Effect of Electromagnetic Field on Serum Biochemical Parameters in Steelworkers

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Abstract: Effect of Electromagnetic Field on Serum Biochemical Parameters in Steelworkers: Boguslaw KULA, et al. Department of Biochemistry and Chemistry, Medical University of Silesia—The aim of the study was to evaluate some biochemical parameters in the serum of steelworkers exposed to electromagnetic field (electric field strength of 20 V/m and magnetic field strength of 2 A/m) generated by induction heaters. We found significant decreases in the levels of total protein, β- and γ-globulins, and in the activities of γ-glutamyltranspeptidase (E.C.2.3.2.2) and malate dehydrogenase (E.C.1.1.1.37). The activity of aspartate aminotransferase (E.C.2.6.1.1) decreased, but the activity of alanine aminotransferase (E.C.2.6.1.2) was unchanged. Total lipid, cholesterol, triglycerides and pre-β-lipoproteins decreased, but α-lipoproteins increased. The most pronounced changes in the biochemical parameters studied were found in workers with the longest exposure to an electromagnetic field.

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Key words: Electromagnetic field, Blood serum, Protein and protein fractions, Serum enzymes, Serum lipids

Numerous biochemical studies have been carried out to evaluate the effects of electric1–7) and magnetic8–13) fields on the metabolism of cell cultures, animals and humans14–17). The studies showed significant disturbances in the metabolism of carbohydrate, lipid and protein reflected by altered blood glucose levels and by accelerated glycolysis and glycogenolysis with a metabolic block of conversion of pyruvic acid to acetylcoenzyme A. The levels of total protein and its fractions were also changed. The Krebs cycle was disturbed probably due to a metabolic block of conversion of alpha-ketoglutaric acid to succinyl-coenzyme A. It is likely that the disturbances lead to adaptative changes, which in turn result in altered lactate dehydrogenase activity and accelerated transamination processes.

Electromagnetic fields penetrate the human body and act on all organs, altering the cell membrane potential and the distribution of ions and dipoles10, 12, 13). These alterations may influence biochemical processes in the cell, thus changing both biochemical parameters and enzyme activities of serum. Data on the effects of electric and magnetic fields on human health are inconsistent probably due to differences in the exposure conditions, populations and parameters studied.

The aim of this study, which was a part of research into the effect of electromagnetic fields on humans, was to evaluate the levels of proteins and lipids and the activities of some enzymes in serum from steelworkers exposed to electromagnetic fields generated by induction heaters.

Subjects and methods

1. Exposure

The study was performed in steelworkers (men only) who worked in a tool shop and heavy processing shop, where two GJS-50 induction heaters were located (induction of 1.3 mT). An electromagnetic field was used for sintering turning cutters and hardening toothed wheels. The shops were closed rooms with appropriate humidity, ventilation and temperature. The indices of electromagnetic field exposure established by the National Inspection Committee for the Control of Radiation were as follows:

1. electric field intensity 20 V/m., f=50 Hz
2. magnetic field intensity 2 A/m., f=50 Hz

2. Subjects

Sixty-four steelworkers were selected for the study according to the following inclusion criteria:

a) no history of liver disease
b) no abnormalities on physical examination
c) no complaints on physical examination
d) no previous contact with toxic substances
e) no shift work

They were exposed to an electromagnetic field from Monday to Friday, 34 h a week (mean 6.8 h a day). The workers were divided into 3 groups which differed in the duration of exposure (Table 1).

The control group consisted of 25 persons aged 20–45 years (mean age 35.2 ± 9.9 yr) who worked at the steelworks but were not exposed to magnetic and electric radiation (accountants and engineers).

### 3. Biochemical parameters

All biochemical parameters were measured in serum. Serum samples were collected every 4 weeks (on Friday) at 8 a.m. (2 h after the start of work) after a 12-h fast. Twelve serum samples were taken from each subject and control. The following parameters were measured:

1. total serum protein
2. serum protein fractions by polyacrylamide-gel electrophoresis
3. aspartate aminotransferase activity (AspAT; EC. 2.6.1.1)
4. alanine aminotransferase activity (ALAT; EC. 2.6.1.2)
5. malate dehydrogenase activity (EC. 1.1.1.37)
6. sorbite dehydrogenase activity (EC. 1.1.1.14)
7. γ-glutamyltranspeptidase activity (GGTP; EC. 2.3.2.2)
8. total lipid level
9. triglyceride level by an enzymatic method with Boehringer reagents
10. total cholesterol by an enzymatic method with Boehringer reagents
11. lipoprotein separation by agar-gel electrophoresis with an ERJ-65 Zeiss Jena densitometer

The results were analyzed with Student’s t-test. Differences were considered significant when p<0.05.

### Results

In group 2 (3–10 yr of exposure), there was a statistically significant decrease in total serum protein content (Table 2). None of the groups showed changes in albumin levels. The levels of β-lipoprotein decreased in all groups, and γ-lipoprotein decreased in groups 1 and 2 (Table 2). Serum ALAT activity did not show any significant change in any group, but AspAT activity increased 35% in group 3 (Table 3). GGTP activity decreased significantly only in group 3, and so did malate dehydrogenase activity. Sorbite dehydrogenase activity did not change in any group studied (Table 3).

Total serum lipid and cholesterol levels significantly decreased in groups 2 and 3 (Table 4). Triglyceride levels significantly decreased only in group 3, where we also found a significant increase in the levels of α-lipoproteins.

### Discussion

Our previous studies of the effect of electromagnetic fields on living organisms showed that the initial effect of an electromagnetic field is the triggering of key biochemical processes in various metabolic pathways. The effect of an electromagnetic field on the living organism is a complex phenomenon. The initial mechanism is physicochemical in nature; and afterwards biological effects develop. The physicochemical action of an electromagnetic field consists in electron, ion, dipolar, macrostructural and electrolytic polarization. Other factors may also play a role, such as molecular excitation, biochemical activation, generation of radicals, chemical bond weakening, hydration change, altered relaxation...
Table 3. Serum enzyme activities in steelworkers exposed to an electromagnetic field

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>AspAT [UJ]</td>
<td>34.2</td>
<td>42.5</td>
<td>42.6</td>
<td>46.3</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 4.0</td>
<td>± 4.7</td>
<td>± 4.5</td>
<td>± 6.4</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>ALAT [UJ]</td>
<td>25.3</td>
<td>26.7</td>
<td>26.3</td>
<td>22.4</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 4.9</td>
<td>± 4.6</td>
<td>± 3.3</td>
<td>± 4.5</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>γ-Glutamyltranspeptidase GGTP [UJ]</td>
<td>2.48</td>
<td>2.85</td>
<td>2.45</td>
<td>2.08</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 0.28</td>
<td>± 0.63</td>
<td>± 0.63</td>
<td>± 0.23</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Malate dehydrogenase [UJ]</td>
<td>1.45</td>
<td>1.12</td>
<td>1.24</td>
<td>0.89</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 0.154</td>
<td>± 0.103</td>
<td>± 0.200</td>
<td>± 0.146</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>+</td>
</tr>
<tr>
<td>Sorbit dehydrogenase [UJ]</td>
<td>0.13</td>
<td>0.14</td>
<td>0.13</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 0.010</td>
<td>± 0.035</td>
<td>± 0.021</td>
<td>± 0.020</td>
</tr>
</tbody>
</table>

(+) p<0.05, (++) p<0.01, (–) insignificant.

Table 4. Serum lipid parameters in steelworkers exposed to an electromagnetic field

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Control</th>
<th>Group 1</th>
<th>Group 2</th>
<th>Group 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total lipids [g/l]</td>
<td>7.96</td>
<td>8.4</td>
<td>6.6</td>
<td>7.0</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 1.46</td>
<td>± 1.57</td>
<td>± 1.3</td>
<td>± 2.1</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>++</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Cholesterol [mmol/l]</td>
<td>5.25</td>
<td>5.74</td>
<td>5.00</td>
<td>4.86</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 1.12</td>
<td>± 0.98</td>
<td>± 0.92</td>
<td>± 0.58</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Triglycerides [mmol/l]</td>
<td>1.80</td>
<td>1.85</td>
<td>1.48</td>
<td>1.37</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 0.92</td>
<td>± 0.80</td>
<td>± 0.35</td>
<td>± 0.36</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>–</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>α-lipoproteins [%]</td>
<td>29.1</td>
<td>30.0</td>
<td>31.1</td>
<td>36.1</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 9.7</td>
<td>± 10.6</td>
<td>± 8.9</td>
<td>± 6.2</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>–</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>Pre-β-lipoproteins [%]</td>
<td>20.0</td>
<td>23.0</td>
<td>20.6</td>
<td>18.3</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 9.2</td>
<td>± 9.0</td>
<td>± 9.7</td>
<td>± 7.4</td>
</tr>
<tr>
<td><strong>p</strong></td>
<td>–</td>
<td>–</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td>β-lipoproteins [%]</td>
<td>50.1</td>
<td>47.7</td>
<td>47.7</td>
<td>54.0</td>
</tr>
<tr>
<td><strong>SD</strong></td>
<td>± 10.5</td>
<td>± 11.5</td>
<td>± 8.5</td>
<td>± 6.3</td>
</tr>
</tbody>
</table>

(+) p<0.05, (++) p<0.01, (–) insignificant

protein fractions of serum; but the levels of albumins and γ-globulins were most affected.

In this study, we observed a decrease in β- and γ-globulins. The decreases may have resulted from disturbed protein synthesis in the liver, which is controlled by steroid hormones. The availability of tissue proteins, release of amino acids and their metabolism in the liver are triggered by the katabolic action of glucocorticoids, but the changes observed in steelworkers cannot be attributed to glucocorticoids only. The action of glucocorticoids is also determined by the function of the liver and nutritional status.

It is likely that the 35% increase in aspartate aminotransferase activity observed in group 3 resulted from the intensification of transamination processes. This intensification, noted in animals and humans exposed to electromagnetic fields, seems to be caused by increased gluconeogenesis. Glucocorticoids also enhance transamination processes. In such cases, the activation of aminotransferases most probably consists in substrate induction. The fact that the activities of serum GGTP, malate dehydrogenase, and sorbit dehydrogenase were not diminished suggest the normal function of liver parenchyma. The decreased malate dehydrogenase activity in group 3 suggests adaptive changes in the metabolism of fumaric acid to oxaloacetic acid.

The decreased total lipid and cholesterol levels in groups 2 and 3 suggest decreased energetic demand. The findings concerning fat metabolism may be of some importance with respect to the early development of atherosclerosis, especially in group 2, which showed significant changes in the level of lipoproteins that prevent...
the development of atherosclerosis. The changes in the profile of lipoproteins in those workers correlate with frequent electrocardiographic abnormalities (presented in another report). Lowered cholesterol and triglyceride levels were also found in the serum of rats exposed to another report). Lowered cholesterol and triglyceride frequent electrocardiographic abnormalities (presented in profile of lipoproteins in those workers correlate with the development of atherosclerosis. The changes in biochemical parameters are mild.

References

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