ORIGINAL ARTICLE

pISSN: 1907-3062 / eISSN: 2407-2230

Evaluation of blood metal levels of hockey teams after playing on synthetic turf fields

Esin GULLU[1], Abdulsamet EFDAL[2*], Abdullah GULLU[3*], and Ihsan ÇETIN[4]

ABSTRACT

BACKGROUND
Artificial turf fields are widely used as an alternative to natural grass in many areas such as parks, playgrounds, and playing fields. In this study, we aimed to evaluate the toxicological effects of the chemicals contained in the fields consisting of artificial turf and crumb rubber on the blood metal levels in field hockey players.

METHODS
A cross-sectional study was conducted involving 28 apparently healthy men aged 20-25 years who participated in this study voluntarily. They consisted of 17 field hockey athletes [athlete group (AG)] and 11 sedentary males [control group (CG)]. Before and after the 7-day tournament, blood samples were taken from AG and CG to measure mercury, arsenic, aluminum, lead, zinc, magnesium and iron levels. An independent t-test was used to analyze the data.

RESULTS
In comparisons between CG and AG, the magnesium level of AG before the tournament was higher, while the iron and mercury levels were significantly lower ($p<0.05$). In intragroup comparisons, a significant increase was observed in the post-tournament magnesium and iron variables in the AG group ($p<0.05$). In post-tournament intergroup comparisons, increases in the Mg and decreases in the Hg variables of AG were significant ($p<0.05$).

CONCLUSION
It is thought that as a result of the tournament on fields with synthetic grass surfaces, the male field hockey players in the 20-25 age group were toxicologically not affected by the harmful heavy metals present in these fields, because the Hg, As, Pb, Zn, Al, Fe, and Mg levels are within the international reference ranges.

Keywords: Field hockey, artificial turf field, blood metal level, male players

[1]Uşak University, Faculty of Sports Sciences, Department of Recreation, Uşak, Turkey

[2]Hitit University, Vocational School of Health Services, Department of Medical Services and Techniques, Program of Environmental Health, Çorum, Turkey

[3]Uşak University, Faculty of Sports Sciences, Department of Sports Management, Uşak, Turkey
[4]Hitit University, Faculty of Medicine, Department of Medical Biochemistry, Çorum, Turkey

***Correspondence:**
Abdulsamet Efdal
Hitit University, Vocational School of Health Services, Department of Medical Services and Techniques, Program of Environmental Health, Çorum, TURKEY
Email: a.sametefdal@gmail.com,
ORCID ID: 0000-0001-8325-2438

Date of first submission, June 25, 2023
Date of final revised submission, August 23, 2023
Date of acceptance, September 4, 2023

Cite this article as: Gullu E, Efdal A, Gullu A, Çetin I. Evaluation of blood metal levels of hockey teams after playing on synthetic turf fields. Univ Med 2023;42:255-62. doi: 10.18051/UnivMed.2023.v42:255-262

INTRODUCTION

Artificial turf fields, also called "synthetic" surfaces, are widely used as an alternative to natural grass in many areas such as residential areas, parks, playgrounds and playing fields.[1] Although the reason given as to why artificial turf grounds are widely used in sports and playgrounds is that they allow useful activities such as exercise, it is reported that the main reason is cost savings and the ability to use artificial grass fields in all weather conditions. Crumb rubber from tires contains various metals such as cadmium, chromium, zinc, aluminum and lead. They also contain volatile organic compounds (VOCs) and polycyclic aromatic hydrocarbons (PAHs) such as benzopyrenes (a and e), benzo (a) anthracene, and phthalates.[2] In 2016, the United States Environmental Protection Agency (US EPA) made a statement on the use of crumb rubber in artificial turf fields: it reported that the crumb rubber found in such fields will increase health risk factors. In addition, it has been reported that the negative effects of the crumb rubber on health have not been comprehensively evaluated in the existing literature. As a matter of fact, it is known that some metals contained in the crumb rubber used in artificial turf fields are known to be carcinogens, neurotoxins, and potential endocrine disruptors. It is known that hundreds of thousands of adults and children around the world are exposed to these synthetic (artificial) surfaces almost every day. Due to this situation, it is stated that people who use these areas frequently are also exposed to various chemicals. In addition, it is emphasized that it is essential to reveal the possible effects of entry into the body through inhalation, skin absorption or ingestion.[2] Therefore, it is of great importance to examine the possible toxicological effects of the crumb rubber used in artificial turf fields on the athletes who use these fields frequently.

Little is still known about the health risks of using artificial turf playing fields, especially in the long term.[3] When the literature was examined, it was seen that the studies on artificial turf fields focused on two separate fields of study. While the first field of study is examining the toxic substances contained in artificial turf fields,[1,2,4-9] the other field of study is examining the effects of artificial turf fields on sports injuries.[10-16] In a study on metals that included mercury (Hg), arsenic (As), lead (Pb), zinc (Zn), aluminum (Al), iron (Fe), and magnesium (Mg) in samples taken from 32 different synthetic fields, a total of 25 metals were examined and it has been reported that Mg, Fe and Zn levels were significantly higher than those of the other metals.[8] In addition, in studies on crumb rubber, it has been reported that while tire rubber contains high levels of Zn, it also contains Fe and Mg, albeit at low levels.[9] However, no study has been found that measured the levels of these metals in athletes using artificial turf fields.

As can be understood from the literature reviews, there is extensive literature about artificial turf fields and sports injuries. A Dutch study found no elevated health risks from playing sports on synthetic turf fields with recycled rubber granulate.[17] Likewise, Cheng et al.[18] report that users of synthetic turf fields are not exposed to elevated health risks. Yet, information is limited to reach any definitive conclusion about the potential health risks associated with synthetic turf. In particular, research is lacking on the long-term health effects for users of synthetic turf surfaces.

Therefore, in this study, we aimed to evaluate serum Hg, As, Al, Pb, Zn, Mg, and Fe levels in field hockey players before and after the tournament and to compare them with the healthy control group.

METHODS

Research design

A cross-sectional study was conducted during the Field Hockey Turkey Championship in Konya between 15-24 May 2020.

Research subjects

A total of 28 healthy men, aged between 20-25 years, participated in this study voluntarily. Although a field hockey team consists of 18 male players, as an athlete was excluded from the study because he was injured in his first competition, our study was completed with 17 players. Therefore the athlete group (AG) consisted of 17 field hockey players, whose mean age, height, and weight were 21.24±1.79 years, 175.82±5.67 cm, and 68.94±9.95 kg, respectively, and the control group (CG) consisted of 11 sedentary men with mean age, height, and weight of 22.45±1.97 years, 177.09±3.39 cm, and 73.91±9.63 kg, respectively. In determining the AG, the selection was made by considering the following criteria: being a healthy male athlete between the ages of 20 and 25 years, regularly training and competing on synthetic turf fields for at least three months, taking part in the same team, not smoking or using any medications, living in the same region, and following a similar diet. Also, in determining the CG, the selection was made by considering the following criteria: Being a healthy man between the ages of 20 and 25 years, not smoking or using any medications, living in the same region, and following a similar diet. The tournament lasted for 7 days, and the AG competed on the same synthetic turf field every day. Each match lasted 75 minutes, with two 35-minute periods and a 5-minute halftime break. Athletes who took part in the competitions full time (7 matches x 75 minutes = 525 minutes) were included in the study.

Physical tests

The physical tests of the research group were taken once before the competition. The age of the participants in years was recorded from their identity cards. Height was measured by means of a stadiometer with an accuracy of ±0.01 cm in the upright barefoot position and recorded in cm. Body weight values were measured with the participants being barefoot in shorts and T-shirts, using scales with ±0.1 kg accuracy, and recorded in kg.

Collection of blood samples

Blood samples of AG and CG were taken into serum or plasma tubes to measure Hg, As, Al, Pb, Zn, Mg, and Fe levels in accordance with the method in which the measurements would be made. For AG, blood samples were taken twice in the morning on an empty stomach, one day before the start of the 7-day tournament and on the last day of the tournament. Also, for CG, blood samples were taken once, on an empty stomach, one day before the start of the tournament.

Preparation of blood samples

The Hg, As, Al, Pb, Zn, Mg, and Fe levels were measured in blood samples taken from the participants included in this study. Blood samples from AG and CG were taken into purple- capped hemogram tubes containing ethylene diamine tetra acetic acid for Hg, As, and Pb measurement. Blood samples for Zn and Al measurement were taken into red-capped serum tubes, and blood samples for Mg and Fe measurement were taken into yellow-capped biochemistry tubes. Then, the blood samples in these tubes were centrifuged and sent to be studied in a laboratory (E-lap Laboratory, Ankara, Türkiye) under appropriate storage conditions. The elements Hg, As, Pb, Zn, and Al were studied by atomic absorption spectroscopy, while Fe and Mg were studied by colorimetric method in a biochemistry analyzer. In healthy adults the normal zinc concentration in serum or plasma is 80 to 120 μg/dL.[19] The normal range of blood magnesium level is 1.82 to 2.30 mg/dL and that of blood iron level 60 to 170 μg/dl.[20,21] Serum mercury, aluminum, and lead levels in healthy individuals are expected to be less than 10 μg/L.[22-24] In addition, arsenic is expected to be less than 10 μg/dL in healthy individuals.[25]

Ethical considerations

Ethics committee approval of this study, which was planned in accordance with the Helsinki Principles, was obtained from Ondokuz Mayýs University (2018/211).

Table 1. Distribution of several characteristics and metal levels in the athlete and control groups before the tournment

Characteristics	Control group (n=11)	Athlete group (n=17)	p value
Age (years)	22.45±1.97	21.24±1.79	0.100
Height (cm)	177.09±3.39	175.82±5.67	0.510
Weight (kg)	73.91±9.63	68.94±9.95	0.200
Magnesium (mg/dL)	1.90±0.11	2.04±0.15	**0.011**
Iron (µg/dL)	89.82±12.44	72.12±23.33	**0.030**
Arsenic (µg/L)	4.08±0.33	4.18±0.75	0.700
Lead (µg/dL)	3.14±1.45	3.21±2.26	0.930
Aluminum (µg/L)	5.62±1.59	5.07±3.11	0.600
Mercury (µg/L)	1.06±0.56	0.39±0.41	**0.000***
Zinc (µg/dL)	97.00±8.67	98.00±15.76	0.850

Note : Data presented as Mean±SD

Statistical analysis

Statistical analysis of the obtained data was made with the IBM SPSS 25.0 package program. Descriptive statistics of all data were made and presented in the text as mean and standard deviation (X±SD). The Shapiro-Wilk test was used for normality tests of the data and parametric tests were applied since all data showed a normal distribution ($p>0.05$). The differences between the mean of the variables of AG and CG obtained before and after the tournament were determined by independent samples t-test. The $p<0.05$ level was accepted as significant in all statistical calculations.

RESULTS

As a result of this study, the findings obtained from AG and CG are given in the tables below. In Table 1 age, height, and weight values were not significantly different as a result of the intergroup comparisons of AG and CG made at the 95% confidence interval before the tournament ($p>0.05$). Therefore, it can be said that AG and CG have similar or homogeneous properties. On the other hand, the Mg level of AG was significantly higher than that of CG ($p<0.05$). In addition, Fe and Hg levels in AG were significantly lower than in CG ($p<0.05$). However, although there was a decrease and/ or increase in some values of the remaining variables of AG and CG, these changes were not significant ($p>0.05$).

In Table 2 as a result of the intergroup comparisons of AG and CG at the 95% confidence interval after the tournament, the Mg level of AG increased significantly compared to CG ($p<0.05$). In addition, a significant decrease was found in the Hg variable of AG compared to CG ($p<0.05$). On the other hand, although there was a decrease in some values and an increase in other values of the remaining variables of CG and post-tournament AG, these changes were not at a significant level ($p>0.05$).

Table 2. Comparison of mean serum levels of several metals in the athlete and control groups after the tournament

Substance group	Control group (n=11)	Athlete group (n=17)	p value
Magnesium (mg/dL)	1.90±0.11	2.12±0.10	**0.000***
Iron (µg/dL)	89.82±12.44	91.76±35.20	0.860
Arsenic (µg/L)	4.08±0.33	4.13±0.82	0.860
Lead (µg/dL)	3.21±2.26	3.19±2.04	0.940
Aluminum (µg/L)	5.62±1.59	5.62±4.39	0.650
Mercury (µg/L)	1.06±0.56	0.41±0.39	**0.000***
Zinc (µg/dL)	97.00±8.67	104.59±14.19	0.120

Note: Data presented as Mean±SD

Table 3. Comparison of mean serum levels of several metals in the AG group before and after the tournament

Substance group	Pre-tournament levels	Post-tournament levels	p value
Magnesium (mg/dL)	2.04±0.15	2.12±0.10	**0.010***
Iron (μg/dL)	72.12±23.33	91.76±35.20	**0.000***
Arsenic (μg/L)	4.18±0.75	4.13±0.82	0.700
Lead (μg/dL)	3.21±2.26	3.19±2.04	0.870
Aluminum (μg/L)	5.07±3.11	5.62±4.39	0.650
Mercury (μg/L)	0.39±0.41	0.41±0.39	0.630
Zinc (μg/dL)	98.00±15.76	104.59±14.19	0.180

Note: Data presented as Mean±SD; AG: athlete group

In Table 3, as a result of the intra-group comparisons of the AG before and after the tournament at the 95% confidence interval, a significant increase was observed in the Mg and Fe variables after the tournament compared to the pre-tournament values ($p<0.05$). However, although there was a decrease in some values and an increase in other values of the remaining variables after the tournament compared to the values before the tournament, the changes were not at a significant level ($p>0.05$). According to the results obtained, it is seen that the values of Hg, As, Pb, Zn, Al, Fe, and Mg are within the international reference ranges.

DISCUSSION

Although there were studies on the chemical analysis of artificial turf fields and the crumb rubber used in their production, no studies have been found on the toxicological effects of metal levels in the peripheral tissues of athletes using artificial turf fields. For this reason, we foresee that our study findings will make important contributions to the literature on this topic.

In our study, it was found that the AG post-tournament peripheral Mg levels increased significantly compared to pre-tournament values and CG (Tables 3 and 4). When the levels of these measured elements are examined, it can be argued that there is no toxic effect considering that they are in the normal range. Crumb rubber from synthetic sites has been reported to contain Mg.[8,9] In this direction, the first mechanism we will suggest for the increased Mg levels in field hockey players is that Mg in the crumb rubber content may cause an increase in peripheral Mg levels of field hockey players through respiration. We also suggest that there may be another mechanism triggering the increase in peripheral Mg level of AG. This is because, besides its functions such as contraction of muscles in the body, conversion of carbohydrates into energy, and transmission of impulses between nerve cells, Mg is also responsible for maintaining the necessary biochemical processes for removing toxic metals from the body and suppressing oxidative stress.[26] In addition, Mg levels were found to increase in case of toxicity caused by high bilirubin levels.[27] Thus, it can be said that the fact that AG did a total of 7 competitions (525 minutes), including one high-intensity competition (75 minutes) every day,[28,29] caused an increase in serum Mg values.[30] Already, our study findings and the data in the literature suggested that high Mg levels in field hockey athletes play a role in the maintenance of the necessary biochemical processes in removing toxic metals from the body and suppressing oxidative stress. This evaluation was also supported by our findings regarding the increased post-competition Mg levels that were obtained in our study.

In our study, post-tournament peripheral Fe values of AG were found to be significantly higher than their pre-tournament values (Table 4), while peripheral Fe values were found to be higher, although not significantly, when compared with the Fe values of CG (Table 3 and 4). In addition, it was remarkable that peripheral Fe values of AG were significantly lower than CG before the tournament (Table

2). Studies had reported that Fe is included in more than 60 elements that can have toxic effects.[31] Accordingly, it had been stated that Fe may have neurotoxic effects [32] and that when Fe is present in excess in cells and tissues, it may cause oxidative stress by disrupting redox homeostasis.[33] It had also been reported that crumb rubber contains Fe, other than Mg.[8,9] Because of all these, it had been reported that overexposure to Fe may be a potential biohazard.[34] In this direction, it was thought that Fe in the content of crumb rubber may cause an increase in peripheral Fe levels in field hockey players.[35-37] In addition, this increase in serum Fe concentration was thought to be due to erythrocyte fragmentation and hemolysis during physical exercise and circulatory stress.[38-40] These reasons can explain the increase in peripheral Fe levels of AG after the tournament, and accordingly, it can be said that cellular damage due to Fe toxicity may occur in individuals exposed to artificial turf for extended periods of time, such as field hockey players.

It was observed that both the peripheral Hg values of AG before and after the tournament were significantly lower than the peripheral Hg values of CG (Tables 3 and 4). It is known that sweating plays an important role in the detoxification of harmful elements.[41] It has also been noted that mercury may be eliminated through sweat, and it has been suggested that "sweating should be the first and preferred treatment for patients with high mercury urine levels".[22] Similarly, in a systematic review by Sears et al.[41] the authors reported that a significant part of the mercury acquired through exposure can be excreted through sweat. In addition, in one case of a severely poisoned worker, it was stated that the mercury level in the sweat returned to normal with daily sweating and physiotherapy application for a few months, and the patient recovered. According to these explanations, the fact that the peripheral Hg levels of AG in our study decreased compared to the control group, supports the literature, and may be due to sweating during the competitions. On the other hand, although not statistically significant, it was determined that the mean peripheral Al, Hg, and Zn values of AG after the tournament increased compared to the values before the tournament (Table 4). However, when compared to CG, the high As and Pb levels in field hockey players were not significant (Tables 3 and 4).

It can be stated that the parameters measured at the blood level in the current studies constitute a limitation for comparing our findings in the artificial turf field. Due to budgetary constraints, only blood metal levels were examined in our study. In the literature, it was recommended to evaluate the blood and urine levels together, especially in determining the Hg contact. In this context, not analyzing the levels of these metals in biological samples such as urine, saliva, and sweat constituted an important limitation. However, it is thought necessary to examine both toxic substances and acute and chronic toxicity markers in biological samples such as blood, urine, saliva, and sweat of male and female athletes, in which a larger number of participants from different sports branches and different age groups will compete on synthetic fields.

CONCLUSION

According to our study, the values of Hg, As, Pb, Zn, Al, Fe, and Mg are within the international reference ranges. When the levels of these measured elements are examined, it can be argued that there is no toxic effect considering that they are in the normal range.

CONFLICT OF INTEREST

The authors declare no conflict of interest

ACKNOWLEDGEMENTS

We would like to thank the research unit of Hitit University for their support and all the volunteers who participated in the study.

FUNDING

This research was supported by the scientific research project unit of Hitit University (Project Number: SBF19001.18.001).

AUTHOR CONTRIBUTIONS

AG: investigation, formal analysis, resources, writing – review and editing, supervision, project administration. AE: conceptualization, investigation writing - original draft, data curation. EG: data curation, investigation, writing - review and editing. IC: conceptualization, methodology, resources, data curation, writing – original draft, visualization, supervision, project administration. All authors have read and approved the final manuscript.

DATA AVAILABILITY STATEMENT

The data used to support the findings of this study is available from the corresponding author upon request.

REFERENCES

1. Foøt J, Kobetièová K, Böhm M, et al. Environmental consequences of rubber crumb application: soil and water pollution. Polymers (Basel) 2022;14:1416. doi: 10.3390/polym14071416.
2. Watterson A. Artificial turf: contested terrains for precautionary public health with particular reference to Europe? Int J Environ Res Public Health 2017;14:1050. doi:10.3390/ijerph14091050.
3. United States Environmental Protection Agency. Tire Crumb Questions and Answers; 2023.
4. Bleyer A. Synthetic turf fields, crumb rubber, and alleged cancer risk. Sports Med 2017;47:2437-41. doi: 10.1007/s40279-017-0735-x.
5. Cheng H, Hu Y, Reinhard M. Environmental and health impacts of artificial turf: a review. Environ Sci Technol 2014;48:2114-29. doi: 10.1021/es4044193.
6. Pavilonis BT, Weisel CP, Buckley B, Lioy PJ.. Bioaccessibility and risk of exposure to metals and SVOCs in artificial turf field fill materials and fibers. Risk Anal 2014;34:44-55. doi: 10.1111/risa.12081.
7. Llompart M, Sanchez-Prado L, Lamas JP, Garcia-Jares C, Roca E, Dagnac T. Hazardous organic chemicals in rubber recycled tire playgrounds and pavers. Chemosphere 2013;90:423-31. doi: 1016/j.chemosphere.2012.07.053.
8. Graça CAL, Rocha F, Gomes FO, et al. Presence of metals and metalloids in crumb rubber used as infill of worldwide synthetic turf pitches: exposure and risk assessment. Chemosphere 2022;299: 134379. doi: 10.1016/j.chemosphere.2022.134379.
9. Krüger O, Kalbe U, Richter E, Egeler P, Römbke J, Berger W. New approach to the ecotoxicological risk assessment of artificial outdoor sporting grounds. Environ Pollut 2013;175: 69-74. doi: 10.1016/j.envpol.2012.12.024.
10. Xiao M, Lemos JL, Hwang CE, Sherman SL, Safran MR, Abrams GD. Increased risk of acl ýnjury for female but not male soccer players on artificial turf versus natural grass: a systematic review and meta-analysis. Orthop J Sports Med 2022;10: 23259671221114353. doi: 10.1177/23259671221114353.
11. Ngatuvai MS, Yang J, Kistamgari S, Collins CL, Smith GA. Epidemiological comparison of ACL ýnjuries on different playing surfaces in high school football and soccer. Orthop J Sports Med 2022;10:23259671221092321. doi: 10.1177/23259671221092321.
12. Howard M, Solaru S, Kang HP et al. Epidemiology of anterior cruciate ligament ýnjury on natural grass versus artificial turf in soccer: 10-year data from the National Collegiate Athletic Association ýnjury surveillance system. Orthop J Sports Med 2020;8:2325967120934434. doi: 10.1177/2325967120934434.
13. O' Leary F, Acampora N, Hand F, O' Donovan J. Association of artificial turf and concussion in competitive contact sports: a systematic review and meta-analysis. BMJ Open Sport Exerc Med 2020;6:e000695. doi: 10.1136/bmjsem-2019-000695.
14. Lanzetti RM, Lupariello D, Venditto T, et al. The influence of playing surface on injury risk in Italian elite rugby players. Muscles Ligaments Tendons J 2017;7:180-5. doi: 10.11138/mltj/2017.7.1.180.
15. Williams JH, Akogyrem E, Williams JR. A meta-analysis of soccer ýnjuries on artificial turf and natural grass. J Sports Med (Hindawi Publ Corp) 2013;2013:380523. doi: 10.1155/2013/380523.
16. Kuitunen I, Immonen V, Pakarinen O, Mattila VM, Ponkilainen VT. Incidence of football injuries sustained on artificial turf compared to grass and other playing surfaces: a systematic review and meta-analysis. EClinicalMedicine 2023;59:101956. doi: 10.1016/j.eclinm.2023.101956.
17. Pronk MEJ, Woutersen M, Herremans JMM. Synthetic turf pitches with rubber granulate infill: are there health risks for people playing sports

on such pitches? J Expo Sci Environ Epidemiol 2020;30:567-84. doi: 10.1038/s41370-018-0106-1.
18. Cheng H, Hu Y, Reinhard M. Environmental and health impacts of artificial turf: a review. Environ Sci Technol 2014;48:2114-29. doi: 10.1021/es4044193.
19. National Institue of Health. Zinc: fact sheet for health profesionals; 2022.
20. Razzaque MS. Magnesium: are we consuming enough? Nutrients 2018;10:1863. doi: 10.3390/nu10121863.
21. Markell M, Siddiqi HA. Vitamins and trace elements. In: McPherson RA, Pincus MR, eds. Henry's clinical diagnosis and management by laboratory methods. 24th ed. Philadelphia, PA: Elsevier; 2022.
22. Ye BJ, Kim BG, Jeon MJ, et al. Evaluation of mercury exposure level, clinical diagnosis and treatment for mercury intoxication. Ann Occup Environ Med 2016; 28: 5. doi: 10.1186/s40557-015-0086-8.
23. Mcguigan MA. Chronic poisoning: trace metals and others. In: Goldman L, Schafer AI, editors. Cecil medicine. 24th ed. New York: Elsevier Saunders; 2012.
24. Ruckart PZ, Jones RL, Courtney JG, et al. Update of the blood lead reference value - United States, 2021. MMWR Morb Mortal Wkly Rep 2021;70: 1509-12. doi: 10.15585/mmwr.mm7043a4.
25. U.S. Department of Health and Human Services – Public Health Service - Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological Profile for Arsenic. Atlanta: Agency for Toxic Substances and Disease Registry; 2016.
26. Hodges RE, Minich DM. Modulation of metabolic detoxification pathways using foods and food-derived components: a scientific review with clinical application. J Nutr Metab 2015;2015: 760689. doi: 10.1155/2015/760689.
27. Ehsanipour F, Norouzi E, Khosravi N, Mirfakhraee H. Serum magnesium levels in neonatal jaundice: Is there any correlation between hypermagnesemia and moderate to severe hyperbilirubinemia in term newborns? J Compr Pediatr 2020;11:e94278. doi: 10.5812/compreped.94278.
28. Malliaropoulos N, Tsitas K, Porfiriadou A, et al. Blood phosphorus and magnesium levels in 130 elite track and field athletes. Asian J Sports Med 2013;4:49-53. doi: 10.5812/asjsm.34531.
29. Döker S, Hazar M, Uslu M, Okan Ý, Kafkas E, Boþgelmez ÝÝ. Influence of training frequency on serum concentrations of some essential trace elements and electrolytes in male swimmers. Biol Trace Elem Res 2014;158:15-21. doi: 10.1007/s12011-014-9912-z.
30. Westmoreland D, Anderson D, Porta S. Effects of maximal and submaximal exercise on plasma electrolyte shifts. Trace Elem Electrolyte 2006;23: 312–317. doi: 10.5414/TEP23312.
31. Özbolat G, Tuli A. Aðýr metal toksisitesinin insan saðlýðýna etkileri. Arþiv Kaynak Tarama Dergisi 2016; 25:502-21. doi: 10.17827/aktd.253562.
32. Hsu HW, Bondy SC, Kitazawa M. Environmental and dietary exposure to copper and ýts cellular mechanisms linking to alzheimer's disease. Toxicol Sci 2018;163: 338-45. doi: 10.1093/toxsci/kfy025.
33. Galaris D, Barbouti A, Pantopoulos K. Iron homeostasis and oxidative stress: An intimate relationship. Biochim Biophys Acta Mol Cell Res 2019;1866:118535. doi: 10.1016/j.bbamcr.2019.
34. Eid R, Arab NT, Greenwoo, MT. Iron mediated toxicity and programmed cell death: a review and a re-examination of existing paradigms. Biochim Biophys Acta Mol Cell Res 2017;1864:399–430. doi: 10.1016/j.bbamcr.2016.12.002.
35. Podgórski T, Kryœciak J, Konarski J, et al. Iron metabolism in field hockey players during an annual training cycle. J Hum Kinet 2015;47:107-14. doi: 10.1515/hukin-2015-0066.
36. Khlif R, Marrakchi R, Jamoussi K, Sahnoun Z, Chtourou H, Souissi N. Plasma iron status in elite weightlifters after four weeks of intensive training. Sci Sports 2019;34:328.e1-e8. doi: 10.1016/j.scispo.2019.02.003.
37. Kaufmann CC, Wegberger C, Tscharre M, et al. Effect of marathon and ultra-marathon on inflammation and iron homeostasis. Scand J Med Sci Sports 2021;31:542-52. doi: 10.1111/sms.13869.
38. Goto K, Kojima C, Kasai N, Sumi D, Hayashi N, Hwang H. Resistance exercise causes greater serum hepcidin elevation than endurance (cycling) exercise. PLoS One 2020;15:e0228766. doi: 10.1371/journal.pone.0228766.
39. Tomczyk M, Kortas J, Flis D et al. Marathon run-induced changes in the erythropoietin-erythroferrone-hepcidin axis are iron dependent. Int J Environ Res Public Health 2020;17:2781. doi: 10.3390/ijerph17082781.
40. Peeling P, Dawson B, Goodman C, et al. Training surface and intensity: inflammation, hemolysis, and hepcidin expression. Med Sci Sports Exerc 2009;41:1138-45. doi: 10.1249/MSS.0b013e318192ce58.
41. Sears ME, Kerr KJ, Bray RI. Arsenic, cadmium, lead, and mercury in sweat: a systematic review. J Environ Public Health 2012;2012: 184745. doi: 10.1155/2012/184745.