EFFECT OF MOBILE PHONE RADIATION ON HEART RATE VARIABILITY

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ABSTRACT

BACKGROUND

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 50 healthy male 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.

KEYWORDS

Heart Rate Variability, Electromagnetic Radiation, Heart Rate, Mobile Phone, Autonomic Tone.

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BACKGROUND

Mobile phones enable wireless information transmission. Mobile Phone technology relies on pulsed high-frequency electromagnetic (EM) fields. Therefore, the health risks associated with electromagnetic fields remain undetermined.[1]

In India, the total number of mobile phone subscribers had reached 9 – 9.37 millions as per a May 2012 report.

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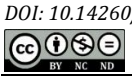

The rapid increase in the use of mobile phones in recent years has raised the problem of health risk connected with high-frequency electromagnetic fields. There are reports of headache, dizziness, numbness in the thigh, heaviness in the chest and cancer among mobile phone users.[2]

Though, it has long been speculated that the electromagnetic fields emitted by the mobile phones may interact with the cardiovascular system (CVS), these effects of exposure to electromagnetic fields on human cardiovascular parameters remain undetermined. Only very few studies have been conducted on the response of electromagnetic field exposure on CVS.[3]

It is possible that electromagnetic field emitted by cellular telephones may influence the autonomic tone, thus modifying the functioning of the circulatory system.

The heart rate variability (HRV) is a consistent marker & an independent predictor of ANS changes in the heart.[4] HRV, essentially, the continuous changes of heart beats, measured by electrocardiography procedure is, in general, influenced by the sympathetic and parasympathetic nervous activity.

Studies show that such beat to beat changes in the heart rate are modulated by the Autonomic Nervous System (ANS), essentially reveals the body's homoeostasis mechanisms.[5]

Therefore, the present study is being designed to test the effects of electromagnetic waves emitted by mobile phones on heart rate variability (HRV) in order to predict & prevent any cardiovascular ailments.

The effect of mobile phone radiations on human health is the subject of recent interest and study as there is enormous increase in mobile phone usage throughout the world.

Regarding the widespread use of mobile phones, closer attention should be paid to the 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 could exert influence on heart that is not related to mental stress.[6]

Mobile phones use electromagnetic radiation in the microwave range. Other digital wireless systems, such as data communication networks produce similar radiation.[7]

Part of the radio waves emitted by a mobile telephone handset are absorbed by the body. The radio waves emitted by a Global System for Mobile Communication handset can have a peak power of 2 watts. Studies show the frequent use of mobile phone gives health risks such as dizziness, numbness in the thigh, and heaviness in the chest, cancer, cognitive effects.

Bluetooth radiation is emitted from all Bluetooth headsets and is a type of wireless radio wave frequency (RF) also known as "microwave radiation".

These microwave frequencies have a short wavelength and a rapid rate of oscillation which enables them to travel long distances carrying information without needing to be contained in a wire.

Long-term exposure to microwave radiation has deleterious effects on human beings. Non-thermal microwave radiation has also been shown to affect the biological changes within the body as they penetrate living tissue down to a cellular level and their effects can be passed on to offspring via genetic damage (DNA, RNA).

Bluetooth devices emit non-ionising radiation at frequencies ranging from 1 to 2.5 GHz, while a mobile phone needs to transmit with enough power to reach a base station antenna a couple of miles away. A Bluetooth device can transmit at a range of not more than 30 feet. "Provocation Study using Heart Rate Variability Shows Radiation from 2.4 GHz Cordless Phone Affects Autonomic Nervous System".[8]

Bluetooth radiation has been even less studied than cell phone radiation. The lack of any formal studies has enabled the "experts" to claim that Bluetooth radiation is safe. This claim is based not on research proving Bluetooth radiation safe, but rather on the lack of any research proving it to be unsafe.

The Food and Drug Administration felt a need to revisit its approval on cell phones in lieu of a recent study conducted by the Swedish National Institute for Working Life that showed cell phone users have a 240% greater risk of developing brain tumours on the same side of the head where they use their phone. The potential health hazards of wireless signals continue to be debated and studied.

The World Health Organization established the International Electromagnetic Fields Project for the ongoing study of health concerns related to wireless technology. As of 2009, scientific evidence had linked exposure to radiofrequency energy from mobile devices with health problems.[9]

This study investigates neurological effects that are caused by electromagnetic fields radiated from Mobile phone & Bluetooth. The heart rate variability (HRV) can be used as a measure for these neurological effects, because the autonomic nervous system modulates the HRV.

ANS control visceral functions demanded for maintaining the homoeostasis of the organism. Peripheral ANS is controlled by the CNS via complex neuronal interconnections functioning in relation to each other to form a functional entity called central autonomic network (CAN). Neuronal activity within the CAN is affected by arterial pressure, respiration and other physiologic variables.[10]

Heart rate variability (HRV) is a non-invasive, clinically significant physiological and psychological marker of cardiac and autonomic nervous system (ANS). Linear and non-linear techniques can be used to analyse HRV.

Heart rate variability (HRV) analysis attempts to assess autonomic regulation through quantification of sinus rhythm variability. The sinus rhythm time series is derived from the QRS to QRS (R-R) interval sequence of the electrocardiogram (ECG), by extracting only normal sinus to normal sinus (NN) inter-beat intervals. Relatively high frequency variations in sinus rhythm reflect parasympathetic (vagal) modulation, and slower variations reflect a combination of both parasympathetic and sympathetic modulation and non-autonomic factors.[11]

HRV spectrum was obtained via FFT. Two peak values representing autonomic nervous system status, LF and HF, were used to extract the parameter, the LF/HF ratio. Results showed that LF/HF values were increased in the sympathectomy group and decreased in the vagotomy group. The increase in LF% and LF/HF with the decrease in HF indicate augmented sympathetic and attenuated parasympathetic drive.[12]

LF is a marker reflecting both sympathetic and vagal activity, efferent vagal activity is a major contributor to the HF component and the LF/HF ratio is considered to mirror sympathovagal balance or reflect the sympathetic modulations. SDNN represents joint sympathetic and parasympathetic modulation of heart rate.[13]

Aim

The aim of the present study was to determine the influence of the call with a mobile phone and with the use of Bluetooth device on heart rate variability in healthy young male subjects.

Objective

To study the effects of electromagnetic waves emitted by mobile phones and Bluetooth on cardiac autonomic modulation by heart rate variability (HRV) analysis.

MATERIALS & METHODS

Study Design: Observational Study.

Study Population: College students in the age group of 18 to 25 years volunteering for the study were selected.

Sample Size: The study was carried out on 50 male subjects.

Study Setting: Research Lab, Department of Physiology, Chennai Medical College and Research Centre, Trichy.

Selection Criteria

Inclusion Criteria

Normal individuals with normal cardiac function.

Exclusion Criteria

Subjects with previously known cardiac problems or under medications will be excluded.

Ethical Consideration

The study was carried out only after the approval by the Institutional Ethics Committee.

Instruments Used

ECG recording and HRV analysis were done with Student Physiograph (Medicaid, Punjab) and Analogue to Digital Convertor (National Instruments).

The following Parameters were analysed

Time Domain Analysis Parameters

- **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.

Frequency Domain Analysis Parameters

- **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).

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 5 minutes, 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 5 minutes rest between the recordings.

Statistical Analysis

Data obtained were represented as Mean±SD. Paired "t" test was used to compare the difference between resting state HRV, HRV during mobile phone (at ear level) talk and HRV during Bluetooth device at ear level and mobile phone at heart level, $p<0.05$ considered as significant.

OBSERVATIONS AND RESULTS

Sl. No.	Experimental		Time Domain Analysis (Mean ± SD)		
		MRR	pNN50	SDNN	r-MSSD
1.	Normal	874.824±144.23005	30.107±23.27286	58.224±26.35695	60.285±35.40175
2.	Test-I	885.691±145.58095	30.229±23.05086	60.018±27.26727	60.742±36.06687
3.	Test-II	889.577±143.40872	30.918±22.66953	62.0346±26.73323	61.335±34.51860

Table 1

Sl. No.	Experimental	Frequency Domain Analysis (Mean ± SD)			
		LF Value	HF Value	LF/HF Ratio	Total Power
1.	Normal	44.6216±18.58303	55.3784±18.58303	1.0996±0.98359	4180.4382±3203.16428
2.	Test-I	44.557±16.98579	55.443±16.98579	1.0476±0.88567	3991.328±3122.45303
3.	Test-II	47.1338±16.58677	52.8662±16.58677	1.1576±.96359	4558.3608±3806.96908

Table 2

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.

Sl. No.	Parameters	Pairing		Mean ± SD	P Value
1.	MRR	Pair-1	N & Test-I	10.86700± 24.84693	0.003*
2.		Pair-2	N & Test-II	14.75260± 38.10495	0.009*
3.		Pair-3	Test I & II	3.88560±31.22062	0.383
4.	pNN50	Pair-1	N & Test-I	0.12200±7.00391	0.902
5.		Pair-2	N & Test-II	0.81140±9.43557	0.546
6.		Pair-3	Test I & II	0.68940±8.47148	0.568
7.	SDNN	Pair-1	N & Test-I	1.79400±13.05986	0.336
8.		Pair-2	N & Test-II	3.81060±14.70673	0.073
9.		Pair-3	Test I & II	2.01660±14.02694	0.314
10.	r-MSSD	Pair-1	N & Test-I	0.45620±14.75717	0.828
11.		Pair-2	N & Test-II	1.04960±15.56028	0.636
12.		Pair-3	Test I & II	0.59340±15.19260	0.784
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	0.133
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	0.685
21.		Pair-3	Test I & II	0.11000±.68822	0.264
22.	Total Power	Pair-1	N & Test-I	189.11020± 2265.18478	0.558
23.		Pair-2	N & Test-II	377.92260± 3162.21219	0.402
24.		Pair-3	Test I & II	567.03280± 2352.21043	0.095

Table 3. Paired Samples Test

N = Normal

*** =** statistically significant p (<0.05)

DISCUSSION

In this present study, 50 healthy young male 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.

The parameters of heart rate variability measured were grouped under time domain analysis and frequency domain analysis. The results were tabulated and compared [Table: 1 & Table: 2] and also paired between normal, test-I and test-II [Table: 3].

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.

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.

On the contrary to the report by Ryszard Andrzejak et al, "the tone of the parasympathetic system measured indirectly by analysis of heart rate variability was increased while the sympathetic tone was lowered during the call with the use of a mobile phone." Our study showed that there was not much reduction in sympathetic tone in mobile phone usage as when compared with resting state.

Several recent articles suggested that cell phone radiation damages sperm, harmful to developing foetus, etc. For example, a 2009 study in Turkey found that after pregnant rats were exposed to cell phone radiation for 15 minutes twice a day during the entire gestation period, their female pups had fewer ovarian follicles (Gul 2009). A 2012 study by researchers at the Yale University School of Medicine found that mice exposed to cell phone radiation during gestation were hyperactive and had impaired memory (Aldad 2012).

There have been similar findings in two human studies. UCLA researchers reported that cell phone exposure during pregnancy and after birth was associated with behavioural problems in young children (Divan 2008; Divan 2012).

CONCLUSION

Cellular (cell) phone usage has increased dramatically and is still growing in this modern world. In recent decades, both adults and children spend a huge amount of time with their phones. This study not only helps to assess the hazardous effect on cardiovascular activity of EMR emitted by mobile phones, but also on the wireless microwave radiation emitted by the Bluetooth device (which when used).

The study showed that the call with the use of a mobile phone and Bluetooth device may cause an increase in sympathetic tone and decrease in parasympathetic tone thereby causing an altered balance between sympathetic and parasympathetic 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 & to undertake some safety measures.

Summary

- The present study was carried out in the Research Lab (ECG Lab), Department of Physiology, Chennai Medical College and Research Centre. Trichy.
- Fifty young male subjects participated voluntarily with normal cardiac functions.
- ECG recording and HRV analysis were done in all the subjects with Student Physiograph and Analogue to Digital Convertor under three experimental conditions.
    1. **Normal (N):** Resting state (without mobile phone & Bluetooth talk),
    2. **Test-I**: Call on mobile phone at ear level and
    3. **Test-II**: Call on Bluetooth device at ear level and mobile phone at heart level.
- Time domain and Frequency domain parameters were compared and analysis was made on pairing between the above said groups as a pair: 1- normal and test-I, pair: 2- normal and test-II, and pair: 3- test-I and test-II.

  The Results Showed that
    1. There was a significant increase in the heart rate which indicated an increase in sympathetic tone on use of mobile phone and on Bluetooth device usage.
    2. There was a marked reduction in vagal activity in Bluetooth users.
- This study will be a limelight for the future research works on the health effects of microwaves transmitted from Bluetooth device on usage and there are serious risks of developing cardiac irregularities on long-term exposure to mobile phone radiation which might be triggered by electromagnetic radiation.

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