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An Observational Study of Effect of Mobile Phone Radiation on Heart Rate Variability

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Abstract
Introduction: *Mobile phone technology revolution has resulted in a high-frequency electromagnetic environment which has resulted in a spectrum of potential health hazards. The effects of this widespread electromagnetic radiation (EMR) directly on autonomic tone of the body and thereby indirectly on modifying the functions of cardiovascular functions remains understudied. Studies have confirmed that autonomic system influences the beat to beat variability of heart rate and so heart rate variability (HRV) analysis is considered to be an independent predictor of cardiovascular risk. And so, this study was designed to measure the effects of electromagnetic waves emitted by mobile phones and Bluetooth on cardiac autonomic modulation by heart rate variability (HRV) analysis.*
Materials and Methods: *ECG recording and HRV analysis were done for 200 healthy male and female volunteers aged between 18-25 years using Student Physiograph and Analogue to Digital Convertor. Time Domain Analysis Parameters and Frequency Domain Analysis Parameters were observed for mobile call usage -test I and Bluetooth usage -Test II.*
Results: *There was a significant increase in the heart rate which indicated an increase in sympathetic tone on mobile phone and Bluetooth device usage. Paired "t" test showed statistically significant value of 0.003 and 0.009 (P<0.05) for mean MRR only, while the rest of the parameters studied exhibited considerable differences in between all the three pairs.*
Conclusion: *This study shows an impact of the hazardous effect of EMR emitted by mobile phones and Bluetooth devices on cardiovascular activity. With a sharp rise on mobile phone and Bluetooth users, it is very much essential to create awareness among the individuals regarding the hazardous effects of radiation emitted by these devices/gadgets so as to reduce the usage of the same and to undertake some safety measures.*
Key Words: *Heart Rate Variability, Electromagnetic Radiation, Heart Rate, Mobile Phone, Autonomic Tone.*

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I. Introduction

The number of mobile phones and its use have been increased massively in the past decade. There were 5-9 billion mobile phone subscribers in 2011; in 2010, about 16.7 billion text messages were sent almost every day. In pace with the technological advancements, mobile phones have also grown into minicomputers and multimedia devices with umpteen functions. Thus, mobile phones have become an integral part of life.[1]

Mobile phones emit radio frequency energy in the form of non-ionizing radiations. The mobile phone radiations are microwaves in the range of 900/1800 MHz. The maximum power transmission that a mobile phone is allowed is 2.0 W for 900 MHz and 1.0 W for 1800 MHz frequency.[2,3]

Mobile phones have specific absorption rate (SAR), the rate at which the whole body absorbs energy from a radio frequency magnetic field. The SAR limit for hand-held devices varies in different regions of the world. International commission on non-ionizing radiation protection recommends a SAR limit of 0.08 W/kg and 2.0 W/kg average for entire body and head, respectively.[2] The European guidelines permit up to a maximum of 2.0 W/kg averaged over 10 g of tissue, whereas the American guidelines restrict it at or below 1.6 W/kg measured over 1.0 g of tissue. In 2012, India adopted the American guidelines.[4]

Mobile phones emit maximum radiations during network search, ringing, while sending SMS than on active call.[5] The electromagnetic radiations have effects on different tissues and organs to variable degree, especially those involved in signal transmission such as nerve fibers, pacemaker, and conducting system of the heart.[6]

The heart rate variability (HRV) analysis is a sensitive indicator of pacemaker activity of the heart modulated by autonomic nervous system (ANS). It is used in healthy and diseased subjects for the assessment of sympathovagal balance. Nowadays, the state of sympathovagal balance as assessed by HRV is increasingly being used in predicting, diagnosing, managing, and preventing cardiovascular dysfunctions.[7]

It has been shown in many studies that electromagnetic frequency (EMF) emitted by mobile phones interferes with the working of implanted cardiac pacemakers. [8-10] The effects of mobile phone radiations range from trivial symptomatology such as headache, nausea, and dizziness to more dreaded effects such as teratogenesis.[11] Some studies reported cataracts, skin burns, miscarriages, or birth defects due to negative thermic effects on living organisms.[12-15] On the contrary, some of the studies have shown no harmful effects on the body including cardiovascular parameters.[16-18]

II. Materials And Methods

- **Study design** : Observational Study.
- **Study site** : Department of Physiology**,** M.G.M Medical College, Jamshedpur.
- **Study population** : College students in the age group of 18 to 25 years of either sex volunteering for the study were selected.
- **Sample size** : 200 students.
- **Instrument used** : ECG recording and HRV analysis were done with Student by using ECG recoder and counting pulse rate

- **Inclusion criteria** : Normal individuals with normal cardiac function.

- **Exclusion criteria** : Subjects with previously known cardiac problems or under medications will be excluded.

Procedure: The ECG was recorded by using standard limb lead II by connecting the subject with the appropriate lead placement, in the ECG lab (Research Lab). The subject was asked to lie in a supine position comfortably on the couch.

After accommodation of 5minutes, the ECG was recorded for 5 minutes without any interruption by mobile phone or Bluetooth call (normal).

After 5 minutes rest, the ECG was recorded while the subject spoke through a mobile phone as per the experimental design given below.

In test-I, the mobile phone was fastened at the left ear of the subject by using an elastic strap. A phone call was made from a predefined number and a standard dialogue is continued for 5 minutes.

In test-II, a Bluetooth device was placed in the left ear of the subject and the mobile phone was placed in the chest pocket at the heart level. The same procedure of test-I was continued with a phone call.

Throughout the study, a standard mobile phone and Bluetooth device was used for all the 50 subjects. All the ECG recordings were for 5 minutes with 5minutes rest between the recordings.

III. Results

- **MRR** - Mean RR intervals of the sinus rhythm in ms,
- **pNN50** - The percentage of successive normal sinus RR intervals >50 ms in %,
- **SDNN** - Standard deviation of all normal sinus RR intervals in ms and
- **r-MSSD** - Root-mean-square of successive normal sinus RR interval difference in ms.

S.No	Experimental	Total Domain Analysis (Mean ± SD)			
		MRR	**pNN50**	**SDNN**	**r-MSSD**
1	Normal	873.862 ±143.21400	31.674 ±22.68123	57.23542 ±26.54671	60.543 ±35.43576
2	Test I	885.705 ±145.56046	30.118 ±22.68135	60.125 ±27.28732	60.673 ±36.4657
3	Test II	886.563 ±142.38901	31.798 ±21.66843	62.54654 ±26.54367	61.564 ±32.65891

Table 1: Total Domain Analysis

Normal (N): resting state (without mobile phone & Bluetooth talk)

Test-I: Call on mobile phone at ear level.

Test-II: Call on blue-tooth device at ear level & mobile phone at heart level.

S.No	Group	Pulse rate
1	Normal	70 beats/min
2	Test I	85 beats/min
3	Test II	95 beats/min

Table 2: Pulse rate

- **Low Frequency (LF) Normalised Power -** 0.04 Hz to 0.15 Hz.
- **High Frequency (HF) Normalised Power -** 0.15 Hz to 0.4 Hz.
- **LF/HF** ratio and
- **Total Power** (Absolute Power).

S.No	Experimental	Total Domain Analysis (Mean ± SD)			
		LF Value	**HF value**	**LF/HF Ratio**	**Total Power**
1	Normal	43.7632 ±18.58902	54.2876 ±18.7623	1.0875 ±0.9736	4186.4265 ±3205.1642
2	Test I	44.605 ±16.7689	55.442 ±16.6837	1.0671 ±0.8873	3991.427 ±3122.4657
3	Test II	47.1543 ±15.5976	52.798 ±16.8794	1.1565 ±.9436	4551.5642 ±3078.9689

Table 3: Frequency Domain Analysis

S.No	Parameters	Pairing		Mean ± SD	P Value
1	MRR	Pair-1	N&Test-I	10.78100 ±23.74200	0.002
2		Pair-2	N&Test-II	14.6540 ±36.1256	0.009
3		Pair-3	Test I&II	3.6743 ±31.5436	0.374
4	pNN50	Pair-1	N&Test-I	0.12300 ±7.00283	0.902
5		Pair-2	N&Test-II	0.82254 ±9.42366	0.546
6		Pair-3	Test I&II	0.7532 ±8.54667	0.568
7	SDNN	Pair-1	N&Test-I	1.78300 ±13.564709	0.335
8		Pair-2	N&Test-II	3.80156 ±14.3076	0.742
9		Pair-3	Test I&II	2.01654 ±12.04672	0.315
10	r-MSSD	Pair-1	N&Test-I	0.54670 ±14.65789	0.782
11		Pair-2	N&Test-II	1.04980 ±15.6790	0.656
12		Pair-3	Test I&II	0.59376 ±15.19087	0.786
13	LF Value	Pair-1	N&Test-I	0.06460±17.73802	0.980
14		Pair-2	N&Test-II	2.51220±17.48046	0.315
15		Pair-3	Test I&II	2.57680±11.92217	0.133
16	HF Value	Pair-1	N&Test-I	0.06460±17.73802	0.980
17		Pair-2	N&Test-II	2.51220±17.48046	0.315
18		Pair-3	Test I&II	2.57680±11.92217	0.144
19	LF/HF Ratio	Pair-1	N&Test-I	0.05200±1.03994	0.725
20		Pair-2	N&Test-II	0.05800±1.00583	0.675

21		Pair-3	Test I&II	0.11000 ±.68822	0.265
22	Total Power	Pair-1	N&Test-I	176.1102 ±2365.1856	0.557
23		Pair-2	N&Test-II	376.7625± 3215.1754	0.405
24		Pair-3	Test I&II	546.3256± 2453.546	0.097

Table 4: Paired Samples Test

IV. Discussion

In this present study, 200 healthy young male and female subjects participated voluntarily. The study was made under three experimental conditions: Normal (N): resting state (without mobile phone & Bluetooth talk), Test-I: call on mobile phone at ear level and Test-II: call on Bluetooth device at ear level and mobile phone at heart level.

On analysing Time Domain Parameters

The mean values of m-RR were 874.824±144.23005 for Normal, 885.691±145.58095 for Test-I and 889.577± 143.40872 for Test-II [Table: 1]. The result showed that there was a significant increase in m-RR in Test –II when compared to that of normal and Test-I, and also increase in m-RR in Test –I when compared to that of normal owing to show there was an increased sympathetic activity.

The pNN50 values were 30.107±23.27286 for Normal, 30.107±23.27286 for Test-I and 30.229±23.05086 for Test-II [Table: 1]. The pNN50 was comparatively more in Test-II which indicates the influence of Bluetooth using affect in the short term on autonomic tone; particularly parasympathetic activity.

The mean SDNN value for Normal was 58.224±26.35695, for Test-I was 60.018±27.26727 and for Test-II was 62.0346±26.733023 [Table: 1]. On comparing these values, there was a progressive increase from normal to mobile & mobile with Bluetooth which indicates the tendency towards these effects on long-term circadian rhythm. On comparing the mean values of r-MSSD 60.285±35.40175, 60.742±36.06687 and 61.335±34.51860 for normal, test-I and test-II respectively [Table: 1], the result showed that there was a mild increase from normal to mobile & mobile with Bluetooth. [19,20]

On analysing Frequency Domain Parameters

The mean LF value for Normal was 44.6216±18.58303, for Test-I was 44.557±16.98579 and for Test-II was 47.1338± 16.58677 [Table: 2]. LF component when compared was higher during the blue-tooth call showing an increased sympathetic dominance in comparison with the resting state and mobile phone call, but there was not a vivid difference between the latter and the resting state.

The mean HF during Normal, Test-I and Test-II were 55.3784±18.58303, 55.443±16.98579 and 52.8662± 16.58677 respectively [Table: 2]. On comparing these three tests, there was an HF decrease which showed the effect of radiation affected mostly parasympathetic activity.

The mean LF/HF ratio values were 1.0996±0.98359 for Normal, 1.0476±0.88567 for Test-I and 1.1576±.96359 for Test-II [Table: 2]. The result showed that there was an increase in Test-II mean LF/HF ratio which indicated an increased sympathovagal balance or sympathetic modulations when compared to normal and test-I. On comparing, the mean Total Power 4180.4382±3203.16428 and 3991.328±3122.45303 of normal and test-I respectively [Table: 2], the result showed a gradual decrease and the mean Total Power of Test-II 4558.3608±3806.96908 [Table: 2] was comparatively high which indicated an increased sympathetic activity.

Paired Sample t Test was performed between the three experimental conditions, Normal, Test-I and Test-II as Pair- 1= Normal & Test-I, Pair-2= Normal & Test-II, and Pair-3=Test-I and Test-II.

From the results observed, the mean values of MRR in Pair-1 and Pair-2 were 10.86700± 24.84693 and 14.75260**±** 38.10495 which showed a drastic increase and proved to be (0.003***** and 0.009*****) statistically significant p (< 0.05) [Table: 3] which indicated an increase in the sympathetic activity.

In this study, the rest of the parameters though statistically not significant there were considerable differences in between all the three pairs. The findings of our study showed an increased sympathetic tone compared to parasympathetic tone during the call on Bluetooth device at ear level and mobile phone at heart level.

V. Conclusion

This study concludes that there is a statistically significant change in mean HR and mean RR interval when mobile phone is kept in direct contact with the ear and also when it is connected using earphones. The increase in mean HR is more when mobile phone is kept in direct contact with the ear than with the use of earphones. There is a decrease in parasympathetic tone and increase in sympathetic tone measured indirectly through HRV parameters, i.e., change in LF and HF components. Thus, this study shows that the use of mobile phones has an effect on heart rhythmicity and conductivity; therefore, the population at large should be advised on minimizing the use of mobile phones in their day-to-day life. Subjects should be encouraged to use earphones during active call and to minimize using phones with direct contact to the ear because the electromagnetic field developed around a mobile phone during active call may cause interference with electrical impulses in the body. Due to the close proximity of the phone to the heart, the rhythmicity and conductivity of impulses may be affected directly or indirectly through the modulation of ANS.

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