Original Article

Effects of mobile phone radiation on heart rate variability of healthy young subjects

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Abstract

Background and Aim: The potential health risk of the radiofrequency electromagnetic fields which are emitted by mobile phones (MPs) is of considerable public interest. The aim of the present study was to determine the influence of the call with a MP on heart rate variability (HRV) in healthy young male and female subjects.

Methods: Heart rate variability was measured in 100 young healthy subjects of either sex from 5 min continuous recording of heart rate using windows-based HRV analysis system during three conditions: (1) When MP is switched off (Period I) (2) when MP is switched on (Period II) (3) during call on MP for 5 min (Period III).

Results: In female subjects, we found that the time domain parameters like root of the mean of the sum of the squares of differences between adjacent NN intervals, standard deviation of differences between adjacent NN intervals, NN50, pNN50 were significantly reduced during Period II and Period III as compared to Period I. Furthermore, the frequency domain parameters such as low frequency (LF) and LF/high frequency (HF) were significantly increased during Period II and Period III as compared to Period I. Whereas HF was significantly reduced during Period II and Period III as compared to Period I in female subjects. In the male, only NN50 count was significantly reduced during Period II and Period III as compared to Period I.

Conclusion: Increase in the sympathetic tone concomitant with the decrease in the parasympathetic tone was observed during the MP usage in female subjects. However, only the parasympathetic tone may be reduced in male subjects while using MPs.

Key words: Autonomic balance, electromagnetic fields, heart rate variability, mobile phone

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INTRODUCTION

Recent years have witnessed rapid worldwide growth in the use of cell phone and enormous attention about its effect on human health. Mobile phones (MPs) radiation might induce or promote cancer, and the symptoms which are associated with their use include sleep disturbances, memory problems, headaches, nausea, dizziness and changes in the electroencephalographic activity.[1] The Global System for Mobile Communication MPs are low power radio devices that receive and transmit electromagnetic fields (EMFs). According to the present standards, the maximum powers that MP is permitted to transmit are 2 and 1 W for 900 and 1800 MHz, respectively.[2,3] According to European Guidelines, the specific absorption rate (SAR) limit for hand-held devices is 2.0 W/kg averaged over 10 g of tissue. SAR levels according to American guidelines requires hand-held devices to be at or below 1.6 W/kg measured over 1.0 g of tissue. For whole body exposures, the limit is 0.08 W/kg. India switched from the European limits to the American limits for mobile handsets in 2012.[4] Malaric *et al*. measured the EMF emitted by MP in various conditions and noticed that these measures are much higher particularly during preparing handshaking, ringing and sending short message service message than while speaking.[5] The analysis of heart rate variability (HRV) is a noninvasive clinical technique for indirectly investigating the cardiac and autonomic nervous system in both healthy and diseased subjects. HRV signals are analyzed using linear and nonlinear techniques.[6] Frequency domain

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and time domain parameters have been recommended for HRV analysis with 5 min recordings.[7] Reduced HRV predicts ominous clinical output in various conditions and it is associated with increased risk of mortality and susceptibility to life-threatening arrhythmias.[8,9] EMFs emitted by MPs may alter cardiac autonomic regulation. Studies conducted by Barutcu *et al*.[10] and Tamer *et al*.[11] shows that short-term exposure to EMFs emitted by a MPs has no effect on short-term HRV parameters in healthy subjects. Studies conducted by Andrzejak *et al*.[12] and Al-Hazimi.[13] shows that the increase in the parasympathetic tone concomitant with the decrease in the sympathetic tone measured indirectly by analysis of HRV were observed during the mobile call. A study conducted by Stars *et al*.[14] shows that maximum strong radiation emitted from cellular phones can lead to increase in parasympathetic autonomic activity of young and healthy individuals. A study conducted by Kodavanji *et al*.[15] shows that the mobile users had a higher sympathetic tone and a lower parasympathetic tone as compared with the mobile nonusers. Thus, effects of MP radiation on HRV still remains inconclusive, and all the previous studies does not exclude the effects of speaking and emotions related to talking during mobile call on HRV. Therefore, the present study was designed to test the possible effects of radiofrequency waves emitted by MPs on cardiac autonomic modulation by short-term HRV analysis. We used Nokia X2 MP (highest SAR value for use of this device at the ear is 0.82 W/kg) for our research project. We avoided actual speaking during the call to avoid effects of speaking and emotions related to talk on autonomic nervous system, but mobile call was going on during recording of HRV so we can get conclusive results.

MATERIALS AND METHODS

After obtaining the permission of Institutional Review Board and Ethical Committee, the study was carried out at autonomic function laboratory, Physiology department, Government Medical College and Sir T Hospital, Bhavnagar. Written informed consent was taken from all participants before allotment to study. The study group was comprised of 100 young healthy subjects of either sex (male: 60, female: 40, age group: 17–25). Subjects were enrolled from of students and staff members of Government Medical College, Bhavnagar. Subjects aged between 17 and 25 years of either sex and with the ability to give written informed consent was included in the study.

Exclusion criteria

- Presence of any serious cardiovascular disease including arterial hypertension, ischemic or rheumatic heart diseases, serious arrhythmias, left ventricular dysfunction, diabetes mellitus, etc
- Presence of metabolic and neurological disorders could influence the HRV
- Subjects taking drugs affecting cardio-respiratory response (anti psychotics, antidepressants, antiarrhythmic)
- Subjects consuming alcohol and smokers
- Patient having implanted pacemaker

Detail history taking and clinical examination of every subject were done before the HRV measurement. Pulse and blood pressure were also recorded. We follow the standard procedure of measurement of short-term HRV. The changes in the HR were measured with an instantaneous HRV software (Variowin-HR) interfaced with a microcomputer.

Pretest preparations

Subjects should not to eat, drink, etc., at least half an hour prior to test as this result in a shift of results. Subjects will be advised to abstain from consuming caffeinated beverages and excessive physical activity including gymnastics within 12 h preceding data collection. Subjects should abstain from the drugs which are known to affect the HR for at least 24 h before the test. Subjects must be allowed to relax for 10–20 min before starting the test. Test should be done in relaxed supine position. Allow the normal pattern of breathing. HRV recording was done in the morning time between 9:00 and 11:00 am in a semi-darkened, temperature controlled, quiet laboratory at room temperature (21°). HRV was measured from 5 min continuous recording (short-term HRV) of HR (based on r-r interval) using windows-based HRV analysis system Variowin-HR with 100% accuracy during 3 conditions: (1) Basal condition when MP is switched off (Period I) (2) when MP is switched on (Period II) (3) during call with of MP for 5 min when MP is attached to right ear of subject with a band (Period III). We used Nokia X2 MP for our research project. The highest SAR value for use of this device at the ear is 0.82 W/kg. We avoid actual speaking during the call to avoid effects of speaking and emotions related to talk on autonomic nervous system, but the mobile call was switched on during recording of HRV. We measured the following time domain such as standard deviation of all NN intervals (SDNN), standard deviation of the averages of NN intervals in all 5 min segments of the entire recording (SDANN), The square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD), standard deviation of differences between adjacent NN intervals (SDSD), number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording (NN50 count), NN50 count divided by the total number of all NN intervals (pNN50), triangular HRV index and frequency domain parameters during HRV measurements such as very low frequency (VLF), LF, high frequency (HF) and LF:HF ratio.

Statistical analysis of data

All the data were expressed in the form of mean ± S.D. We used GraphPad InStat 3 (GraphPad Software Inc., San Diego, CA, USA) demo version software for statistical analysis. Statistical analysis was done by one-way ANOVA test followed by *post-hoc* Tukey test among 3 phases. $P < 0.05$ was taken as a statistically significant.

RESULTS

All study subjects had sinus rhythm. They had normal systolic and diastolic blood pressure [Table 1]. There was no any significant difference in all the time domain parameters in male subjects during recording of HRV in three different periods except NN50 count. NN50 count was significantly reduced when MP was switched on and during the call with MP as compared to theirs basal values when MP was switched off [Table 2]. There was no significant difference in all frequency domain parameters in male subjects during recording of HRV in three different periods [Table 3]. While recording HRV in female subjects, we have found that the time domain parameters such as RMSSD, SDSD, NN50, pNN50 were significantly reduced when MP was switched on and during call with MP as compared to their basal values when MP was switched off. There was no significant difference in other time domain parameters in female subjects during recording of HRV in three different periods [Table 4]. We also found that in female subjects frequency domain parameters such as LF and LF/HF were significantly increased when MP was switched on and during call with MP as compared to their basal values when MP was switched off. Whereas, HF was significantly reduced when MP was switched on and during the call, compared to their basal values when MP was switched off [Table 5].

Table 1: Anthropological and other parameters

Parameters	Male (*n*=60)	Female (*n*=40)
Age (years)	18.68±2.59	19.9±2.98
Height (cm)	168.85±7.48	155.9±8.21
Weight (kg)	62.18±11.46	48.68±6.51
Heart rate (per/min)	85.7±10.44	80.95±6.44
Systolic BP (mmHg)	122.1±2.71	124.55±3.32
Diastolic BP (mmHg)	75.3±3.92	75.95±3.46

BP: Blood pressure

DISCUSSION

The present study demonstrated that the call with the use of a MP may cause the increase in sympathetic tone and the decrease in parasympathetic tone particularly in female subjects. It is known that the efferent vagal activity is a major contributor to the HF component.[16-18] On the other hand, LF is a marker reflecting both sympathetic and vagal activity and the LF/HF ratio is considered to mirror of sympathovagal balance or reflect the sympathetic modulations.[17,19] While recording time domain parameters HRV, SDNN reflects the total power, SDANN reflects ultralow frequency power, SDNN index reflects VLF power and LF power while SDSD, RMSSD, NN50 count and pNN50 reflects HF power.[20]

In our study mean HR did not change significantly during HRV recording of different three conditions [Tables 2 and 4]. These findings are similar to other studies done previously.[10-14] In our study while recording HRV time domain parameters in female subjects we found that RMSSD values were significantly reduced when MP was switched on (period II) and during call with MP (period III) as compared to their basal values when MP was switched off (period I) (P = 0.0148, I-III: 0.0330, II-III: 0.0495) as per Table 4. SDSD values were significantly reduced when MP was switched on (period II) and during call with MP (period III) as compared to their basal values when MP was switched off (P = 0.0138, I-III: 0.0315, II-III: 0.0476) as per Table 4. NN50 values were significantly

Table 2: Time domain HRV parameters in male subjects

Parameters	When MP switched off (period I)	When MP switched on (period II)	During call with MP (period III)	*P*
MHR (per/min)	85.7±10.44	85.58±10.41	84.88±9.80	0.1289
R-R (ms)	705.56±84.28	706.36±83.54	698.43±118.12	0.6574
SDNN (ms)	43.85±14.71	44.07±14.28	45.1±18.08	0.4462
RMSSD (ms)	39.73±18.06	40.23±18.97	40.93±22.29	0.5184
SDSD (ms)	38.75±18.80	39.25±19.68	39.98±22.95	0.5133
NN50	69.21±54.75	70.43±56.23	61.11±53.90*,##	0.0018
pNN50 (%)	18.03±15.38	18.31±15.67	18±16.75	0.9031
Triangular HRV	10.56±3.03	10.54±3.04	10.41±4.44	0.8779

*Comparison with Period I, *P<0.05. #Comparison with Period II, ##P<0.01. Statistical analysis was done by one-way ANOVA test followed by *post-hoc* Tukey test among 3 phases. MHR: Mean heart rate, MP: Mobile phones, HRV: Heart rate variability, SDNN: Standard deviation of all NN intervals, SDANN: Standard deviation of the averages of NN intervals in all 5 min segments of the entire recording, RMSSD: The square root of the mean of the sum of the squares of differences between adjacent NN intervals, SDSD: Standard deviation of differences between adjacent NN intervals, NN50 count: Number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording, pNN50: NN50 count divided by the total number of all NN intervals, Triangular HRV index: The integral density distribution divided by the maximum of density distribution

Table 3: Frequency domain HRV parameters in male subjects

Parameters	When MP switched off (period I)	When MP switched on (period II)	During call with MP (period III)	*P*
VLF (ms^2/Hz)	1106.05±631.38	1065.16±513.17	1133.08±699.79	0.7234
LF (ms^2/Hz)	932.75±669.39	946.03±678.21	935.46±656.35	0.9746
HF (ms^2/Hz)	1102.83±728.58	1121.30±732.18	1173.31±870.84	0.5504
LF/HF	1.098±0.81	1.099±0.81	1.039±0.63	0.3095

Statistical analysis was done by one-way ANOVA test followed by *post-hoc* Tukey test among 3 phases. MP: Mobile phone, HRV: Heart rate variability, VLF: Very low frequency, LF: Low frequency, HF: High frequency

Table 4: Time domain HRV parameters in female subjects

Parameters	When MP switched off (period I)	When MP switched on (period II)	During call with MP (period III)	*P*
MHR (per min)	80.95±6.44	81±6.46	80.77±7.46	0.8682
R-R (ms)	743.19±59.52	742.48±59.90	744.47±69.13	0.8695
SDNN (ms)	49.25±9.89	49.13±9.93	50.40±9.66	0.1633
RMSSD (ms)	46±14.23	45.76±14.45	43.67±17.25*,#	0.0148
SDSD (ms)	45.41±14.44	45.16±14.66	43.02±17.47*,#	0.0138
NN50	95.07±51.98	93.8±52.99	81.77±63.90**,#	0.0017
pNN50 (%)	24.31±13.81	23.99±14.07	21.19±71.10*,#	0.0053
Triangular HRV	12.34±2.39	12.30±2.39	12.68±2.55	0.2339

*Comparison with period 1, **P*<0.05, ***P*<0.01. #Comparison with period 2, #*P*<0.05. Statistical analysis was done by one-way ANOVA test followed by *post-hoc* Tukey test among 3 phases. MP: Mobile phones, HRV: Heart rate variability, MHR: Mean heart rate, SDNN: standard deviation of all NN intervals, SDANN: Standard deviation of the averages of NN intervals in all 5 min segments of the entire recording, RMSSD: The square root of the mean of the sum of the squares of differences between adjacent NN intervals, SDSD: Standard deviation of differences between adjacent NN intervals, NN50 count: Number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording, pNN50: NN50 count divided by the total number of all NN intervals, Triangular HRV index: The integral density distribution divided by the maximum of density distribution

Table 5: Frequency domain HRV parameters in female subjects

Parameters	When MP switched off (period I)	When MP switched on (period II)	During call with MP (period III)	*P*
VLF (ms^2/Hz)	1181±736.13	1180.1	1285.7±754.87	0.4478
LF (ms^2/Hz)	1165.5±455.09	1173.3±457.89	1355.9±488.08***,###	<0.0001
HF (ms^2/Hz)	1256.5±627.83	1240.9±632.85	1056.6±588.42**,#	<0.0003
LF/HF	1.30±1.19	1.33±1.18	1.87±1.63***,###	<0.0001

*Comparison with period 1, ***P*<0.01, ****P*<0.001. #Comparison with period 2, #*P*<0.05, ###*P*<0.001. Statistical analysis was done by one-way ANOVA test followed by *post-hoc* Tukey test among 3 phases. MP: Mobile phones, HRV: Heart rate variability, VLF: Very low frequency, LF: Low frequency, HF: High frequency

reduced when MP was switched on (period II) and during call with MP (period III) as compared to their basal values when MP was switched off (*P* = 0.0017, I-III: 0.0092, II-III: 0.0151) as per Table 4. pNN50 values were significantly reduced when MP was switched on (period II) and during call with MP (period III) as compared to their basal values when MP was switched off (*P* = 0.0053, I-III: 0.0176, II-III: 0.0281) as per Table 4. There was no any significant difference found in other time domain parameters in female subjects during recording of HRV in three different periods.

In our study we have also found in female subjects that the frequency domain parameters like LF values were significantly increased when MP was switched on and during call with MP as compared to their basal values when MP was switched off (*P* < 0.0001, I-III: 0.0002, II-III: 0.0002) as per Table 5. Furthermore, LF/HF ratio values were significantly increased when MP was switched on and during call with MP as compared to their basal values when MP was switched off (*P* < 0.0001, I-III: 0.0004, II-III: 0.0003) as per Table 5. HF values were significantly reduced when MP was switched on and during call with MP as compared to their basal values when MP was switched off (*P* < 0.0003, I-III: 0.0033, II-III: 0.049) as per Table 5.

There was no any significant difference found in all the time domain and frequency domain parameters in male subjects during recording of HRV in three different periods except NN50 count. NN50 count was significantly reduced when MP was switched on and during call with MP as compared to their basal values when MP was switched off (*P* = 0.0018, I-III: 0.0111, II-III: 0.0068) as per Table 3.

Our findings are not similar with findings of other previous studies. Barutcu *et al*.[10] and Tamer *et al*.[11] found that neither frequency nor time domain HRV parameters altered significantly during turn on and calling mode compared to their baseline values. Andrzejak *et al*.[12] and Al-hazimi[13] have reported that during 15–20 min call with a MP, the parasympathetic tone was increased whereas the sympathetic tone was lowered during the call with use of a MP. Stars *et al*.[14] also found that due to the radiation emitted from the MP at maximum power, some changes may occur that are associated, with the parameters of HRV with increased parasympathetic activity.

Hence, here in our study we found reduced values of time domain parameters in female subjects such as RMSSD, SDSD, NN50, pNN50 during call with MP and when MP was switched on. Also frequency domain parameters in female subjects like LF and LF/HF were significantly increased while HF was significantly reduced when MP was switched on and during call with MP. This suggests that increase in the sympathetic tone concomitant with the decrease in parasympathetic tone measured indirectly by HRV was observed during call with MP mainly in female subjects our study. We found opposite results as compared to majority of previous studies which shows that there is increase in parasympathetic tone during call with MP. While in male subjects only NN50 count was significantly reduced when MP was switched on and during call as compared to their basal values when MP was switched off. Hence, vagal activity decreased during MP call and when MP was switched on. Results of our investigation suggest that a call with use of a MP may exert a noticeable effect on autonomic balance; the pattern it represents is typical for the deleterious effect on HRV, that is, lack of a typical decrease in parasympathetic activity with the domination of sympathetic system.

It was demonstrated that change in forearm position may have an impact on sympathetic nerves in muscles of the hand.[21] However, reports are concentrated on forearm raise together with handgrip exercises performed more or less intensively, which could cause the increase in sympathetic activity.[21,22] Hence, to avoid these effects we measured HRV in lying down position, and MP was attached to right ear of the subject with a rubber band. Speaking can increase the speed of breathing and, therefore, changes in respiratory frequency may have an influence on HR.[23,24] Reading aloud and free talking may increase LF component.[24] Hence, we avoided actual speaking during the call to avoid effects of speaking and emotions related to talk on autonomic nervous system. Gender difference found in our study can be explained by some previous studies. Studies carried out by Cowan *et al*.[25] and Stein *et al*.[26] shows that there is low parasympathetic and high sympathetic activity in females as compared to males. Psychogenic influences play a major role in females for this autonomic tone difference. Regarding widespread use of MPs nowadays closer attention should be paid to a problem of workers who use MPs for a long time and are occupationally exposed to EMF.

Limitations of the study

The sample size of the present study was moderate and, therefore, the results obtained could not be directly applied to the general population. Furthermore, in the present study only short-term HRV was recorded. In such studies, inclusion of 24 h HRV would be more informative and reliable to validate the results.

CONCLUSION

Results of our study demonstrate that the call with a MP may influence HRV and change the autonomic balance. The increase in the sympathetic tone with a concomitant decrease in the parasympathetic tone measured indirectly by analysis of HRV was observed during the MP call particularly in female subjects. Parasympathetic tone may be reduced in male subjects while using MPs. Thus, MP may exert a deleterious effect on HRV.

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