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Sweat lead and copper concentrations during exercise training

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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 = 1.64E-4) than the 14th day (Me = 0.37E-4) p = 0.027. In the sweat samples collected with a plaster, the lead concentration on day 14 of rehabilitation (Me = 0.08E-4) is statistically significantly lower than before the beginning of the training cycle (Me = 1.19E-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. Lead is a toxic metal, especially for the nervous system. Previous studies have reported excretion of lead with

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sweat while in the sauna, which indicates that increased sweating under the influence of a thermal stimulus contributes to detoxification. 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. 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 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. 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.

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 \( (\bar{M} = 47.62; SD = 15.91) \). The height of patients in the study ranged from 158 to 187 cm, while on average it was close to 170 cm \( (\bar{M} = 169.62; SD = 8.42) \). Patients weight was from 47 to 92 kg, and their average body weight is over 70 kg \( (\bar{M} = 70.14; SD = 3.29) \). 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.

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 \( (0.1 \text{ ml sweat sample} + 4.9 \text{ ml deionized water}) \).

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 InorganicVentures ANALITYK-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 mea-
sures, 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 drop 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 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 ($Me = 0.08\times10^{-4}$) is significantly statistically lower than before the start of the rehabilitation cycle ($Me = 1.19\times10^{-4}$) $Z = 2.01, p = 0.044$. 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 $1.64\times10^{-4}$, while in samples taken on day 14 of exercises it was $0.37\times10^{-4}$.

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

<table>
<thead>
<tr>
<th>Method</th>
<th>Me</th>
<th>Q</th>
<th>M</th>
<th>SD</th>
<th>Me</th>
<th>Q</th>
<th>M</th>
<th>SD</th>
<th>Z</th>
<th>P</th>
<th>rc</th>
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</thead>
<tbody>
<tr>
<td>patch</td>
<td>$1.19\times10^{-4}$</td>
<td>$13.24\times10^{-4}$</td>
<td>$1.73\times10^{-4}$</td>
<td>$3.64\times10^{-4}$</td>
<td>$0.08\times10^{-4}$</td>
<td>$0.29\times10^{-4}$</td>
<td>$0.099\times10^{-4}$</td>
<td>$0.08\times10^{-4}$</td>
<td>2.01</td>
<td>0.044</td>
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<tr>
<td>swab</td>
<td>$1.64\times10^{-4}$</td>
<td>$24.87\times10^{-4}$</td>
<td>$5.22\times10^{-4}$</td>
<td>$8.74\times10^{-4}$</td>
<td>$0.37\times10^{-4}$</td>
<td>$4.16\times10^{-4}$</td>
<td>$1.10\times10^{-4}$</td>
<td>$1.42\times10^{-4}$</td>
<td>2.22</td>
<td>0.027</td>
<td>0.57</td>
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</tbody>
</table>

$Me$ - 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: $1.19\times10^{-4}$

*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 \((Me = 1.64 \times 10^{-4})\) than the 14th day \((Me = 0.37 \times 10^{-4})\) 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 drop 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 \((Me = 6.98 \times 10^{-4})\) and in 14th \((Me = 8.39 \times 10^{-4})\) 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 \((Me = 95.65 \times 10^{-4})\) does not differ significantly from the content of samples collected on day 14 \((Me = 80.57 \times 10^{-4})\) \(Z = 0.93, p = 0.352\).

**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

<table>
<thead>
<tr>
<th>Method</th>
<th>Me</th>
<th>Q</th>
<th>M</th>
<th>SD</th>
<th>Me</th>
<th>Q</th>
<th>M</th>
<th>SD</th>
<th>Z</th>
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</thead>
<tbody>
<tr>
<td>patch</td>
<td>6.98 (-E-4)</td>
<td>742.80 (-E-4)</td>
<td>95.62 (-E-4)</td>
<td>206.74 (-E-4)</td>
<td>8.39 (-E-4)</td>
<td>93.99 (-E-4)</td>
<td>17.74 (-E-4)</td>
<td>24.51 (-E-4)</td>
<td>0.77</td>
<td>0.445</td>
</tr>
<tr>
<td>swab</td>
<td>95.65 (-E-4)</td>
<td>2281.62 (-E-4)</td>
<td>339.31 (-E-4)</td>
<td>734.00 (-E-4)</td>
<td>80.57 (-E-4)</td>
<td>869.17 (-E-4)</td>
<td>197.05 (-E-4)</td>
<td>280.74 (-E-4)</td>
<td>0.93</td>
<td>0.352</td>
</tr>
</tbody>
</table>

\(Me\) – 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 \(\times 10^{-4}\)

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 Croxford 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 served in people who were previously administered lead.13 In case of workers exposed to lead, driving on an ergometer in a hot environment was observed no increase in excretion of lead from sweat while driving on an ergometer in a hot environment was observed.14

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.

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


