RESEARCH ARTICLE

The Effects of Heart-to-Mobile Phone Distance on the Circulatory System

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ABSTRACT

Objective: The effect of the change in the distance between the mobile phone(MP) and the heart on heart rate variability (HRV) was examined, and the influence of the MP's distance to heart on the circulatory system was investigated.

Methods: Healthy volunteers using MPs were included in this study. The distance from the heart to the right ear is about four centimeters greater than its distance to the left ear. Taking advantage of this distance difference, the volunteers were divided into two groups: right-hand dominant and left-hand dominant individuals. A total of 31 right-hand dominant (Group 1) and 32 left-hand dominant (Group 2) volunteers were enrolled. HRV was automatically calculated by a commercially available FDA-approved three-channel Holter monitoring device (Holter ECG Recorder DMS300-4A.

Results: The mean tragus to apex distance of the first group was 37.5 cm and the mean of the second group was 33.6 cm. There was no statistically significant difference between standard deviation of N–Ns (SDNN), the standard deviation of the 5-min mean values of N–Ns (SDANN), root mean square successive difference of N–Ns (RMSSD), low-frequency (LF), and high frequency (HF) values and LF/HF ratio between the two groups. The percentage of successive N–N differences that were greater than 50 ms for each 5-min interval (pNN50%) was significantly lower in Group 2 compared to Group 1 (p = 0.014).

Conclusions: Our findings show that even a small increase in MPs to heart distance can reduce its negative effects on the cardiovascular system.

Keywords: Cardiac Autonomic Modulation, Electromagnetic Field, Heart Rate Variability, Mobile Phone

Kalp-Cep Telefonu Mesafesinin Dolaşım Sistemine Etkileri

ÖZET

Amaç: Cep telefonu ile kalp arasındaki mesafenin kalp hızı değişkenliğine (KHD) etkisi incelenerek cep telefonunun kalbe olan uzaklığının dolaşım sistemine etkisi araştırıldı.

Gereç ve Yöntem: Cep telefonu kullanan sağlıklı gönüllüler çalışmaya dahil edildi. Kalbin sağ kulağa uzaklığı, sol kulağa olan uzaklığından yaklaşık dört santimetre daha fazladır. Bu mesafe farkından yararlanılarak gönüllüler sağ el baskın ve sol el baskın bireyler olarak iki gruba ayrıldı. Toplam 31 sağ el baskın (Grup 1) ve 32 sol el baskın (Grup 2) gönüllü kaydedildi. KHD, piyasada bulunan FDA onaylı üç kanallı Holter izleme cihazı (Holter ECG Kaydedici DMS300-4A) tarafından otomatik olarak hesaplandı.

Bulgular: Birinci grubun ortalama tragustan apekse mesafesi 37,5 cm ve ikinci grubun ortalaması 33,6 cm idi. N – Ns (SDNN) standart sapması, N – Ns (SDANN) 5 dakikalık ortalama değerlerinin standart sapması, N – Ns (RMSSD) karekök ortalama ardışık farkı (RMSSD), düşük frekans (LF) ve yüksek frekans (HF) değerleri ve iki grup arasındaki LF / HF oranı arasında istatistiksel olarak anlamlı bir fark yoktu. Her 5 dakikalık aralık için 50 ms'den büyük olan ardışık N-N farklarının yüzdesi (pNN% 50) Grup 2'de Grup 1'e göre anlamlı olarak daha düşüktü (p = 0,014).

Sonuç: Bulgularımız, cep telefonu kalp mesafesindeki küçük bir artışın bile kardiyovasküler sistem üzerindeki olumsuz etkilerini azaltabileceğini göstermektedir.

Anahtar Kelimeler: Kardiyak Otonomik Modülasyon, Elektromanyetik Alan, Kalp Hızı Değişkenliği, Cep Telefonu

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INTRODUCTION

Mobile phones (MPs) emit electromagnetic waves, which may have an influence on human tissues (1). Electromagnetic field (EMF) caused by MPs can affect the autonomic nervous system (ANS) which regulates the function of the circulatory system (2). There are many studies showing the effects of EMF from MP on the cardiovascular system (3-5). These studies investigated the duration of cardiovascular exposure to EMF. However, the distance between the EMF-source and the tissue is also an important factor (6). For example, in a study by Forouharmajd et al, it was shown that a four-centimeter (cm) MP to head distance could decrease heat exposure in brain tissues when compared to four-millimeter MP to head distance (7).

Heart rate variability (HRV) is a rough measure of the variation in time between each heartbeat, and is regulated by the ANS. Previous data indicate that MP use and related EMF exposure may change the autonomic balance in healthy subjects and thus influence HRV (8). The distance between the right ear and the heart is about 4 cm greater than the distance between the left ear and the heart. Therefore, the impact of the EMF originating from a MP may be different in subjects using their MPs on the right or left ears. Although there is sufficient evidence that MP use influences HRV, data concerning the impact of MP distance on HRV during phone calls has not been studied yet. Given the significant effects of EMF on HRV, we hypothesized that a shorter MP-to-heart distance would result in greater HRV change compared to longer MP-to-heart distance.

Thus, this study was conducted to examine the effect of the distance between MP and the heart (with regard to which ear was used during phone calls) on HRV values using Holter monitoring.

MATERIAL AND METHODS

The sample was obtained from a population of 485 sequential volunteers who were scheduled for 24-h ambulatory ECG monitoring. All volunteers were gathered from medical school students and hospital staff. The inclusion criteria were, having completed interference-free 24-h Holter ECG monitoring and being aged older than 18 years. All of the participants were healthy and none of them were on any medications. There were no individuals with sedentary lifestyle and none were professional athletes. To ensure that the phones' specific absorption rate (SAR) values remained the same, only those who had been using cell phones of the same brand and model for the preceding year were included in the study. Subjects were included in this study if right-hand dominant subjects used MPs to their right ear and left-hand dominant subjects to their left ear. All participants underwent electrocardiography and echocardiography before the study and laboratory analysis values were recorded from the hospital's electronic database. Patients with arrhythmia, structural heart disease, anemia or endocrine disease were excluded from the study. After these qualifications, 63 individuals were enrolled in the study.

The volunteers were divided into two groups: right-hand dominant and left-hand dominant individuals. There were 31 right-hand dominant (Group 1) and 32 left-hand dominant (Group 2) volunteers. All individuals reported that they were using their MPs on their dominant side for calls. The phone-heart distance was defined as the distance from the left nipple to the tragus of the right ear for the right-hand dominant group, and the distance from the left nipple to the tragus of the left ear for the left-hand dominant group. The duration of MP use (only including call duration) was recorded from the individuals' phone histories after completing holter monitoring.

We carried out 24-h ECG monitoring using a three-channel amplitude-modulation tape recorder (Holter ECG Recorder DMS300-4A). The 24-h Holter recordings were used to assess HRV parameters. The program specified and labeled each QRS complex that was automatically detected. Each holter recording was assessed by experienced cardiologists for QRS results and consistency. R-R intervals from the 24-hour ECG Holter monitoring were observed visually and the artifacts were detected and removed. As described in the literature, estimation of the time and frequency domain characteristics of HRV was taken (9). The time domain analysis of HRV contained the standard deviation of N–Ns (SDNN), the standard deviation of the 5-min mean values of N–Ns (SDANN), the percentage of successive N–N differences >50 ms for each 5-min interval (pNN50%) and the root mean square successive difference of N–Ns (RMSSD). The frequency domain analysis of HRV involved total power components (0.01–1.00 Hz), high-frequency power (HF: 0.16–0.40 Hz), low-frequency power (LF: 0.04–0.15 Hz) and the LF/HF ratio (10-12).

Comparison of HRV results in subjects using their right or left ears for MP calls during the Holter recording was the primary outcome measure of this study.

This study protocol was approved by the local ethics committee (Decision no: 2011-KAEK-27/2019-E.1900088400). Written and verbal information was given to all individuals before testing.

Statistical Analysis: The data obtained during the study were transferred to a computer spreadsheet file and were evaluated in the SPSS Version 15.0 package program. Distribution of data was tested using the Shapiro-Wilk test. In the analysis of the data, chi-square test was used to compare qualitative variables, and the independent sample t-test was used to compare quantitative variables. P value <0.05 was considered statistically significant.

RESULTS

A total of 63 subjects were enrolled in the study. 31 of them used MP with their right hand on their right ear (Group 1) and 32 used it with their left hand on their left ear (Group 2). Demographic information of the participants are presented in Table 1. All volunteers included in the study had normal sinus rhythm with a mean heart rate of 77 beats/min. There were no significant differences between the two groups in terms of echocardiography parameters, alcohol use and smoking. The mean MP call time of the two groups during the Holter monitoring was 128.2 ± 16.6 and 122.2 ± 16.9 minutes, respectively (p=0.161). The mean tragus to apex distance of Group 1 was 37.5 ± 0.8 cm and the mean of the Group 2 was 33.6 ± 0.9 cm (p<0.001).

Table 1. Sociodemographic Distributions and Clinical Features of the Study Groups

	Group 1 (n=31)	Group 2 (n=32)	p values
Age (year)	22.5±1.8	22.5±1.8	0.862
Sex (n, %)			
Male	15(48.4)	15(46.9)	0.904
Female	16(51.6)	17(53.1)	
BMI (kg/m^2)			
Normal	27(87.2)	30(93.8)	0.368
Overweight-obese	4(12.9)	2(6.2)	
Smoking	12(38.7)	10 (31.2)	0.535
Alcohol	12(38.7)	7(21.9)	0.146
SBP (mmHg)	115.3±9.8	114.1±10.9	0.632
DBP (mmHg)	72.4±8.4	71.6±8.8	0.694
LVEDD (mm)	43.3±2.6	42.6±2.8	0.352
LVESD (mm)	28.2±2.3	27.9±2.6	0.607
EF (%)	62.9±3.1	63.7±2.9	0.306
RA (mm)	40.4±2.5	40.2±1.9	0.766
RV (mm)	37.8±3.2	38.6±2.0	0.256
PAP (mmHg)	23.6±6.6	24.2±5.4	0.675
LA (mm)	32.1±3.5	32.0±3.1	0.938
IVS(mm)	8.4±1.1	8.3±1.1	0.968
Distance of Tragus to apex (cm)	37.5±0.8	33.6±0.9	**<0.001**
Call history (hour)	128.2±16.6	122.2±16.9	0.161

Data are presented as number (percentage), mean ± standard deviation
SBP, Sistolik Blood Presure; DBP, Diastolic blood pressure; LVEDD, Left Ventricule End Diastolik Daimeter; LVSDD, Left Ventricular End Systolic Diameter; EF, Ejection Fraction; RA, Right Atrium; RV, Right Ventricular; PAP, Pulmonary Artery Pressure; LA, Left Atrium; IVS, Interventricular Septum.

There was no statistically significant difference between SDNN, SDANN, RMSSD, LF, HF and LF/HF between the two groups. However, PNN50 was significantly lower in Group 2 compared to that of the Group 1 (15.5 ± 9.8 vs. 22.7 ± 11.4, p = 0.014) (Table 2).

Table 2. Heart Rate Variability Values of the Study Groups

	Group 1 n (%)	Group 2 n(%)	P values
Min HR (beats/minute)	45.1±8.9	46.4±7.3	0.525
Max HR (beats/minute)	149.1±18.2	152.5±27.3	0.526
Mean HR (beats/minute)	77.2±10.1	77.5±10.9	0.918
SDNN	152.8±33.2	152.9±39.0	0.991
SDANN	136.3±33.6	139.7±37.1	0.705
RMSSD	42.8±14.9	38.6±13.3	0.245
PNN50	22.7±11.4	15.5±9.8	**0.014**
LF	1161.5±442.5	1014.7±471.7	0.208
HF	527.8±293.3	479.8±305.3	0.527
LF/HF ratio	2.65±1.16	2.46±0.88	0.483

Data are presented as mean ± standard deviation
Min HR, Minimal Heart Rate; Max HR: Maximum Heart Rate; SDNN, standard deviation of N–Ns; SDANN, standard deviation of the 5-min mean values of N–Ns; RMSSD, the root mean square successive difference of N–Ns, PNN50, the percentage of successive N– N

DISCUSSION

This study aimed to investigate the effects of MP to heart distance on HRV and showed that a mean 4-cm reduction in MP to heart distance during phone call resulted in a significant reduction of the PNN50 value; however, SDNN, SDANN, RMSSD, LF, HF and LF/HF values remained similar.

The signals sent and received by an MP is in the form of microwave radiation which may lead to changes in tissues and water molecules. These changes have been associated with thermal and non-thermal effects in human tissues (13-15). Cardiovascular mortality, cognitive disability and birth defects are among the negative outcomes that have been associated with these thermal and non-thermal effects (16). Additionally, emission of these microwaves has been shown to be related with the development of some symptoms, such extreme irritation, decreased reflexes and an increase in arterial blood pressure, albeit rarely (13). However, while there are many studies investigating the relationship between cell phone call time and HRV, the changes in these effects with regard to distance have not been adequately studied yet (2, 3, 10).

The literature on this topic has mainly assessed the effect of MP on the heart by examining HRV. It is considered that HF is associated with parasympathetic activity and LF with sympathetic activity. The LF/HF ratio reflects sympathovagal balance and sympathetic regulation (17). RMSDD and PNN50 are known to reflect parasympathetic tone activity and these are considered as the 'short-term' HRV parameters. SDNN and SDANN represent both sympathetic and parasympathetic activities and are indicative of 'long-term' HRV. A reduced HRV has been shown to be a risk factor for the onset of malignant arrhythmias associated with sympathetic over activity in patients with cardiovascular disease (18). It has been shown that radiofrequency waves emitted by MP may affect HRV through their influence on the ANS (19).

The present study examined HRV values in two groups included. In the second group with shorter MP-to-heart distance, a decrease in PNN50 was observed. This decrease indicates a reduction in parasympathetic nervous system activity and an increased risk for cardiovascular disease.

The distance from the target organ to MP is relevant to EMF exposure, and therefore, its effects. A recent study by Kivekas et al. revealed that the easiest way to decrease SAR exposure was to increase the distance between the body and MP (20). Another study conducted by Hirata et al. identified significant factors affecting the absorption rate of electromagnetic waves. The authors noted that the electrical properties of the tissue, the size of the withstanding tissue and the distance between the source of the electromagnetic wave and user's body were effective on absorption (18). Furthermore, even changes of a few centimeters have been shown to result in significant changes in the impact of EMF on the tissues (7, 21). In our study, we used an objective and continuous measure of the distance from the heart to the MP using the ears as the reference points. Our findings show that subjects using the MP with their right hands had lower PNN50 values compared to those using MP with their left hands. This significant difference between the two groups of PPN50 alone may not be clinically significant because there was no difference in other HRV values. However, the difference in this parameter may be predictive of the decrease in other HRV parameters if this study was to be repeated in a larger population.

From this point of view, our results support the evidence put forth by previous studies which showed that electromagnetic interference on pacemakers was most significant when the phone antenna was placed in close proximity (22). Our findings also support the international guidelines which recommend using MPs via the ipsilateral ear in patients with implanted devices (23).

The present study has some limitations to be mentioned. Firstly, this study used the same MP brand and model and selected individuals with similar BMI to avoid differences between SAR values. This led to a limited sample size. Secondly, in this study, the duration of telephone calls was taken into consideration, but nowadays telephones are used for many purposes such as internet, watching videos and taking photos and also used for other usages like a health applications(24). Thirdly, the lack of iterated long-term HRV analysis (25) may have caused some misinterpretations in HRV analysis. Lastly, although the participants stated that their MP use was similar, it may have affected the results since there was no objective evidence to confirm this.

With this study, we call attention to the impact of MP-to-heart distance on HRV parameters. Our findings show that even a small increase in distance can reduce possible negative effects on the cardiovascular system.

CONCLUSION

It is well-established that SAR value decreases with increased device-to-tissue distance. Therefore, increasing the distance between the heart and MP, at least during use, can be effective in reducing heart-related possible adverse effects caused by MPs. The significance of MP-to-heart distance has not been directly investigated. In order to determine the optimal distance, there is a need for a wide range of studies.

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