The Influence of the Call with a Mobile Phone on Heart Rate Variability Parameters in Healthy Volunteers

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Abstract: It is possible that electromagnetic field (EMF) generated by mobile phones (MP) may have an influence on the autonomic nervous system (ANS) and modulates the function of circulatory system. The aim of the study was to estimate the influence of the call with a mobile phone on heart rate variability (HRV) in young healthy people. The time and frequency domain HRV analyses were performed to assess the changes in sympathovagal balance in a group of 32 healthy students with normal electrocardiogram (ECG) and echocardiogram at rest. The frequency domain variables were computed: ultra low frequency (ULF) power, very low frequency (VLF) power, low frequency (LF) power, high frequency (HF) power and LF/HF ratio was determined. ECG Holter monitoring was recorded in standardized conditions: from 08:00 to 09:00 in the morning in a sitting position, within 20 min periods: before the telephone call (period I), during the call with use of mobile phone (period II), and after the telephone call (period III). During 20 min call with a mobile phone time domain parameters such as standard deviation of all normal sinus RR intervals (SDNN [ms] – period I: 73.94 ± 25.02, period II: 91.63 ± 35.99, period III: 75.06 ± 27.62; I–II: \( p < 0.05 \), II–III: \( p < 0.05 \)) and standard deviation of the averaged normal sinus RR intervals for all 5-mm segments (SDANN [ms] – period I: 47.78 ± 22.69, period II: 60.72 ± 27.55, period III: 47.12 ± 23.21; I–II: \( p < 0.05 \), II–III: \( p < 0.05 \)) were significantly increased. As well as very low frequency (VLF [ms²] - period I: 456.62 ± 214.13, period II: 566.84 ± 216.99, period III: 477.43 ± 203.94; I–II: \( p < 0.05 \), II–III: \( p < 0.05 \)), low frequency (LF [ms²] – period I: 607.97 ± 201.33, period II: 758.28 ± 307.90, period III: 627.09 ± 220.33; I–II: \( p < 0.01 \), II–III: \( p < 0.05 \)) and high frequency (HF [ms²] – period I: 538.44 ± 290.63, period II: 730.31 ± 445.78, period III: 590.94 ± 301.64; I–II: \( p < 0.05 \)) components were the highest and the LF/HF ratio (period I: 1.48 ± 0.38, period II: 1.16 ± 0.35, period III: 1.46 ± 0.40; I–II: \( p < 0.05 \), II–III: \( p < 0.05 \)) was the lowest during a call with a mobile phone. The tone of the parasympathetic system measured indirectly by analysis of heart rate variability was increased while sympathetic tone was lowered during the call with use of a mobile phone. It was shown that the call with a mobile phone may change the autonomic balance in healthy subjects. Changes in heart rate variability during the call with a mobile phone could be affected by electromagnetic field but the influence of speaking cannot be excluded.

Key words: Mobile phone, Heart rate variability (HRV), Electromagnetic field (EMF), Holter monitoring, Autonomic function

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Introduction

Radiofrequency (RF) electromagnetic fields (EMF) of mobile communication systems are widespread in the living environment. The potential health risk of electromagnetic field emitted by mobile phones (MP) is of considerable public interest. Exposition to high-power RF energy may have negative thermic effects on living organisms and cause cataracts, skin burns, miscarriages or birth defects\(^1\,\text{--}\,5\). Such negative effects have never been demonstrated at the power levels associated with public exposure to RF energy emitted by mobile phone base station antennae. In this case the produced power is too low to cause the dangerous heating but there are few reports of non-thermal effect exerted by standard Global System for Mobile Communication (GSM)\(^1\,\text{,}\,6\,\text{,}\,7\). Many authors suggest that electromagnetic fields emitted by cellular phones may interfere with work of cardiac pacemakers and other implantable medical devices\(^8\,\text{--}\,10\). The influence of mobile phones on heart rate and blood pressure is still problematic\(^11\,\text{,}\,12\). There are some reports confirming so called non-thermic effect of mobile phones on humans that is not related to heat stress\(^1\,\text{,}\,6\,\text{,}\,7\). It was shown that occupational exposition to EMF can cause fluctuations in heart rate and heart rate variability (HRV)\(^13\,\text{--}\,15\). It is possible that electromagnetic field emitted by cellular telephones may influence the autonomic tone, thus modifying the functioning of circulatory system.

The aim of the present study was to determine the influence of the call with a mobile phone on heart rate variability in healthy young male and female subjects. The study was designed to assess cardiac regulatory mechanisms during exposure to radiofrequency electromagnetic field of low-intensity emitted by a mobile phone with a non-invasive, widely used method of autonomic function evaluation.

Materials and Methods

32 volunteers, students of the fifth year of Faculty of Medicine from Wroclaw Medical University (18 women and 14 men, mean age 23.0 ± 1.4 yr) entered the study. The investigated persons underwent 12-lead electrocardiographic (ECG) examination at rest, 24-h ECG Holter monitoring and echocardiography. All participants were healthy and none of them were on pharmacological treatment. The following exclusion criteria were accepted for the investigation: presence of any serious cardiovascular disease, including arterial hypertension, metabolic and neurological disorders that could influence heart rate variability and serious arrhythmias. In all participants systolic and diastolic function of left ventricle assessed by echocardiography was normal. Mean value of ejection fraction was 65.2 ± 5.1% and no hemodynamically significant valvular pathologies were found. All participants had used mobile phones for 5 to 7 yr prior to the study. The mean number of telephone calls was 140 per month, mean total duration of calls was 500 min per month and mean duration of each telephone call was 3 min and 30 s per each call. The written informed consent was obtained from all students taking part in the study. The study was approved by the local ethics committee and followed the Declaration of Helsinki. All subjects got up between 6:30 a.m and 7:00 a.m. and were asked to abstain from consuming caffeinivated beverages and excessive physical activity including gymnastics within 12 h preceding data collection. They were also requested not to eat and drink on the morning of the experiment or take a shower. Students were fully habituated to equipment, protocols, and experimenters.

Our investigation was performed in a semi-darkened, temperature-controlled quiet laboratory at room temperature (21 °C). Before the experiment participants had rested in a laboratory room in a sitting posture for about 20 min. Records were performed between 08:00 and 09:00 in the morning in similar conditions (the same place of the experiment and sitting position) over 20 min periods: before the telephone call (period I), during 20 min call with a cellular telephone (period II) and 20 min after the telephone call (period III). Throughout the 20 min period of the investigation the subjects were exposed to a RF field emitted by 1,800 MHz frequency band GSM mobile phone held in the right hand. The GSM Sony Ericsson K700i model was used in all cases. The highest Specific Absorption Rate (SAR) value for this model phone tested by Sony Ericsson for the ear is 0.48 W/kg (10 g). SAR data information for residents in countries that have adopted the SAR limit recommended by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) is given in watts/kilogram (W/kg) averaged over ten (10) grams of tissue (European Union, Japan, Brazil and New Zealand).

The telephone was switched on during the whole time of the experiment so that the effect of logging into the mobile phone network on the maximal emission of EMF could be avoided. Only neutral, non-exciting topics were discussed during the phone talks so that stress associated with speaking and subsequent overactivity of autonomic nervous system should be minimized.

All volunteers underwent a three-lead ECG Holter recording (HolCARD 24W System, Aspel S.A., Poland) for 60 min. The program automatically detected and labeled each QRS complex with a precise determination of fiducial points for QRS complexes. The successive RR intervals from ECG Holter recordings were visually...
examined for detecting and eliminating artifacts, as it has been described by numerous authors, and then the estimation of time and frequency domain characteristics of HRV from period I, II and III was performed\cite{13,14}. Definitions and abbreviations for time domain analysis are shown in Table 1. The following frequency domain variables were computed: ultra low frequency (ULF) power from 0 to 0.0033 Hz, very low frequency (VLF) power from 0.0033 Hz to 0.04 Hz, low frequency (LF) power from 0.04 Hz to 0.15 Hz, high frequency (HF) power from 0.15 Hz to 0.4 Hz, and LF/HF ratio was also calculated. The autoregressive method was used to evaluate the power spectral density of the RR series in the studied 20 min periods. The time and frequency domain measures of heart rate variability were analyzed by methods recommended by the Task Force of the European Society of Cardiology\cite{16}. Blood pressure was measured before and after the experiment with a standard mercury sphygmomanometry in all participants and it was in normal range with no significant changes. Participants were quietly breathing during the study and respiratory rhythm was 12–16 breaths per min. In this way we attempted to minimize the effect of respiration on HRV. Moreover, having created the same experimental conditions (place of the study, temperature, neutral topics of the telephone call) we tried to avoid any factors that could influence respiratory rate.

Statistical analysis was performed with “STATISTICA PL 6.0” package (StatSoft Poland). The data were expressed as means and standard deviations. The Shapiro-Wilk test for normality was employed. The distribution of variables was not normal and further analysis was performed using non-parametric Friedman ANOVA followed by the post hoc Newman-Keuls test. A $p$-value $<0.05$ was considered statistically significant.

**Results**

Maximal, mean and minimal heart rate did not change significantly over 20 min period before the telephone call (period I), during 20 min telephone call (period II) and after the telephone call (period III) in the whole investigated group (Table 2). There were no statistically significant changes in maximal, mean and minimal heart rate either in men or in women (Table 2). No arrhythmias were noted in the analyzed records before, during and after the telephone call.

The analysis of the time domain HRV parameters in the whole study group for the period I, II and III showed that SDNN and SDANN were significantly higher during

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### Table 1. Definitions and abbreviations for time domain analysis of heart rate variability

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>mRR</td>
<td>mean RR intervals of the sinus rhythm in ms</td>
</tr>
<tr>
<td>SDNN</td>
<td>standard deviation of all normal sinus RR intervals in ms</td>
</tr>
<tr>
<td>SDANN</td>
<td>standard deviation of the averaged normal sinus RR intervals for all 5-mm segments in ms</td>
</tr>
<tr>
<td>SDNNi (index)</td>
<td>means of the standard deviations of all normal sinus RR intervals for all 5-min segments in ms</td>
</tr>
<tr>
<td>r-MSSD</td>
<td>root-mean-square of successive normal sinus RR interval difference in ms</td>
</tr>
<tr>
<td>pNN50</td>
<td>the percentage of successive normal sinus RR intervals $&gt;$50 ms in %</td>
</tr>
</tbody>
</table>

### Table 2. The mean, maximal and minimal heart rate assessed by counting R waves per minute in 20-min intervals during ECG-Holter monitoring before mobile phone call (period I), during mobile phone call (period II) and after mobile phone call (period III) in young healthy subjects

<table>
<thead>
<tr>
<th>Parameter</th>
<th>period I</th>
<th>period II</th>
<th>period III</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>mean heart rate beats/min</td>
<td>wh 85.34 ± 10.34</td>
<td>83.15 ± 14.29</td>
<td>84.64 ± 14.37</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>m 86.24 ± 12.14</td>
<td>83.04 ± 12.78</td>
<td>84.98 ± 13.04</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>w 84.58 ± 14.17</td>
<td>83.27 ± 11.34</td>
<td>85.12 ± 14.98</td>
<td>ns</td>
</tr>
</tbody>
</table>

| maximal heart rate beats/min | wh 132.28 ± 14.28 | 128.15 ± 12.34 | 131.48 ± 12.67 | ns    |
|                            | m 130.42 ± 15.34 | 127.24 ± 13.74 | 130.11 ± 14.43 | ns    |
|                            | w 134.61 ± 16.34 | 129.31 ± 14.86 | 129.43 ± 16.71 | ns    |

| minimal heart rate beats/min | wh 67.54 ± 12.30 | 63.17 ± 14.30 | 68.14 ± 11.65 | ns    |
|                             | m 66.48 ± 13.47 | 64.14 ± 15.27 | 66.76 ± 13.52 | ns    |
|                             | w 69.03 ± 14.91 | 62.74 ± 13.74 | 64.02 ± 9.47  | ns    |

$p$ – statistical significance; ns – non-significant; wh – the whole group; m – men; w – women; each value represents the mean ± SD.
the telephone call (period II) in comparison with period I \((p<0.05)\) and period III \((p<0.05)\). The rest of the parameters of the time analysis measured within the particular periods of the investigation did not differ significantly from each other (Table 3). In a group of men SDNN and SDANN were significantly higher during the telephone call in comparison with the period after termination of the phone call \((p<0.05)\) (Table 3). In a group of women SDNN and SDANN parameters were significantly increased during the 20 min telephone call with the cellular phone in comparison with the 20 min period before the telephone call \((p<0.05)\), (Table 3).

The analysis of the frequency domain HRV parameters in the whole study group demonstrated that VLF, LF and HF parameters were significantly increased over the 20 minute period of the telephone call in comparison with the 20 min period before it (respectively \(p<0.05\); \(p<0.01\); \(p<0.05\)). LF in the whole study group was significantly decreased during 20 min period after the telephone call in comparison with the time of the telephone call \((p<0.05)\). LF/HF ratio was also significantly lower in the whole group during the telephone call in comparison with the period before and after the telephone call \((p<0.05)\) (Table 4). In men HF power was significantly increased during the period of the telephone call in comparison with the period before the telephone call \((p<0.05)\) (Table 4). In a group of women there was a significant increase in VLF, LF and HF parameters \((p<0.05)\) and a decrease in LF/HF ratio \((p<0.01)\) during the 20 min telephone call as compared with the period before the telephone call. It was also demonstrated in women that LF/HF ratio was significantly increased during period after the telephone call \((p<0.01)\), (Table 4).

**Discussion**

The present study demonstrated that the call with use of a mobile phone may cause the increase in parasympathetic tone (the highest values of HF parameter were noted during the telephone call) and the decrease in sympathetic tone (the lowest values of LF/HF ratio during the telephone call). It is known that the efferent vagal activity is a major contributor to the HF component\(^{17–19}\). LF is a marker reflecting both sympathetic and vagal activity\(^{18, 20}\) and the LF/HF ratio is considered to mirror sympathovagal balance or reflect the sympathetic modulations. SDNN and SDANN parameters were the highest

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**Table 3. Time domain heart rate variability (HRV) parameters in 20-min intervals before mobile phone call (period I), during mobile phone call (period II) and after mobile phone call (period III) in young healthy subjects**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>period I</th>
<th>period II</th>
<th>period III</th>
<th>(p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>mRR (ms)</td>
<td>wh</td>
<td>716.13 ± 135.12</td>
<td>718.25 ± 126.34</td>
<td>716.25 ± 132.24</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>719.24 ± 137.29</td>
<td>726.37 ± 135.27</td>
<td>721.64 ± 139.45</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>712.72 ± 129.11</td>
<td>717.74 ± 122.43</td>
<td>709.94 ± 118.0</td>
</tr>
<tr>
<td>SDNN (ms)</td>
<td>wh</td>
<td>73.94 ± 25.02</td>
<td>91.63 ± 35.99</td>
<td>75.06 ± 27.62</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>82.35 ± 22.63</td>
<td>90.00 ± 21.75</td>
<td>75.21 ± 25.16</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>67.38 ± 25.41</td>
<td>92.88 ± 43.46</td>
<td>74.94 ± 26.36</td>
</tr>
<tr>
<td>SDNNi (ms)</td>
<td>wh</td>
<td>53.50 ± 18.29</td>
<td>59.44 ± 22.52</td>
<td>54.87 ± 19.84</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>57.57 ± 16.62</td>
<td>59.28 ± 16.62</td>
<td>52.50 ± 20.90</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>50.33 ± 21.82</td>
<td>59.55 ± 26.70</td>
<td>56.72 ± 19.38</td>
</tr>
<tr>
<td>SDANN (ms)</td>
<td>wh</td>
<td>47.78 ± 22.69</td>
<td>60.72 ± 27.55</td>
<td>47.12 ± 23.21</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>56.35 ± 26.31</td>
<td>62.50 ± 21.13</td>
<td>43.00 ± 19.35</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>41.11 ± 17.38</td>
<td>59.33 ± 32.21</td>
<td>50.33 ± 25.89</td>
</tr>
<tr>
<td>rMSSD (ms)</td>
<td>wh</td>
<td>35.69 ± 20.78</td>
<td>40.94 ± 27.03</td>
<td>37.94 ± 22.92</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>37.64 ± 14.36</td>
<td>38.50 ± 21.19</td>
<td>37.57 ± 24.28</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>34.16 ± 24.97</td>
<td>42.83 ± 31.30</td>
<td>38.22 ± 22.50</td>
</tr>
<tr>
<td>pNN50 (%)</td>
<td>wh</td>
<td>14.05 ± 13.46</td>
<td>13.82 ± 12.83</td>
<td>14.35 ± 13.56</td>
</tr>
<tr>
<td></td>
<td>m</td>
<td>15.62 ± 10.84</td>
<td>13.17 ± 13.26</td>
<td>14.80 ± 11.03</td>
</tr>
<tr>
<td></td>
<td>w</td>
<td>15.26 ± 14.09</td>
<td>12.82 ± 15.38</td>
<td>13.05 ± 14.33</td>
</tr>
</tbody>
</table>

\(p\) – statistical significance; ns – non-significant; wh – the whole group; m – men; w – women; each value represents the mean ± SD.
Table 4. Frequency domain heart rate variability (HRV) parameters in 20-min intervals before mobile phone call (period I), during mobile phone call (period II) and after mobile phone call (period III) in young, healthy subjects

<table>
<thead>
<tr>
<th>Parameter</th>
<th>period I</th>
<th>period II</th>
<th>period III</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>ULF ultra low frequency power (ms²)</td>
<td>wh 337.56 ± 331.06</td>
<td>344.69 ± 339.01</td>
<td>314.72 ± 301.97</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>m   423.57 ± 344.52</td>
<td>447.14 ± 358.34</td>
<td>387.50 ± 291.14</td>
<td>ns</td>
</tr>
<tr>
<td></td>
<td>w   252.33 ± 289.97</td>
<td>267.77 ± 323.24</td>
<td>258.11 ± 306.12</td>
<td>ns</td>
</tr>
</tbody>
</table>
| VLF very low frequency power (ms²)     | wh 456.62 ± 214.13 | 566.84 ± 216.99 | 477.43 ± 203.94 | I–II: $p<0.05$
|                                        | m   507.14 ± 228.75 | 597.50 ± 123.39 | 521.42 ± 191.68 | ns   |
|                                        | w   417.32 ± 199.63 | 543.00 ± 245.90 | 443.21 ± 211.91 | I–II: $p<0.05$
| LF low frequency power (ms²)           | wh 607.97 ± 201.33 | 758.28 ± 307.90 | 627.09 ± 220.33 | I–II: $p<0.01$
|                                        | m   648.00 ± 233.52 | 696.59 ± 397.50 | 654.14 ± 207.62 | ns   |
|                                        | w   576.83 ± 233.52 | 742.94 ± 347.82 | 606.05 ± 233.41 | I–II: $p<0.05$
| HF high frequency power (ms²)          | wh 538.44 ± 290.63 | 730.31 ± 445.78 | 590.94 ± 301.64 | I–II: $p<0.05$
|                                        | m   540.14 ± 248.30 | 733.42 ± 341.40 | 620.78 ± 344.94 | I–II: $p<0.05$
|                                        | w   537.11 ± 326.91 | 727.88 ± 305.97 | 567.72 ± 271.32 | I–II: $p<0.05$
| LF/HF                                  | wh 1.48 ± 0.38     | 1.16 ± 0.35     | 1.46 ± 0.40     | I–II: $p<0.05$
|                                        | m   1.45 ± 0.47     | 1.33 ± 0.35     | 1.42 ± 0.45     | ns   |
|                                        | w   1.50 ± 0.49     | 1.08 ± 0.36     | 1.51 ± 0.53     | I–II: $p<0.01$

$p$ – statistical significance; ns – non-significant; wh – the whole group; m – men; w – women; each value represents the mean ± SD.

Frequency domain variables: ULF power: 0–0.0033 Hz, VLF power: 0.0033 Hz–0.04 Hz, LF power: 0.04 Hz–0.15 Hz, HF power: 0.15 Hz–0.4 Hz.

during the telephone call. SDNN represents joint sympathetic and parasympathetic modulation of heart rate. In the other studies the increased SDNN was observed after physical training, in aerobic athletes and it was also associated with increased testosterone level.

We observed some gender differences in cardiac autonomic modulation. In women LF was significantly higher before the telephone call than in men. The LF/HF ratio was significantly lower during the call compared with periods before and after the telephone call. Hoikuri et al. demonstrated that men had higher indexes of sympathetic function than women. In this context lower sympathetic activity in women could be explained. However, Hoikuri et al. investigated subjects that were middle-aged. The lower LF/HF ratio was also observed in women at young age in comparison with men.

In our experiments ULF did not change significantly, but VLF increased during the telephone call in the whole group and in a group of women. The increase in very low frequency in the exposed subjects could be related to parasympathetic activation as VLF is very much dependent on parasympathetic tone. Taylor et al. suggested that parasympathetic nervous system is the dominant determinant of VLF. In studies on atrial fibrillation (AF) the increase in VLF component together with other parasympathetic markers predicted the early recurrence of AF after cardioversion. However, the physiologic interpretation of VLF oscillations is still a subject of debate. Reduction in VLF is associated with increased risk for sudden cardiac death. Different physiological mechanisms for VLF have been proposed: physical activity, thermoregulation, renin-angiotensin-aldosterone system, slow respiratory patterns and parasympathetic mechanisms.

Some authors do not confirm connections between the use of mobile telephones and changes in circulatory system. As reported by Tahvanainen et al. there were no significant changes in arterial blood pressure and heart rate during or after the RF exposures to 900 MHz or 1,800 MHz cellular phones. Additionally, tests of autonomic regulation were conducted during each RF exposure and sham exposure session. Braune et al. observed that changes in heart rate and in arterial blood pressure were independent of the EMF exposure with the use of...
900 MHz mobile phones\(^\text{12}\). Wilen \textit{et al}. reported the
dominance of sympathetic tone in response to EMF expo-
sure, but correlated it with emotional stress related to solv-
ing the psychophysiological tests by the participants\(^\text{33}\).
Subjects who experienced symptoms related to MP use
were recruited into the study and compared with a con-
trol group with no symptoms in association with MP use.
In our investigation and in the rest of the discussed arti-
cles only healthy volunteers were participating. In studi-
ies conducted by Wilen \textit{et al}. a film was shown on a com-
puter screen during the exposure, which could potential-
ly have an influence on HRV\(^\text{33}\). The majority of subjects
reported a history of MP use for 8–14 yr or 15–22 yr with a
calling time more than 60 min a day or 15–60 min a day\(^\text{32}\). It is difficult to compare the MP use history with
results of our studies as those obtained by Wilen \textit{et al}.
are presented in separate subgroups. It seems that the
total exposition time was shorter in our case. Results of
our studies are also not in concordance with Parazzini \textit{et al}.
who demonstrated no significant effect of GSM
900 MHz cellular phones on heart rate variability in quiet
conditions, indicating that changes in HRV parameters in
our study might not be caused only by EMF exposure\(^\text{34}\).
Parazzini \textit{et al}. observed a weak interaction between some
HRV parameters such as SDNN and LF and RF exposure
during standing\(^\text{34}\). However, it seemed to be the symp-
pathetic reaction to standing position as participants
stayed in supine resting condition for the first 13 min of
the session which was then followed by 13 min in stand-
ing condition\(^\text{34}\).

In the discussed reports participants did not hold a tele-
phone in a typical telephoning position as it was in our
experiments but used a computer-controlled phone locat-
ed on a head helmet, placed on a framework or the tele-
phone was mounted on the right-hand side of the head
and fixed with a headband as described by Parazzini \textit{et al}.
\(^\text{11, 12, 33, 34}\). It was demonstrated that change in fore-
arm position may have an impact on sympathetic nerves
in muscles of hand\(^\text{35}\). However, reports are concentrat-
ed on forearm raise together with handgrip exercises per-
formed more or less intensively, which could cause the
increase in sympathetic activity\(^\text{35, 36}\). For these reasons
we think that results of our experiments were not ulti-
mately interfered by holding a telephone.

Our studies were performed between 8.00 and 9.00
a.m., while Tahvanainen \textit{et al}. chose the time between 1
p.m. and 3 p.m., Wilen \textit{et al}. either a.m. or p.m., while
Parazzini conducted the investigations between 9.00 a.m.
and 1.00 p.m.\(^\text{11, 33, 34}\) In this aspect the influence of cir-
cadian rhythms could be present. The duration of the
exposition to EMF in our experiments was 20 min and in
the other studies it varied from 20 to 50 min\(^\text{11, 12, 33, 34}\).

In studies on occupational exposition Bortkiewicz \textit{et al}.
reported a negative correlation between the maximum
intensity of EMF and HF component in individuals
exposed to EMF\(^\text{14, 37}\). In workers with occupational expo-
sure to 50 Hz EMF there was a higher relative risk of
decreased HRV in the exposed group in comparison with
controls and the percentage of subjects with dominant
sympathetic function was also significantly higher in the
study group\(^\text{13}\). Moreover, VLF component was signifi-
cantly increased in the exposed subjects, which was also
observed in our study. Additionally, according to the pre-
vious study of the same authors similar changes in VLF
occurred also in subjects exposed to medium frequency
EMF\(^\text{14}\). Bortkiewicz \textit{et al}. claimed that VLF component
was under the influence of both parts of the autonomic
nervous system, i.e sympathetic and parasympathetic and
correlated the increase in this component with the control
of blood pressure\(^\text{13, 38}\). However, several reports sug-
gested that VLF mainly reflects parasympathetic activity.
\(^\text{27, 28, 32}\) Although, it seems that EMF generally
induces increase in VLF it is still possible that the inter-
pretation of those changes is much more complex as
expected and simultaneously a pattern of autonomic bal-
ance may be different in occupational studies.

The character of the influence of EMF on autonomic
nervous system may depend on intensity of electromag-
netic field, exposition during the experiment, total time
of exposition in the past, duration of the study (short peri-
od measurements or 24 h analysis) and other factors. For
those reasons and the differences in protocols of the pre-
viously mentioned studies the data from our investigation
may not be quite comparable with results presented by
other authors.

The International Comission on Non-Ionising Radiation
Protection (IRCP) stated that localized radiofrequency
radiation limit for general public exposure (2 W/kg) was
not exceeded by handsets\(^\text{39}\). In Poland limits for the fre-
quency range of 0.3–300 GHz are expressed as a power
density value of 0.1 W/m\(^\text{2}\)\(^\text{40}\). The European Union (EU)
standards are more sophisticated and relate limit values
to specific frequencies\(^\text{41}\). The electromagnetic energy
produced by cellular telephones may reach very high val-
ues of power density during logging into the telephone
network or starting the connection\(^\text{42, 43}\). In order to elim-
ninate such extreme conditions our study was performed
at a place with a stable high network signal and after the
mobile phone was logged into the network.

Speaking can increase the speed of breathing and,
therefore, changes in respiratory frequency may have an
influence on heart rate\(^\text{44, 45}\). This possibility should be
taken into account while HRV analysis is performed
without simultaneous acquisition and analysis of respira-
tion\(^\text{45}\). Reading aloud and free talking may increase LF
component\(^\text{45}\). We tried to create conditions simulating a
real telephone call in our experiment and that is why subjects were asked to speak during the experiment. However, it is possible that the observed increase in LF during the telephone call in comparison with the periods before and after the phone conversation could be somehow affected by speaking.

Regarding widespread use of mobile phones closer attention should be paid to a problem of workers who use mobile phones for a long time and are occupationally exposed to electromagnetic field. On the other hand, it is important to evaluate whether the extensive use of mobile phones in various types of jobs could exert influence on heart that is not only related to mental stress. Results of our investigation suggest that a call with use of a mobile phone may exert a noticeable effect on autonomic balance, though the pattern it represents is not typical for the detrimental effect on HRV, i.e. lack of a typical decrease in parasympathetic activity with the domination of sympathetic system. The increase in vagal activity can be beneficial in cardiovascular diseases. However, it has not been elucidated yet how much vagal activity or its markers have to increase in order to provide adequate protection or how the proper balance between parasympathetic and sympathetic tone should be expressed\(^ \text{16} \). Thus, results of our investigation do not show that EMF can have a positive health effect. This is a preliminary study to demonstrate that the call with a mobile phone may cause changes in autonomic balance probably related to a non-thermal bioeffect.

Limitations of the study. We did not include a control group, however the results from period with the use of mobile phone were compared with periods before the telephone call and after it. The period before the telephone call may serve as a suitable control regarding that sub- jects were healthy volunteers and they are good representatives of the population. We did not measure SAR, which is not accessible for routine evaluation of real-life exposure. Participants were exposed to RF with intensity below existing safety limits based on SAR values characteristic of the GSM Sony Ericsson K700i model. SAR measurements were performed using a phantom in other studies\(^ \text{11, 33, 34} \).

Conclusions

1. Results of the present study demonstrate that the call with a mobile phone may influence heart rate variability and change the autonomic balance.
2. The increase in the parasympathetic tone concomitant with the decrease in the sympathetic tone measured indirectly by analysis of heart rate variability were observed during the mobile telephone call.
3. Changes in heart rate variability during the call with a mobile phone could be affected by electromagnetic field, but the influence of speaking cannot be excluded.

References


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