The effects of the duration of mobile phone use on heart rate variability parameters in healthy subjects

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Abstract

Objective: This study aimed to estimate the influence of the duration of mobile phone use on heart rate variability (HRV) in healthy individuals.
Methods: One hundred forty-eight individuals without any established systemic disease and who had undergone 24-h ambulatory ECG monitoring were included in the case-control study. All the individuals had been using mobile phones for more than 10 years. Three-channel 24-h Holter monitoring was performed to derive the mean heart rate, standard deviation of normal NN intervals (SDNN), standard deviation of 5-min (m) mean NN intervals (SDANN), the proportion of NN50 divided by the total number of NNs (pNN50), the root mean square differences of successive NN intervals (RMSSD), high (HF)-, low (LF)-, very low (VLF)-frequency power, total power components, and the LF/HF ratio. Individuals were divided into four groups according to their duration of mobile phone use [no mobile phone use (Control group), <30 min/day (Group 1), 30–60 min/day (Group 2), and >60 min/day (Group 3)].
Results: All the groups had similar features with regard to demographic and clinical characteristics. No significant arrhythmias were observed in any of the groups. The LF/HF ratio was higher, whereas the SDNN, SDANN, RMSSD, and pNN50 values were lower in the study groups than in the control group ($p<0.05$). No significant differences were identified among groups with respect to heart rate, VLF, and total power values ($p>0.05$).
Conclusion: In this study, it was shown that the duration of mobile phone use may affect the autonomic balance in healthy subjects. The electromagnetic field created by mobile phone use may induce HRV changes in the long term. *(Anatol J Cardiol 2016; 16: 833-8)*
Keywords: electromagnetic field, heart rate variability, mobile phone

Introduction

Mobile phone (MP) technology has grown significantly over the past decade and has become an essential part of our everyday lives. However, due to the widespread exposure to electromagnetic fi elds (EMF) from mobile communication systems, there may be some negative effects on health in the living environment. It is possible that EMF generated by MPs may have an influence on the autonomic nervous system (ANS), which modulates the function of the circulatory system (1). The assessment of heart rate variability (HRV) is one of the most popular methods for evaluating autonomic modulations of the heart. It reflects the normalizing autonomic function and identifies the cardiac autonomic regulation. Increasing evidence has suggested that EMF emitted by MPs interacts with the human organism because they represent a potential source of electromagnetic interference. Thus, the cardiovascular system may be a potential target for the EMF emitted by MPs (2). HRV analysis is a non-invasive method for assessing autonomic imbalance, where a low HRV is correlated with a high cardiovascular risk (3). Nowadays, MPs are almost ubiquitously used as communication tools, so knowing their effects on humans, especially on the autonomic nervous system, is very important. However, there are only a limited number of studies on the effects of the duration of MP use on HRV parameters in healthy subjects. The aim of the study was therefore to estimate the influence of the duration of MP use on HRV in healthy subjects. Time and frequency domain HRV analyses were performed to assess the changes in sympathovagal balance in a group of 148 healthy individuals with a normal electrocardiogram and echocardiogram at rest.

Methods

Participants and the study design

The sample was derived from a population of 251 consecutive volunteers who underwent 24-h ambulatory ECG monitoring

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for the study purposes. These volunteers were recruited from the hospital staff with no known diseases, healthy friends and relatives of the hospital staff, and healthy volunteers who presented to the blood bank unit of the hospital (three participants) for blood donation. The HRV analyses of the three participants were done 1 week after blood donation in order not to affect the results. The inclusion criteria were age >18 years, an interference-free 24-h Holter ECG monitoring, and the patient's consent. All the participants were healthy, and none of them were on pharmacological treatment. Also, the investigated persons underwent 12-lead electrocardiographic (ECG) examination and echocardiography at rest. Patients with coronary heart disease, heart failure, congenital heart disease, fever, hypoxia, a history of arrhythmia, neurological disease, endocrine disorder, and hypertension at the time of HRV measurement were not included in the study. The physical activity level and sedentary behavior of the participants were evaluated by an experienced physical therapist using the short-form International Physical Activity Questionnaire (IPAQ), calculated in metabolic equivalent units per week. Participants who had a high or moderate level of physical activity were excluded, while those who had a low level of physical activity were included in the study (4). In all the individuals, systolic and diastolic functions of the left ventricle assessed by transthoracic echocardiography were normal. The median ejection fraction was 64.0 (61.0–65.0), and no hemodynamically significant valvular pathologies were found. In total, 103 patients were excluded because they met the exclusion criteria (n=77) or did not fulfill the inclusion criteria (n=26). Finally, 148 subjects (85 women and 63 men) with no established systemic disease were included in the study. All the participants (except the controls) had been using MPs for >10 years prior to the study. The durations of mobile phone use were determined retrospectively from the individuals' telephone billing records. Daily durations of mobile phone use were calculated automatically by dividing the total duration of calls (total min within a month) into the number of telephone calls (total number within a month). This study protocol was approved by the local Ethics Committee, Ankara, Turkey, and was conducted in accordance with the rules of the Declaration of Helsinki. Written and oral information was given to all patients before testing. All the participants gave their written informed consent for participation. We performed 24-h ECG monitoring using a three-channel amplitude-modulated tape recorder (DMS 300-3A Digital Holter Recorder, California, USA). The whole period of 24-h Holter recordings were used to determine the HRV parameters. The program specified and tagged each QRS complex automatically, with an exact determination of the reference points for the QRS complexes. The consecutive RR intervals from the 24-h ECG Holter monitoring were visually evaluated for identifying and eliminating artifacts, as has been previously described in the literature, and then estimation of the time and frequency domain characteristics of HRV was performed (5). All the tapes were subsequently analyzed by measuring HRV in the time and frequency domain, using a commercially available program. The time domain analysis of HRV included the standard deviation of N–Ns (SDNN), the standard deviation of the 5-min mean values of N–Ns (SDANN), the root mean square successive difference of N–Ns (RMSSD), and the percentage of successive N–N differences >50 ms for each 5-min interval (pNN50%). The frequency domain analysis of HRV included very low-frequency power (VLF: 0.003–0.04 Hz), low-frequency power (LF: 0.04–0.15Hz), high-frequency power (HF: 0.16–0.40Hz), total power (0.01–1.00 Hz) components, and the LF/HF ratio (6–8). Although the parasympathetic mechanisms probably contribute to the power comprised in the LF band, LF/HF is a simple and accepted tool that allows a description of the balance between the two limbs of the autonomic nervous system (9). The individuals were divided into four groups according to the duration of MP use: no mobile phone use (Control group), <30 m/day (Group 1), 30–60 m/day (Group 2), and >60 m/day (Group 3).

Statistical analysis

The data were analyzed with the IBM SPSS Statistics 21 program for Windows. The normal distribution of variables was verified with the Kolmogorov–Smirnov test. Spearman's rho correlation was used when one or both of the variables were not normally distributed. We used the Kruskal–Wallis test for the differences among groups. The Conover–Inman test was used to analyze the specific sample pairs for the significant differences. A chi-square (X^2) test was used to investigate whether the distributions of the categorical variables differed within the groups. Moreover, binary logistic regression analyses were conducted according to age, sex, and BMI. The patients' characteristics were summarized as medians (25^{th}–75^{th} percentile) or as percentages. A p value <0.05 was considered statistically significant.

Results

The median age of the study population was 30.0 (24.0–39.0) years, and 42.6% of the participants were male. LF/HF ratio was significantly greater in the study groups than in the control subjects, which may reflect a change in sympathovagal balance in favor of an increased sympathetic tone (Tables 1, 2, Fig. 1, p<0.001). Similarly, a significant positive correlation was found between the LF/HF ratio and the total duration of calls (Fig. 2, p<0.001, r=0.757). Also, negative correlations were found between the total duration of calls and SDNN, SDANN, RMSSD, and pNN50 parameters (p<0.001, r=–0.335; p<0.001, r=–0.354; p<0.001, r–0.491; and p<0.001, r=–0.499, respectively). Likewise, SDNN, SDANN, RMSSD, and pNN50 were lower in Groups 1–3 than in the control group (p<0.05). After adjustment for age, sex, and BMI, the relationship between the duration of MP use to LF/HF ratio maintained its significance [p<0.001; adjusted OR=1.667 (95% CI, 1.319–2.108)]. Table 1 shows the baseline characteristics according to the duration of the MP use groups. Men were using MPs longer than women in our study (p<0.001). Also, higher LF/HF ratios and SDNN values were calculated in men than in

Table 1. Baseline characteristics according to the duration of mobile phone use

	Controls (n=35)	Group I (n=37)	Group II (n=37)	Group III (n=39)	P
Age, years	28.0 (23.0–33.0)	27.0 (22.0–37.5)	31.0 (26.0–40.0)	33.0 (25.0–40.0)	0.133
BMI, kg/m^2	23.4 (21.1–27.8)	24.0 (21.3–27.4)	27.5 (22.5–32.0)	25.9 (23.0–28.4)	0.078
Telephone calls, n, per month	0.0 (0.0–0.0)^{a,b,c}	101.0 (96.0–108.5)^{a,d,e}	161.0 (131.1–198.2)^{b,d,f}	279.0 (230.1–345.3)^{c,e,f}	**<0.001**
TDC, min, per month	0.0 (0.0–0.0)^{a,b,c}	161.2 (126.2–209.5)^{a,d,e}	429.0 (329.1–537.2)^{b,d,f}	1050.0 (743.2–1458.0)^{c,e,f}	**<0.001**
ETCD, min	0.0 (0.0–0.0)^{a,b,c}	1.2 (0.8–1.6)^{a,d,e}	2.0 (1.5–3.1)^{b,d,f}	3.2 (2.9–4.2)^{c,e,f}	**<0.001**
SDNN	149.0 (125.0–178.0)^{b,c,e}	139.5 (125.2–172.2)^{e}	129.0 (111.2–161.7)	125.0 (99.0–159.0)^{e}	**0.016**
SDANN	135.0 (110.0–164.0)^{b,c,e}	122.0 (111.2–156.5)^{e}	116.0 (97.2–148.5)	107.5 (87.0–131.7)^{e}	**0.007**
RMSSD	37.0 (27.0–48.0)^{b,c}	37.5 (29.2–48.0)^{d,e}	27.5 (21.0–44.0)^{b,d,f}	25.0 (17.0–31.2)^{c,e,f}	**<0.001**
pNN50	15.0 (7.0–23.0)^{b,c,d,e,f}	13.5 (8.0–22.5)^{d,e}	7.5 (2.0–21.0)^{b,d,f}	5.0 (1.0–10.0)^{c,e,f}	**<0.001**
Min HR	47.5 (43.2–51.7)	46.0 (44.0–51.0)	48.0 (43.0–52.0)	49.0 (43.0–55.0)	0.663
Max HR	145.5 (124.5–157.0)	145.0 (128.0–154.0)	137.0 (125.0–148.0)	139.0 (129.0–148.0)	0.296
Av HR	78.0 (71.0–82.0)	79.0 (73.0–84.5)	77.0 (70.5–84.0)	77.0 (72.0–85.0)	0.779
LF	876.2 (576.3–1310.5)	847.5 (610.6–1223.1)	856.1 (501.1–1206.6)	736.3 (455.1–1147.2)	0.675
HF	406.7 (233.2–640.5)^{b,c}	390.8 (243.7–598.4)^{e}	201.2 (117.9–437.0)^{b}	144.6 (70.2–241.9)^{c,e}	**<0.001**
LF/HF ratio	1.9 (1.6–2.8)^{b,c}	2.2 (1.6–3.0)	3.7 (2.2–5.9)^{b}	5.4 (3.6–7.9)^{c}	**<0.001**
VLF	3038.2±1658.3	2274.4 (1655.9–3755.3)	2226.0 (1530.9–3587.8)	2316.9 (1289.7–3387.4)	0.387
Total power	3704.9 (2612.4–5892.2)	3623.5 (2652.1–5580.3)	3251.0 (2230.8–5342.1)	3186.8 (2106.3–4395.3)	0.186

The groups were determined by the duration of mobile phone use (Control group: not using mobile phone, Group I: <30 min/day, Group II: 30–60 min/day, Group III: >60 min/day). Av-average; BMI - body mass index; ETCD - each telephone call duration; HF - high-frequency power; HR - heart rate; LF - low-frequency power; Max - maximum; Min - minimum; pNN50 - the percentage of successive N–N differences >50 ms for each 5-min. interval; RMSSD - the root mean square successive difference of N–Ns; SDANN - the standard deviation of 5 min mean values of N–Ns; SDNN - the standard deviation of N–Ns; TDC - total duration of calls; VLF - very low frequency power. Kruskal–Wallis test was used for the differences among groups. Conover–Inman test was performed for the binary comparisons among the groups and the *P* value was set at 0.05. Significant differences were found between: a - control vs. group I; b - control vs. group II; c - control vs. group III; d - group I vs. group II; e - group I vs. group III; f - group II vs. group III

women [3.8 (2.3–6.6); 2.3 (1.8–4.3) and 146.0 (122.0–178.0); 129.0 (108.0–158.0), respectively] (p=0.001 and p=0.037, respectively). According to the duration of MP use, 35 of the patients (23.6%) were not using MPs (the controls), 37 of the patients (25%) were using a MP for less than 30 min (Group I), 37 of them (25%) were using a MP for 30–60 min (Group II), and 39 of them (26.4) were using a MP for longer than 60 min per day. The median LF/HF ratios were 1.9 (1.6–2.8) in the control group; 2.2 (1.6–3.0) in Group I; 3.7 (2.2–5.9) in Group II, and 5.4 (3.6–7.9) in Group III (Table 1). According to Spearman's rho analysis, positive statistically significant correlations between the LF/HF ratio and age and the LF/HF ratio and BMI were determined (p<0.001, r=0.284; p=0.002, r=0.254, respectively). The binary comparisons according to the duration of mobile phone use are shown in Table 2.

Discussion

In our study, we found a negative correlation between the HRV parameters and the duration of mobile phone use. According to these findings, long-term MP use may reduce the HRV parameters and increase the sympathetic activity. In mobile phone use, the GSM transmits and receives microwave radiation at a frequency of ≈900 and 1.800 MHz, respectively, and these frequencies excite the rotations of water molecules and some organic molecules and have been associated with thermal and

Table 2. Binary comparisons according to the duration of mobile phone use

	Controls-Group I *P*	Controls-Group II *P*	Controls-Group III *P*
Age, years	0.986	0.133	0.074
BMI, kg/m^2	0.537	**0.024**	0.052
SDNN	0.414	**0.044**	**0.003**
SDANN	0.337	**0.032**	**0.001**
RMSSD	0.681	**0.015**	**<0.001**
pNN50	0.734	**0.019**	**<0.001**
Min. HR	0.785	0.798	0.367
Max. HR	0.920	0.134	0.309
Av. HR	0.324	0.789	0.585
LF/HF ratio	0.510	**<0.001**	**<0.001**
VLF	0.639	0.242	0.111
Total power	0.871	0.241	0.055

The groups were determined by the duration of mobile phone use (Control group: not using mobile phone, Group I: <30 min/day, Group II: 30–60 min/day, Group III: >60 min/day). Av - average; BMI - body mass index; HF - high-frequency power; HR - heart rate; LF - low-frequency power; Max - maximum; Min - minimum; pNN50 - the percentage of successive N–N differences >50ms for each 5-min interval; RMSSD - the root mean square successive difference of N–Ns; SDANN - the standard deviation of 5 min mean values of N–Ns; SDNN - the standard deviation of N–Ns; VLF - very low frequency power. Conover–Inman test was performed for the binary comparisons among the groups and the *P* value was set at 0.05

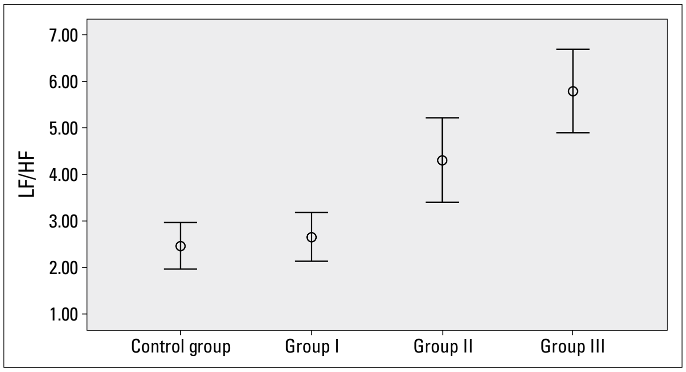

Figure 1. LF/HF ratios according to the duration of mobile phone use. HF - high-frequency power; LF - low-frequency power. The groups were determined by the duration of mobile phone use (Control group: not using mobile phone, Group I: <30 min/day, Group II: 30–60 min/day, and Group III: >60 min/day). For this figure, the error bar graphic was used

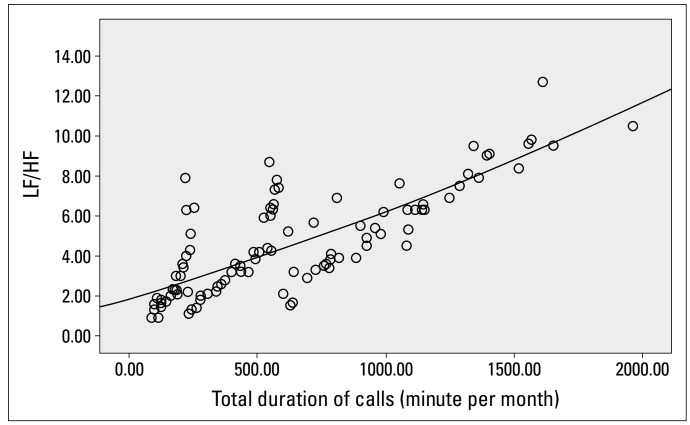

Figure 2. According to Spearman's rank correlation, the positive correlation between the LF/HF ratio and total duration of calls (*P*<0.001, r=0.757) is shown. HF - high-frequency power; LF - low-frequency power

non-thermal effects on the human body (10–13). The emission of these microwaves has been associated with the development of symptoms such as headaches, a sensation of burning skin, fatigue, hot ears, extreme irritation, an increase in carelessness, forgetfulness, a decrease in reflexes, a clicking sound in the ears, and an increase in arterial blood pressure (10). However, despite these well-known effects of MPs, their long-term effect on cardiac electrical activity has not been extensively studied and, to the best of our knowledge, whether MPs alter autonomic regulation of the cardiovascular system has not yet been extensively analyzed.

HRV is a physiological phenomenon that reflects the influence of the autonomic nervous system on sinus node activity, through changes in the length of consecutive RR intervals by breathing and in the heart rate when performing daily activities. It is known that the efferent vagal activity is a major contributor to the HF component, while LF is a marker reflecting both sympathetic and vagal activity, and the LF/HF ratio is considered to mirror the sympathovagal balance or reflect the sympathetic modulations (14). Likewise, it has been reported that RMSSD and PNN50 reflect short-term HRV and are predominantly influenced by the parasympathetic tone, whereas SDNN and SDANN are influenced by both the sympathetic and parasympathetic tone and express long-term HRV. A decreased HRV is found to be a risk factor for the onset of malignant arrhythmias in cardiac patients, related to their sympathetic overactivity (15).

Generally, as MPs are held close to the head, this might affect the autonomic nervous system by their close brain heart connection, which modulates the cardiac pacemaker and provides beat-to-beat regulation of the cardiovascular rhythm (16). Some studies investigating the effect of MP use on cardiac autonomic activity by using HRV analysis are available in the literature. The results of these studies, however, are contradictory. Increased HRV parameters, such as SDNN, SDANN, and VLF, LF, and HF values, and decreased LF/HF ratios have been previously reported with short-term MP use (1). On the contrary, Yıldız et al. (17) reported no significant association between the LF/HF ratio and MP use. It was also reported that the occupational exposition to EMF can cause fluctuations in heart rate and HRV parameters (18). However, Parazzini et al. (19) demonstrated that no statistically significant effect was caused by EMF exposure both on the main (i.e., RR mean) and most of the other HRV parameters. Barutçu et al. (2) showed that short-time exposure to EMF emitted by MPs does not affect cardiac autonomic modulation in healthy subjects. Also, Choi et al. (20) demonstrated that short-term RF radiation emitted by MBs has no effect on either adult or teenager subjects. Likewise, Tamer et al. (21) reported that EMF due to MP use does not affect cardiac electrical activity. Differently, we found an inverse relationship between the duration of MP use and HRV parameters such as SDNN, SDANN, RMSSD, and pNN50. In this case, we can speculate that long-term MP use may cause decreased parasympathetic activity.

Also, the influence of MPs on heart rate and arterial blood pressure is still controversial. Vangelova et al. (22) found that electromagnetic radiation exposure increased blood pressure. Some authors have reported that no relationship between the use of MPs and changes in circulatory system exists. Tahvanainen et al. (23) demonstrated no significant changes in arterial blood pressure and heart rate during or after the RF exposures to 900 MHz or 1800 MHz cellular phones. Also, Braune et al. (24) reported that changes in heart rate were independent of the EMF exposure with the use of MPs. Saini et al. (25) demonstrated no significant changes in terms of the mean, maximum, and minimum heart rates due to MP use. Likewise, we did not find any significant changes between the groups in terms of heart rate in the present study.

The novelty our work was to study the effects of long-term exposure to MPs on the cardiac electrical activity rather than studying the effects of MPs while talking. There was a negative association between the time domain HRV parameters, such as SDNN and SDANN, and the duration of MP use in our study. RMSSD and pNN50, which are supposed to be markers of parasympathetic activity, were also decreased in subjects using a MP for a long time. Although most of the other studies in the literature have reported changes in HRV that were compatible with increased parasympathetic activity during talking on the phone, we found that overall the long-term effects on HRV were in favor of an increased sympathovagal balance. Increased sympathetic activity and decreased parasympathetic tone could be detrimental and could contribute to a higher risk of affecting the cardiac electrical activity. The clinical long-term consequences should be further investigated.

Study limitations

Our study has some limitations. First, the study population was relatively small. A larger study population would provide a higher statistical power. Second, HRV analyses were not performed before, during, and after MP conversation in the current study. However, our aim was to investigate the overall HRV consequences rather than searching the effects of a particular talk situation. Third, the MP models used in this study are not standard and we did not measure the specific absorption rate value (W/kg), which is a measure of the amount of radio-frequency energy absorbed by the human body when using a MP.

Conclusion

In conclusion, the results of the present study demonstrate that a long-term duration of MP use may influence HRV and change the autonomic balance in favor of an increased sympathetic tone. An increase in the sympathetic tone concomitant with a decrease in the parasympathetic tone measured indirectly by analysis of HRV was observed in long-term MP users. EMF generated by the long-term use of MPs was the tentative explanation for the detrimental changes in HRV. Although in this study, no statistically significant difference was found between the groups, BMI differences can affect the results. So, this should also be taken into account in further studies. Large-scale prospective randomized clinical trials are needed to test the probable clinical consequences of HRV changes using different MP models.

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