedentary lifestyle with obesity is associated with impaired RBC deformability, enhanced RBC aggregation, and increased hematocrit and plasma viscosity.[12,14]

Ferritin is an iron storage protein that also acts as an acute phase reactant during inflammation. It is crucial for iron homeostasis in both cells and systems.[15] Previous studies show variable alterations in ferritin levels following exercise.[16,17] Alterations of the haematological parameters, ferritin and plasma viscosity can influence physical performance thereby influencing the overall health of the individuals.

To the best of our knowledge, there is a dearth in literature regarding the relationship between aerobic exercise, ferritin level, plasma viscosity and some haematological parameters in the study population hence the need to evaluate the levels of ferritin, plasma viscosity and some haematological parameters in subjects exposed to Three (3) weeks aerobic exercise.

MATERIALS AND METHODS

Study area

This study was conducted at College of Health Sciences, Nnamdi Azikiwe University, Okofia Otolo Nnewi Campus, Nnewi North Local Government Area of Anambra State. The College is a multi - Faculty College comprising of the faculties of Health Science and Technology, Medical Laboratory Science, Basic Medical Sciences and Medicine with each faculty having many departments.

Study design and population

This is a pre and post study designed to evaluate the levels of ferritin, plasma viscosity and some haematological parameters in subjects undergoing aerobic exercise in Nnewi campus. A total of 30 participants were recruited for the study using simple random sampling method. Participants were male and female students of Nnamdi Azikiwe University, Nnewi campus aged between 18 and 35 years. The aerobic exercise involved skipping rope 30 minutes four times a week for three weeks (21days). Exercise prescription comprised of mode, frequency, intensity and duration of the exercise. There are many techniques in skipping rope in which basic jump or easy jump technique was used. In this technique, jump with both feet slightly apart over the rope and it was performed individually. Samples were collected at baseline (pre-exercise samples; day 0) and after exercise (post-exercise samples; day 21) for determination of the levels of ferritin, plasma viscosity and some haematological parameters in the subjects. Informed Consent were obtained from participants and structured questionnaires were also used to obtain other relevant data of the participants including age, gender, body mass index (BMI), socio - economic status, dietary habits, history of any chronic diseases etc.

Inclusion criteria

The study included participants who were up to the age of 18 without any pathological conditions like cardiovascular diseases, non-smokers, those with no history of bleeding disorders and non-pregnant women.

Exclusion criteria

This study excluded subjects below the age of 18, those with any pathological conditions, smokers and pregnant women.

Ethical consideration

Ethical approval was sought and obtained from the ethics committee of Faculty of Health Sciences and Technology, Nnamdi Azikiwe University, Nnewi Campus, before the commencement of the study.

Informed consent

Informed consent of all the participating Subjects was sought and obtained.

Sample Collection

Six milliliters (6 ml) of fasting venous blood samples were collected from the participants before (day 0) and after exercise (day 21). 2 ml was dispensed into Ethylene Diamine Tetra acetic acid (EDTA) container for full blood count (FBC) and plasma viscosity whereas the remaining 4 ml was dispensed into plain container for serum ferritin assay.

Laboratory methods

Full blood count (FBC) estimation

The red blood cell count (RBC), haemoglobin (Hb) and haematocrit (HCT) was determined using a three part Biobase hematology analyzer (BK-6190, China) by following the manufacturer's instructions.

Serum Ferritin Determination

This was estimated using Sandwich ELISA Technique following manufacturer's protocol for the Ferritin reagent kit.

Plasma Viscosity

This was carried out by modification of the viscometery method by Reid and Ugwu.[18]

Anthropometrics measurements

The weight was obtained using a manual weighing scale while height was obtained by the use of a measuring tape. Weight and height were measured and body mass index (BMI) was calculated as:

$$BMI = \frac{\text{weight (kg)}}{\text{Height}^2\ (\text{m}^2)}$$ [19,20]

Statistical analysis

The SPSS statistical tool, version 26.0, was used to analyze the data collected for this study. Paired t-test was

used to compare the data acquired before (pre) and after (post) aerobic exercise. The correlation between the various parameters was examined using Pearson's correlation coefficient. Statistical significance was assumed at $p<0.05$.

RESULTS

The mean plasma viscosity was significantly decreased post-exercise compared to baseline value **(**0.73±0.17 Vs 1.08±0.15; p = <0.001). There were significantly decreased levels of RBC (4.17±.86 Vs 4.17±.86; p = 0.0004) and HCT (0.37±0.07 Vs 0.40±0.05; p = 0.0006) post-exercise compared to their pre-exercise levels. More so, the mean serum ferritin (64.94±54.24 Vs 93.30±104.04; p = 0.0497) level was significantly decreased in the subjects post-exercise than before exercise (baseline value). However, the mean body mass index and haemoglobin level did not differ significantly when compared before and after exercise (p >0.05) respectively. (See table 1).

The mean levels of RBC were positively correlated with HB (r = 0.739; p = 0.001), HCT (r = 0.728; p = 0.001), and Ferritin (r = 0.386; p = 0.035); levels of HB were positively correlated with HCT (r = 0.947; p = 0.001), Ferritin (r = 0.420; p = 0.021), and HCT with ferritin (r = 0.389; p = 0.034) in the subjects before exercise (See table 2).

Furthermore, the mean levels of RBC were positively correlated with HB (r = 0.887; p = 0.000), and HCT (r = 0.910; p = 0.000); levels of HB were positively correlated with HCT (r = 0.986; p = 0.000) and Ferritin (r = 0.408; p = 0.025), and ferritin with HCT (r = 0.437; p = 0.016) in the participants post-exercise (See table 3).

Table 1: Levels of RBC, HCT, HB, PV and Ferritin of the subjects pre and post exercise.

Variable		Mean±SD		t-value	p-value
		Pre	Post		
BMI	kg/m^2	21.93±3.41	21.94±3.32	-0.165	0.8698
PV	mPa/s	1.08±0.15	0.73±0.17	8.92	<0.001*
RBC	$10^{12}/L$	4.61±.62	4.17±.86	4.01	0.0004*
HB	g/dl	13.27±1.90	13.49±2.64	-0.743	0.463
HCT	L/L	0 .40±0.05	0.37±0.07	3.826	0.0006*
Ferritin	ng/ml	93.30±104.04	64.94±54.24	2.048	0.0497*

**Statistically significant at p-value < 0.05.*

KEY

RBC = Red Blood Cell Count
HCT = Haematocrit
HB = Haemoglobin
PV = Plasma Viscosity

Table 2: Pearson correlation analysis showing the pre exercise levels of RBC, PCV, HB, Ferritin level, PV and BMI.

Pre sample stages		Pre BMI	Pre PV	Pre RBC	Pre HB	Pre HCT	Pre Ferritin
Pre BMI kg/m^2	r-value	1	.207	-.291	-.285	-.200	.054
	p-value		.272	.119	.126	.288	.775
Pre PV mPa/s	r-value	.207	1	-.282	-.188	-.072	-.145
	p-value	.272		.132	.319	.704	.445
Pre RBC $10^{12}/L$	r-value	-.291	-.282	1	.739**	.728**	.386*
	p-value	.119	.132		.000	.000	.035
Pre HB g/dl	r-value	-.285	-.188	.739**	1	.947**	.420*
	p-value	.126	.319	.000		.000	.021
Pre HCT L/L	r-value	-.200	-.072	.728**	.947**	1	.389*
	p-value	.288	.704	.000	.000		.034
Pre Ferritin ng/ml	r-value	.054	-.145	.386*	.420*	.389*	1
	p-value	.775	.445	.035	.021	.034	
	Total	30	30	30	30	30	30

***statistically significant, p-value < 0.05*

Table 3: Pearson correlation analysis showing the post exercise levels of RBC, PCV, HB, Ferritin level, PV and BMI.

Post test stages		Post PV	Post BMI	Post RBC	Post HB	Post HCT	Post Ferritin
Post PV mPa/s	r-value	1	.206	-.175	-.206	-.175	-.012
	p-value		.275	.354	.275	.354	.949
Post BMI kg/m^2	r-value	.206	1	-.023	.006	.014	.049
	p-value	.275		.904	.974	.940	.796
Post RBC $10^{12}/L$	r-value	-.175	-.023	1	.887**	.910**	.299
	p-value	.354	.904		.000	.000	.108
Post HB g/dl	r-value	-.206	.006	.887**	1	.986**	.408*
	p-value	.275	.974	.000		.000	.025
Post HCT L/L	r-value	-.175	.014	.910**	.986**	1	.437*
	p-value	.354	.940	.000	.000		.016
Post Ferritin ng/ml	r-value	-.012	.049	.299	.408*	.437*	1
	p-value	.949	.796	.108	.025	.016	

***statistically significant at p-value < 0.05*

DISCUSSION

Hematological changes have been associated with physical activities and these changes have been found to involve the leucocytes, the thrombocytes and the erythrocytes and are dependent on the intensity and duration of the physical activities.[21]

The present study observed no statistically significant difference in the mean BMI of the participants before and after the aerobic exercise. This is in keeping with the reports of Amah *et al*.[4] and Ezeugwunne *et al*.[22] but remained invariance with the findings of Cicek[23] who reported significant decrease in post BMI and body weight of their participant. This may be due to difference in duration of exercise observed in both studies. In the study by Cicek[23], exercise lasted for 16week whereas the exercise duration for this study was 3weeks leading to non-significant change in participants BMI.

This study found significant decreases in the mean plasma viscosity, RBC count and HCT post-exercise. The decrease in RBC count and HCT observed in the current study after rope skipping (aerobic) exercise indicates the body's adaptive response to short-term aerobic activity, which ultimately results in a reduction in plasma viscosity as seen in the current study. The observed decrease in HCT and RBC in this study is consistent with the study of Musa *et al*.[24], which found lower HCT and RBC in footballers following a 90-minute match in sedentary males. It is however invariance with the study of Okeke *et al*.[25] which found no significant differences in both RBC count and HCT following short-term aerobic exercise. Blood viscosity is generally determined by blood concentration and viscosity, and hematocrit, viscosity, and blood viscosity are all directly related to one another and inversely related to plasma volume.[26] It can be concluded that as the hematocrit increases, the blood viscosity increases, resulting in a lower rate of blood flow, therefore limiting tissue oxygen supply.[26] As a result, the decrease in plasma viscosity seen in this study after exercise suggests a cardioprotective benefit of short-term rope skipping exercise. This finding align with the previous reports of Asaadi *et al*.[27] which noted significant decrease in plasma viscosity post exercise.

In this study, the mean HB level remained similar before and after exercise. This may be due haemodilutional effects as fluid shift from the plasma into the extra-vascular space. It has been shown that the hematological indices decrease after aerobic exercise due to increase in plasma volume. The increase in plasma volume results in a decrease in Hb concentration.[28] Our results agree with that of Okeke *et al*.[25] and Cicek *et al*.[23] who reported no significant alterations in HB levels post aerobic exercise in their study. However, our finding is in contrast with the study of Ghosh *et al*.[29] that recorded significantly increased HB level following 35minutes of resistance exercise.

The post exercise ferritin level reduced significantly when compared to the pre exercise ferritin level. This is in line with the findings of similar studies. Bijeh *et al*.[30] found that eight weeks of aerobic exercise led to a substantial increase in platelet volume and a decrease in blood iron and ferritin levels in the experimental group. A study by Alikarami *et al*.[31] found that eight weeks of moderate-intensity aerobic exercise reduced iron, hematocrit, and serum ferritin levels in club soccer players. Ferritin is the primary mechanism for iron storage and is required to maintain iron homeostasis.[32] Contrary to the present finding, Moghadam *et al*.[33] documented significantly increased ferritin level eight weeks post aerobic exercise. the disparities in results may be due to differences in duration and intensity of exercise.

Furthermore, the mean levels of RBC were positively connected with HB, HCT, and Ferritin, whereas levels of HB were favorably correlated with HCT, Ferritin, and HCT in the subjects before exercise. Also, levels of RBC were positively correlated with HB and HCT; levels of HB were positively correlated with HCT and Ferritin and ferritin with HCT in the participants after exercise. This is suggestive of a linear relationship existing between

these parameters and as such as one increases, the other also increases and vice versa.

CONCLUSION

This study demonstrated that 3 weeks of rope skipping (aerobic) exercise changes hematological parameters; it reduces plasma viscosity, significantly decreases RBC, HCT and ferritin levels. This may be suggestive of an adaptive response to short term aerobic exercise rather than any pathological condition.

REFERENCES

1. Ihim AC, Iloesie SC, Ogbodo EC, Oguaka VN, Meludu SC. Effects of regular exercise on the liver function tests of male subjects in college of health sciences, Nnamdi Azikiwe University, Nnewi campus, Anambra state, Nigeria. *International Journal of Current Research in Medical Sciences*, 2018; 4(3): 73-79. doi: 10.22192/ijcrms.2018.04.03.010
2. Wahid A, Manek N, Nichols M, Kelly P, Foster C, Webster P, Kaur A, Friedemann Smith C, Wilkins E, Rayner M, Roberts N, Scarborough P. Quantifying the Association Between Physical Activity and Cardiovascular Disease and Diabetes: A Systematic Review and Meta-Analysis. *Journal of American Heart Association*, 2016; 5(9): e002495. doi: 10.1161/JAHA.115.002495.
3. Patel H, Alkhawam H, Madanieh R, Shah N, Kosmas CE, Vittorio TJ. Aerobic *vs* anaerobic exercise training effects on the cardiovascular system. *World Journal of Cardiology*, 2017; 9(2): 134–138. doi: 10.4330/wjc.v9.i2.134
4. Amah UK**,** Okoli SN**,** Ogbodo EC**,** Ezeugwunne IP**,** Analike RA**,** Onuegbu AJ**,** Olisekodiaka MJ**,** Njoku CM**,** Oguaka VN**,** Meludu SC**.** Effect of short-term aerobic exercise on liver function of apparently health students of College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria. *Global Scientific Journal*, 2017; 5(7): 67-77.
5. Wardyn GG, Rennard SI, Brusnahan SK, McGuire TR, Carlson ML, Smith LM, McGranaghan S, Sharp JG. Effects of exercise on hematological parameters, circulating side population cells, and cytokines. *Experimental Hematology*, 2008; 36(2): 216-223.
6. Belviranli M, Okudan N, Kabak B. The Effects of Acute High-Intensity Interval Training on Hematological Parameters in Sedentary Subjects. *Medical Sciences (Basel, Switzerland)*, 2017; *5*(3): 15. doi: 10.3390/medsci5030015
7. Mairbäurl H. Red blood cells in sports: effects of exercise and training on oxygen supply by red blood cells. *Frontiers in Physiology*, 2013; 4(332): 1-13. doi: 10.3389/fphys.2013.00332
8. Dos Santos JAR. Increasing running volume elicits hematological changes in trained endurance runners: a case study. *Retos*, 2019; 35(1): 117-120.
9. Connes P, Yalcin O, Baskurt O, Brun JF, Hardeman M. In health and in a normoxic environment, VO2 max is/is not limited primarily by cardiac output and locomotor muscle blood flow. *Journal of Applied Physiology*, (1985), 2006; 100(6): 2099. doi: 10.1152/japplphysiol.00279.2006.
10. Brun JF. Exercise hemorheology as a three acts play with metabolic actors: Is it of clinical relevance? *Clinical Hemorheology* and *Microcirculation*, 2002; 26: 155–174.
11. Romain AJ, Brun JF, Varlet-Marie E, Raynaud de Mauverger E. Effects of exercise training on blood rheology: a meta-analysis. *Clinical Hemorheology and Microcirculation*, 2011; 49(1-4): 199–205. doi: 10.3233/CH-2011-1469
12. Szanto S, Mody T, Gyurcsik Z, Babjak LB, Somogyi V, Barath B, Varga A, Matrai AA, Nemeth N. Alterations of Selected Hemorheological and Metabolic Parameters Induced by Physical Activity in Untrained Men and Sportsmen. *Metabolites*, 2021; 11(12): 870. doi: 10.3390/metabo11120870
13. Ivanov I. Hemorheological Alterations and Physical Activity. *Applied Sciences*, 2022; 12*(20): 10374*. doi: 10.3390/app122010374
14. McClung JP, Martini S, Murphy NE, Montain SJ, Margolis LM, Thrane I, Spitz MG, Blatny J-M, Young AJ, Gundersen Y, Pasiakos SM. Effects of a 7-day military training exercise on inflammatory biomarkers, serum hepcidin, and iron status. *Nutrition Journal*, 2013; 12: 141. doi: 10.1186/1475-2891-12-141
15. Kotla NK, Dutta P, Parimi S, Das NK. The Role of Ferritin in Health and Disease: Recent Advances and Understandings. *Metabolites*, 2022; 12(7): 609. doi: 10.3390/metabo12070609
16. Ward LJ, Hammar M, Lindh-Åstrand L, Berin E, Lindblom H, Ruber M, Holm A-CS, Li W. Does resistance training have an effect on levels of ferritin and atherogenic lipids in postmenopausal women? – *A pilot trial*. *Scientific Reports*, 2020; 10: 3838. doi: 10.1038/s41598-020-60759-z
17. Behzadnezhad N, Esfarjani F, Marandi SM. Impact of resistance training and basic ferritin on hepcidin, iron status and some inflammatory markers in overweight/obese girls. *Journal of Research in Medical Sciences: the official journal of Isfahan University of Medical Sciences*, 2021; 26: 95. doi: 10.4103/jrms.JRMS_511_20
18. Reid HL, Ugwu AC. A simple technique for determination of plasma viscosity. *Nigerian Journal of Physiological Sciences*, 1987; 3: 43–48.
19. WHO. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. *World Health Organization Technical Report Series*, 1995; 854: 1–452.
20. Ogbodo EC, Onah CE, Meludu SC, Ogbodo MC, Ezeugwunne IP, Ehiage FA, Analike RA, Mbam RE. Anthropometric Indices, Blood Pressure and Some Apolipoproteins in older Adults in Nnewi, Southeast Nigeria. *African Journal of Biomedical Research*, 2024; 27(1): 39-47.

21. Al-Taee N. Effect of Cigarette Smoking and physical Exercise on some Haematological parameters in Healthy students. *Australian Journal of Basic and Applied sciences*, 2017; 11(6): 62-68.
22. Ezeugwunne IP, Chukwu GN, Ogbodo EC, Analike RA, Onyegbule OA, Oguaka VN, Mbaeri TU, Amah AK, Meludu SC. Effect of Short Term Aerobic Exercise (Football Training) On Lipid Profile and Myoglobin Levels in Apparently Healthy Students of College of Health Sciences, Nnamdi Azikiwe University, Nnewi Campus, Anambra State, Nigeria. *International Journal of Scientific Research and Management*, 2018; 6(1): 12-20. doi: 10.18535/ijsrm/v6i1.mp03
23. Cicek G. The Effects of Different Exercise Types on Hematological Parameters in Sedentary Women. *Journal of Education and Training Studies*, 2018; 6(8): 96-101. doi: 10.11114/jets.v6i8.3374.
24. Musa I, Suleiman HO, Mabrouk MA, Tanko Y. Effects of 90-Minute Football Match on Red Blood Indices in Sedentary Young Males. *Sahel Journal of Life Sciences FUDMA*, 2024; 2(3): 25-28. doi: 10.33003/sajols-2024-0203.
25. Okeke CO, Mama EI, Akosile CO, Ani KU. Changes in white blood cell, red blood cell and platelet parameters following short term aerobic exercise in students of Nnamdi Azikiwe University, Nigeria. *International Journal of Sport, Exercise and Health Research*, 2020; 4(2): 73-78.
26. Ghanbari-Niaki A, Behzad Khameslo M, Tayebi SM. Effect of pyramidal training on plasma lipid profile and fibrinogen, and blood viscosity of untrained young men. *Annals of Applied Sport Science*, 2013; 1(3): 47-56.
27. Asaadi V, Azizbeigi K, Khosravi N, Haghnazari N, The Effect of Exercise Training on Fibrinogen and Viscosity of Plasma: Comparing Endurance Continuous, Circuit Resistance and High Intensity Interval Trainings in Young Obese Men. *Journal of Clinical Research in Paramedical Sciences*, 2019; 8(2): e97880. doi: 10.5812/jcrps.97880.
28. Walsh NP, Gleeson M, Shephard RJ, Gleeson M, Woods JA, Bishop NC, Fleshner M, Green C, Pedersen BK, Hoffman-Goetz L, Rogers CJ, Northoff H, Abbasi A, Simon P. Position statement. Part one: Immune function and exercise. *Exercise Immunology Review*, 2011; 17: 6–63.
29. Ghosh A, Mukhopadhyay K. Acute Effect of Resistance Exercise on Hemoglobin Level (HBG) Among Physically Trained Boys. *Journal of Sports Medicine and Therapy*, 2025; 10(2): 027-030. doi: 10.29328/journal.jsmt.1001093
30. 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. *Medical Laboratory Journal*, 2018; 12(1): 37-43.
31. 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): 129-133.
32. Hanafe HM, Sherif MM, Magdy AER, Ghada E. Effect of aerobic exercises on iron deficiency Anemia in postnatal women. *Medical Journal of Cairo Univ*ersity, 2019; 87: 1001–1005. doi: 10.21608/mjcu.2019.52829
33. Ansari MS, Aminaei M, Nikoei R. The Effects of Iron Ion Solution Consumption and Aerobic Training on Hematologic Factors among Iron Deficiency Anemia Female Patients. *Journal of Nutrition, Fasting and Health*, 2022; 10(2): 121-128. doi: 10.22038/JNFH.2022.64238.1383.