© Wydawnictwo UR 2018
ISSN 2544-1361 (online); ISSN 2544-2406
doi: 10.15584/ejcem.2018.1.2

http://www.ejcem.ur.edu.pl/en/
European Journal of Clinical and Experimental Medicine
Eur J Clin Exp Med 2018; 16 (1): 14–19

ORIGINAL PAPER

Tomasz Saran [1(ACDFG)], Magdalena Zawadka [2(BCF)], Stanisław Chmiel [3(CDF)], Anna Mazur [4(DEF)]

Sweat lead and copper concentrations during exercise training

[1] Department of General and NeuroRehabilitation, Institute of Rural Health, Lublin, Poland
[2] PhD Student, Faculty of Health Sciences, Medical University of Lublin
[3] Faculty of Earth Sciences and Spatial Management, Department of Hydrology, Maria Sklodowska-Curie University, Lublin, Poland
[4] Institute of Rural Health, Lublin, Poland

ABSTRACT

Introduction. Skin is the largest organ of the human body. It plays an important role in protection against harmful substances found in the surrounding environment and takes part in the elimination of heavy metals from the body by sweating. The aim of the study was to evaluate the changes in the concentration of lead and copper in the sweat collected on the first and the fourteenth day of endurance training.

Materials and methods. The research included 43 patients undergoing a supervised, two-week endurance training on a cycle ergometer and cross-trainer. The lead and copper contents were presented in relation to the sodium content as an indicator of the amount of excreted sweat.

Results. The lead concentration in relation to the sodium content in the samples of sweat taken with the use of swabs is statistically significantly higher on day 1 (Me = 1.64-E-4) than the 14th day (Me = 0.37-E-4) p = 0.027. In the sweat samples collected with a plaster, the lead concentration on day 14 of rehabilitation (Me = 0.08-E-4) is statistically significantly lower than before the beginning of the training cycle (Me = 1.19-E-4) p = 0.044. The concentration of copper in sweat samples collected with swabs and patches on day 1 of the rehabilitation cycle does not significantly differ from the content of samples collected on day 14.

Conclusions. Endurance training with submaximal heart rate results in reduced excretion of lead in the sweat and does not significantly affect the level of copper. Further research into the impact of physical effort on the excretion of metals from the body can help explain the results

Keywords. copper, lead, physical effort

Introduction

Skin is the largest organ of the human body. It plays an important role in protection against harmful substances found in the surrounding environment and takes part in the elimination of heavy metals from the body by sweating. Determining the concentration of biomarkers in sweat can be helpful in diagnosing certain diseases as well as in detecting traces of drugs and narcotics.[1] Lead is a toxic metal, especially for the nervous system.[2,3] Previous studies have reported excretion of lead with

Corresponding author: Magdalena Zawadka, e-mail: magdalenazawadka91@gmail.com

Participation of co-authors: A – Author of the concept and objectives of paper; B – collection of data; C – implementation of research; D – elaborate, analysis and interpretation of data; E – statistical analysis; F – preparation of a manuscript; G – working out the literature; H – obtaining funds

Received: 11.12.2017 | Accepted: 20.02.2018
Publication date: March 2018

Saran T, Zawadka M, Chmiel S, Mazur A. *Sweat lead and copper concentrations during exercise training.* Eur J Clin Exp Med. 2018;16(1):14–19. doi: 10.15584/ejcem.2018.1.2

sweat while in the sauna, which indicates that increased sweating under the influence of a thermal stimulus contributes to detoxification.[4] Lead is excreted to a greater extent in a bound form than in the form of ions. Haber et al. found a decrease in the content of lead in the blood of people threatened with exposure to this element in the workplace during endurance training. The authors suggest that sweating is the main route for lead elimination.[5] Percutaneous absorption of lead causes the element to appear in sweat and saliva, but not in blood and urine. Lead absorbed through the skin is quickly eliminated from this location, so it is not as dangerous as, for example, taken orally.[6] Copper is an important building block of many protein enzymes. It is also a component of cytochrome C oxidase, which participates in the transformations associated with cellular respiration. Homeostasis disorders of copper ions occur in Alzheimer's disease and Wilson's disease.[7–9]

Objective of the paper

The aim of the study was to assess the changes in the concentrations of lead and copper in the human sweat collected on the first and fourteenth day of endurance training.

Material and methods

Characteristics of the studied group

The research included 43 patients undergoing supervised endurance training on cycle ergometer and cross-trainer in the conditions of a Rehabilitation Center. Patients reported to the Center because of lower back pain of low or moderate intensity. They were asked not to take painkillers throughout the training. Persons with diagnosed rheumatological or endocrine diseases, pregnancy, fever, diabetes or cardiovascular diseases, chronic neurological disorders and liver diseases were excluded. Participants were informed about the course of the research process and expressed their written consent to participate in the study in accordance with the protocol approved by the local bioethics commission. The population surveyed was dominated by women, which accounted for almost three quarters of the whole sample (72.4%). The youngest patient was 21 years old, the oldest was 68, and the average age of the respondents was nearly 48 years ($M = 47.62$; $SD = 15.91$). The height of patients in the study ranged from 158 to 187 cm, while on average it was close to 170 cm ($M = 169.62$; $SD = 8.42$). Patients weight was from 47 to 92 kg, and their average body weight is over 70 kg ($M = 70.14$; $SD = 11.07$).

The body mass index (BMI) of the participants ranged from 17.26 to 29.74 and was 24.36 on average ($SD = 3.29$). Almost half of the people (48.3%) were overweight, almost 45.0% had normal body weight (44.8%), while 6.9% of patients were underweight.

Twenty-nine participants completed the whole training cycle. It included exercises on a cycle ergometer and cross-trainer, five days a week for two weeks. In the first week, the training lasted 16 minutes, in the second 20 minutes. The intensity of the training was submaximal, calculated on the basis of the age of the subjects and was 85% of the maximum heart rate obtained from the formula 208-0.7× age (in years).[10]

Sweat analysis

Sweat samples were collected using two methods. The first method was to use a PharmChem patch applied between the shoulder blades, the second sample was taken using a cotton swab immersed in a drop of sweat from the forehead area. Samples were collected at 1 and 14 days of training.

The concentration of Pb and Cu (and Na) in the collected sweat was determined in samples diluted 50 times with deionized water (0.1 ml sweat sample + 4.9 ml deionized water).

Determinations were made with a ThermoScientific model XSERIES2 mass spectrometer, with a collision-collision reaction chamber, with ionisation in inductively coupled plasma (*ICP-MS)*.

The analytical process used reagents of purity for trace analysis and deionized water purified with the Millipore Simplicity 185 UV apparatus. The InorganicVenturesANALITYK-122 pattern was used for calibration of the spectrometer. For the correctness of the calibration curves and for quality control of the performed analyzes, the following certified reference materials were used: EnviroMat ES-L-2 and EnviroMat ES-H-2.

The concentrations of lead and copper expressed in ppb (parts per billion) are presented with reference to the sodium content as an indicator of the amount of sweat produced. The median amount of sodium in the samples taken on the first day with a patch was 183.8 ppm (parts per million). The median amount of sodium in the samples taken on day 14 was 214.7 ppm. These values did not differ with statistical significance ($p > 0.05$).

Statistical tools used

Statistical analyzes were performed using the IBM SPSS 21 statistical suite. The characteristics of the test sample were based on the calculation of the distribution of percentages of the occurrence of qualitative variables, and mean value, standard deviation, and the minimum and maximum for quantitative parameters. The shapes of the distribution of the analyzed data were verified using the Shapiro-Wilk test. The analysis of intra-group differences in the field of variables whose distributions departed from the Gaussian curve was carried out using the Wilcoxon non-parametric signed-rank test, and the results were further refined by means of effect size measures, which were calculated using a *r* Cohen two-level rank correlation coefficient for matching pairs. The values of individual parameters, due to their lack of conformity of their distribution with the normal distribution, were interpreted on the basis of the median, which is a congruent estimator of the expected value in the population without any asymptomatic load. The values of the quarter interval as well as the supplementary - mean and standard deviation are also given.

The work assumes the limit level for false positive error of 0.05.

Results

The results of the comparison of the lead concentration in relation to the amount of sodium in the sweat samples collected from the patients with the PharmChem patch applied between the shoulder blades and the cotton swabs dipped in a sweat spot from the forehead on 1st and 14th day of training are shown in Table 1.

A graphical illustration of the obtained research results is shown in Chart 1.

The median concentration of lead in relation to the amount of sodium in sweat samples taken from patients with a PharmChem patch on day 1 of the rehabilitation cycle is 1.19-E-4, and in samples taken on the 14th day of exercise it was 0.08-E-4.

The calculations demonstrate that lead concentration in comparison to the amount of sodium in the sweat samples of the subjects taken with the PharmChem patch on the 14th day of training (*Me* = 0.08-E-4) is significantly statistically lower than before the start of the rehabilitation cycle (*Me* = 1.19-E-4) $Z = 2.01$, $p = 0.044$. The recorded size of the effect informs about the occurrence of average correlation between the considered dimensions of $r_c = 0.46$.

The median lead concentration in relation to the amount of sodium in sweat samples taken from patients with swabs immersed in a sweat drop from the forehead area on day 1 is 1.64-E-4, while in samples taken on day 14 of exercises it was 0.37-E-4.

Based on the statistical analyzes carried out, it was found that the lead concentration in relation to the

Table 1. Comparison of the lead concentration in relation to the amount of sodium in the sweat samples collected from the patients in the training cycle

Method	Measured value								Intra-group comparisons		
	On the 1st day of exercise				On the 14th day of the exercise						
	Me	*Q*	*M*	*SD*	***Me***	*Q*	*M*	*SD*	*Z*	*P*	r_c
patch	**1.19E-4**	13.24E-4	1.73-E-4	3.64-E-4	**0.08E-4**	0.29-E-4	0.099-E-4	0.08-E-4	2.01	0.044	0.46
swab	**1.64-E-4**	24.87-E-4	5.22-E-4	8.74-E-4	**0.37-E-4**	4.16-E-4	1.10-E-4	1.42-E-4	2.22	0.027	0.57

Me - median; *Q* – quartile deviation; *M* – mean; *SD* – standard deviation; *Z* – Z test; *P* – p-value; r_c – Cohen's correlation coefficient; E-4 – the exponential form e.g: 1.19-E-4=1.19×10^{-4}
Source: own research results.

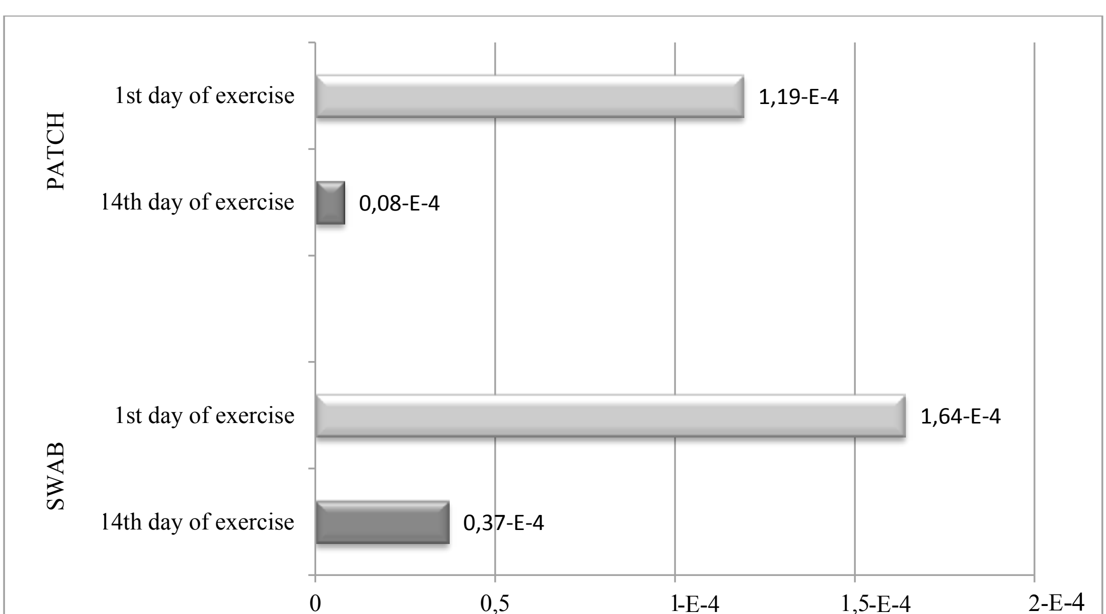

Figure 1. Comparison of the lead concentration in relation to the amount of sodium in the sweat samples collected from the patients in the training cycle
Source: own research results

amount of sodium in the sweat samples of the subjects taken with swabs dipped in a sweat drop from the forehead area, it is statistically higher on day 1 (*Me* = 1.64-E-4) than the 14th day (Me = 0.37-E-4) *FROM* = 2.22, *p* = 0.027, and the obtained effect size indicates a strong correlation between the considered dimensions, r_c= 0.57.

The results of the comparison of the copper concentration in relation to the amount of sodium in the sweat samples collected from the patients with the PharmChem patches applied between the shoulder blades and swabs dipped in a sweat spot from the forehead on 1 and 14 days are shown in Table 2.

A graphical illustration of the obtained research results is shown in Figure 2.

The median concentration of copper in relation to the amount of sodium in sweat samples taken from patients with a PharmChem patch on day 1 of the rehabilitation cycle is 6.98-E-4, and in samples taken on the 14th day of exercise it was 8.39-E-4.

The calculations demonstrate that the concentration of copper in relation to the amount of sodium in the samples of sweat tested with the PharmChem patch in 1st (*Me* = 6.98 -E-4) and in 14th (*Me* = 8.39-E-4) day of rehabilitation is comparable, *Z* = 0.77, *p* = 0.445. The median concentration of copper in relation to the amount of sodium in sweat samples collected from patients using cotton swabs dipped in the forehead sweat on day 1 of the rehabilitation cycle is 95.65-E-4, while in samples taken on the 14th day of exercise it was 80.57-E-4.

On the basis of statistical analyzes it was found that the concentration of copper in sweat samples taken with the help of swabs dipped in a sweat drop from the forehead area on day 1 of the rehabilitation cycle (*Me* = 95.65-E-4) does not differ significantly from the content of samples collected on day 14 (*Me* = 80.57-E-4) *Z*= 0.93, *p*= 0.352.

Discussion

As the amount of sweat collected by means of a patch or swab is not known, the amount of lead and copper in

Table 2. Comparison of the copper concentration with respect to the amount of sodium in the sweat samples taken from the patients in the training cycle

Method	Measured value								Comparisions Intra-group	
	On the 1st day of exercise				On the 14th day of the exercise					
	Me	*Q*	*M*	*SD*	***Me***	*Q*	*M*	*SD*	*Z*	*P*
patch	**6.98-E-4**	742.80-E-4	95.62-E-4	206.74-E-4	**8.39-E-4**	93.99-E-4	17.74-E-4	24.51-E-4	0.77	0.445
swab	**95.65-E-4**	2281.62-E-4	339.31-E-4	734.00-E-4	**80.57-E-4**	869.17-E-4	197.05-E-4	280.74-E-4	0.93	0.352

Me – median; *Q* – quartile deviation; *M* – mean; *SD* – standard deviation; *Z* – Z test; *P* – *p*-value; r_c – Cohen's correlation coefficient; E-4 – the exponential form e.g: 1.19-E-4=1.19×10^{-4}

Source: own research results.

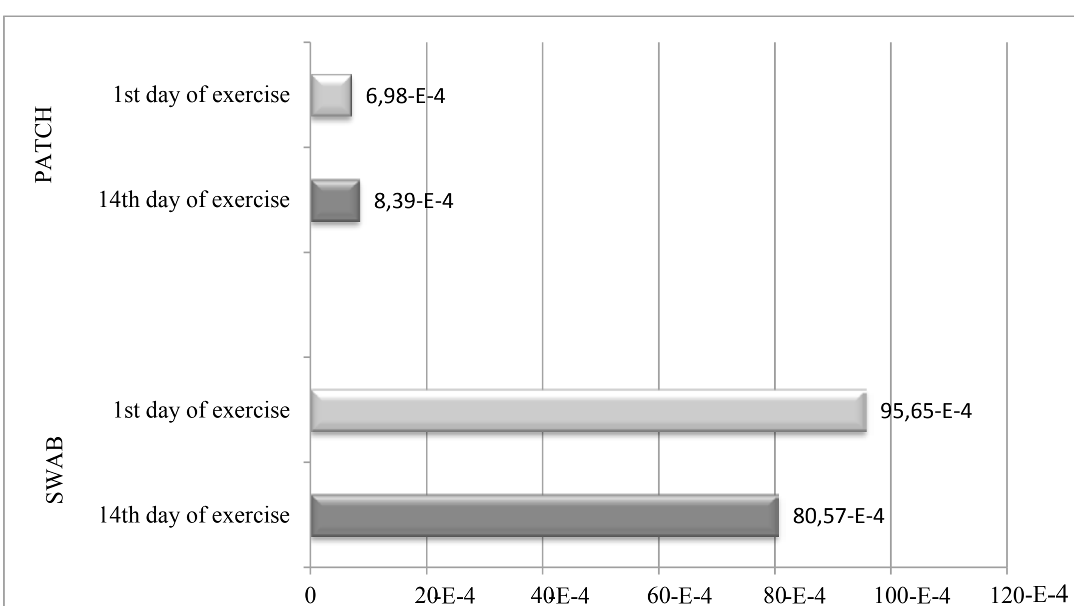

Figure 2. Comparison of the copper concentration with respect to the amount of sodium in the sweat samples taken from the patients in the training cycle

Source: own research results.

the samples was compared to the amount of sodium. As a result of the training, the average amount of sodium in the sweat samples did not change. Based on this observation and literature data, it was considered that sodium ions may be an internal marker of the amount of sweat collected. In addition, the concentration of physiological ions such as sodium ions does not change in the test subjects as the intensity of perspiration increases.[11,12]

Based on the results obtained, it can be concluded that after a fourteen-day training the lead concentration in the sweat samples tested decreases significantly. The lead content on day 14 was lower than on the first day in samples taken with both a patch and a cotton swab. Increased sweating caused by physical effort or environmental temperature causes excretion of toxic substances along with sweat.[4] Earlier works relate mainly to the elimination of elements after their administration or exposure related to work.

In studies carried out by Omokhodion and Crockford no increase in excretion of lead from sweat while driving on an ergometer in a hot environment was observed in people who were previously administered lead chloride orally. An increase in its blood and urine levels has been observed.[13] In case of workers exposed to lead, higher lead concentrations were observed in both sweat, and blood and urine, than in the control group.[14] Obtained discrepancies may result from the lead absorption path. The concentration of lead in the sweat can not be directly related to the content of lead in the blood, as well as the same assessment of lead content in the sweat can be disturbed due to contamination within the epidermis.[15] Exercises may, however, be a preventive tool against oxidative stress and inflammatory processes induced by exposure to lead, thereby counteracting the toxic effects of lead on the body.[16]

The results presented in this paper may form confirmation of the influence of endurance training on excretion of lead as an element (in free and bound form) in the sweat as a result of increased lead movement from tissue stores. However, the lack of a comparative blood analysis makes it impossible to unequivocally confirm changes in lead serum levels. Thus, the assessment of the significance of these reports in the context of monitoring the level of lead and its elimination from the body is not unambiguous.

The second objective of the present study was to examine the effect of training on the copper concentration in human sweat. Based on the results, it was found that the differences in copper content in the sweat samples tested on the first and fourteenth day of training were not statistically significant.

In studies on the concentration of copper and lead obtained by iontophoresis, lower concentrations of these elements were found in women. Sweating induced by a stay in sauna resulted in a similar excretion of copper by both sexes.[17] In other studies on the composition of sweat, in which the method applied was a *total body washdown technique*, sweating was considered the main way to eliminate zinc and copper from the body. On the other hand, the concentration of lead was comparable to its urine content.[18] Campbell et al. found increased urinary excretion of copper as a result of aerobic physical training.[19] Perhaps physical exercise is a factor regulating the level of copper in the body, but according to our research, probably not through the path of sweating. It should be noted that the metal concentration varies depending on where the sweat sample is taken.[20,21] In this work, the results of samples obtained using two methods, and from two body regions, indicate that the differences in the composition of sweat have a similar tendency, but the total amount of elements in relation to sodium differed in both methods of collection, especially when it comes to the copper.

Conclusions

Endurance training with submaximal heart rate results in reduction of lead excretion in the sweat and does not significantly affect the level of copper excretion. Further research into the impact of physical effort on excretion of lead and copper can help explain the results.

References

1. Jadoon S, Karim S, Akram MR, et al. Recent Developments in Sweat Analysis and Its Applications. *Int J Anal Chem*. 2015;2015:1-7. doi:10.1155/2015/164974.
2. Nieboer E, Tsuji LJS, Martin ID, Liberda EN. Human biomonitoring issues related to lead exposure. *Environ Sci Process Impacts*. 2013;15(10):1824-1829.
3. Bressler JP, Goldstein GW. Mechanisms of lead neurotoxicity. *Biochem Pharmacol*. 1991;41(4):479-484.
4. Sears ME, Kerr KJ, Bray RI. Arsenic, Cadmium, Lead, and Mercury in Sweat: A Systematic Review. *J Environ Public Health*. 2012;2012.
5. Haber P, Ring F, Jahn O, Meisinger F. Influence of intensive and extensive aerobic circulatory stress on blood lead levels. *Zentralbl Arbeitsmed Arbeitsschutz Prophyl Ergonomie*. 1985;35(10):303-306.
6. Lilley SG, Florence TM, Stauber JL. The use of sweat to monitor lead absorption through the skin. *Sci Total Environ*. 1988;76(2-3):267-278.
7. Strausak D, Mercer JF, Dieter HH, Stremmel W, Multhaup G. Copper in disorders with neurological symptoms: Alzheimer's, Menkes, and Wilson diseases. *Brain Res Bull*. 2001;55(2):175-185.
8. Rotilio G, Carrì MT, Rossi L, Ciriolo MR. Copper-dependent oxidative stress and neurodegeneration. *IUBMB Life*. 2000;50(4-5):309-314.
9. Hordyjewska A, Popiołek Ł, Kocot J. The many "faces" of copper in medicine and treatment. *Biometals*. 2014;27(4):611-621.

10. Tanaka H, Monahan KD, Seals DR. Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*. 2001;37(1):153-156.
11. Montain SJ, Cheuvront SN, Lukaski HC. Sweat mineral--element responses during 7 h of exercise-heat stress. *Int J Sport Nutr Exerc Metab*. 2007;17(6):574-582.
12. Appenzeller BMR, Schummer C, Rodrigues SB, Wennig R. Determination of the volume of sweat accumulated in a sweat-patch using sodium and potassium as internal reference. *J Chromatogr B*. 2007;852(1-2):333-337.
13. Omokhodion FO, Crockford GW. Sweat lead levels in persons with high blood lead levels: experimental elevation of blood lead by ingestion of lead chloride. *Sci Total Environ*. 1991;108(3):235-242.
14. Omokhodion FO, Howard JM. Sweat lead levels in persons with high blood lead levels: lead in sweat of lead workers in the tropics. *Sci Total Environ*. 1991;103(2-3):123-128.
15. Omokhodion FO, Crockford GW. Lead in sweat and its relationship to salivary and urinary levels in normal healthy subjects. *Sci Total Environ*. 1991;103(2-3):113-122.
16. Mohammadi M, Ghaznavi R, Keyhanmanesh R, Sadeghipour HR, Naderi R, Mohammadi H. Voluntary Exercise Prevents Lead-Induced Elevation of Oxidative Stress and Inflammation Markers in Male Rat Blood. *Sci World J*. 2013;2013.
17. Stauber JL, Florence TM. Estimations of sweat lead in lead workers can be masked by skin contamination. *Sci Total Environ*. 1988;74:235-247.
18. Cohn JR, Emmett EA. The excretion of trace metals in human sweat. *Ann Clin Lab Sci*. 1978;8(4):270-275.
19. Campbell WW, Anderson RA. Effects of aerobic exercise and training on the trace minerals chromium, zinc and copper. *Sports Med Auckl NZ*. 1987;4(1):9-18.
20. Aruoma OI, Reilly T, MacLaren D, Halliwell B. Iron, copper and zinc concentrations in human sweat and plasma; the effect of exercise. *Clin Chim Acta Int J Clin Chem*. 1988;177(1):81-87.
21. Gutteridge JM, Rowley DA, Halliwell B, Cooper DF, Heeley DM. Copper and iron complexes catalytic for oxygen radical reactions in sweat from human athletes. *Clin Chim Acta Int J Clin Chem*. 1985;145(3):267-273.