National Journal of Physiology, Pharmacy and Pharmacology

RESEARCH ARTICLE

Immediate effects of mobile phone radiations on heart rate variability in college going students

Juveriya Yasmeen[1], Mehnaaz Sameera Arifuddin[2], Nazema Khatoon[2], Umaima Mahveen[1], Mohammed Abdul Hannan Hazari[2]

[1]MBBS Student, Deccan College of Medical Sciences, Hyderabad, Telangana, India, [2]Department of Physiology, Deccan College of Medical Sciences, Hyderabad, Telangana, India

Correspondence to: Mehnaaz Sameera Arifuddin, E-mail: mehnaaz@deccancollegeofmedicalsciences.com

Received: July 23, 2017; **Accepted:** August 08, 2017

ABSTRACT

Background: The use of mobile phone has increased excessively these days which can have a deleterious effect on human tissues and organs, especially cardiovascular system (CVS). The effects on CVS can be detected at an early stage by analyzing alterations in heart rate variability (HRV). **Aims and Objectives:** This study was designed to determine the effect of mobile phone use with different components of HRV. **Materials and Methods:** In our study, HRV was measured in 95 college-going students (males: 49 and females: 46) using RMS Polyrite-D during 3 phases with each phase being recorded continuously for 2 min. Phase 1: Basal recording; Phase 2: Mobile phone use during active call with direct contact to the ear; and Phase 3: Mobile phone use during active call with earphones. Data obtained were subjected to statistical analysis using repeated measures non-parametric test followed by multiple comparison tests. **Results:** There was a significant increase in mean HR and decrease in mean RR interval from baseline through Phase 3 to Phase 2. This study shows that there was statistically significant change in root of the mean of the sum of the squares of differences (RMSSD), low frequency (LF), high frequency (HF), and LF/HF ratio between basal recording and during active call (direct contact of mobile phone to the ear and also with use of earphones); however, no change was seen between direct contact of mobile phone to the ear and during the use of earphones. Standard deviation of all normal-to-normal intervals (SDNN) did not show any significant change. We also observed gender differences in some of the HRV parameters. **Conclusion:** There is a considerable effect of mobile phone use on HR and HRV parameters. Furthermore, the changes noted were less with earphone use compared with the use of mobile phone in direct contact with the ear though these differences were not significant statistically.

KEY WORDS: Heart Rate Variability; High Frequency; Low Frequency; Low Frequency/High Frequency Ratio; Mobile Phone; RMSSD; SDNN

Access this article online	
Website: www.njppp.com	Quick Response code
DOI: 10.5455/njppp.2018.8.0727708082017	

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]

Mobile phone radiations alter HRV; these alterations may detect cardiovascular diseases much before the onset of its clinical symptoms. It has been found that decrease in HRV is associated with the risk of sudden cardiac death in patients with heart diseases. Reduction in HRV causes increasing risk of mortality and susceptibility to life-threatening arrhythmias.[19]

The alterations in HRV due to mobile phone radiations are important to study as they may have a deleterious effect on human health. Hence, this study was designed to document effects of mobile phone radiations on HRV in college-going students and to determine any role of duration of mobile phone use with different components of HRV.

MATERIALS AND METHODS

An observational study was conducted in the Department of Physiology of our Medical College during the months of May to October 2016. Participants were 100 college-going students of both genders between the age group of 18 and 25 years. Ethics clearance was obtained from the Institutional Review Board (Reference No.: 2016/11/006) before the start of this study. The study complied with the guidelines of Helsinki declaration.

Those individuals with cardiovascular, metabolic or neurological disorders, alcoholics, smokers, and those taking any medications that are known to affect cardiorespiratory response were excluded from this study.

Informed consent was obtained from all participants before the start of the study. Demographic parameters such as height and weight were recorded for each subject before the recording. Each subject was asked not to eat or drink at least half-hour before the test and was allowed to relax for 10-20 min before recording. To minimize the effect of respiration on HRV, subjects were required to breathe quietly (12-16 breaths/min).

In each subject, lead II ECG signals were recorded in the supine position in 3 different phases for 2 min each using Polyrite-D (Recorders and Medicare Systems, Chandigarh, India) as follows:

Phase 1: Basal recording,

Phase 2: Mobile phone use during active call with direct contact to the ear,

Phase 3: Mobile phone use during an active call with earphones.

During Phase 3, the mobile phone was placed at a short distance from the body. Same "smart" mobile phone (Make: Samsung, Model: Galaxy S III (GT-19300), Generation: 3G, Frequency band: WCDMA (850/900/1900/2100 MHz) + GSM (850/900/1800/1900 MHz), Highest SAR: 0.490 W/kg 1 g (head), 1.02 W/kg 1 g (body)) was used for all participants. Call was made to this mobile phone by one of the investigators with a standard set of questionnaire to avoid interdevice and intersubject conversation differences. After each recording, HRV analysis was done as follows:

HRV Analysis

The following parameters were calculated for every subject in all 3 phases.[20]

1. Time domain parameters:
   a. Standard deviation of all normal-to-normal intervals (SDNN),
   b. Square root of the mean of the sum of the squares of differences between adjacent NN intervals (RMSSD).
2. Frequency domain parameters (fast Fourier transforms):
   a. Low frequency (LF),
   b. High frequency (HF),
   c. LF/HF ratio.
3. Mean RR interval.
4. Mean HR.

Statistical Analysis

Data obtained were tabulated using Microsoft excel and imported into SPSS 17.0 statistical software for analysis. The test data obtained were subjected to Shapiro–Wilk test of normality wherein many parameters deviated from normality. Therefore, repeated measures non-parametric tests were used. Friedman test was applied to know the difference between the means from 3 phases of test. If the Friedman test was statistically significant, Wilcoxon signed-ranks test (multiple comparisons test) was performed. Statistical significance was fixed at $P < 0.05$.

RESULTS

Mobile phone usage while on active call had a very wide range among our subjects starting from as short as 5 min to as long as 6 h per day. 100 young apparently healthy subjects were enrolled for the study after taking consent. For 5 subjects, there was an error in the recording of HRV parameters and hence were excluded from analysis. The data are expressed as mean±standard deviation for scale variables. Table 1 shows the sex distribution (M = 49, F = 46, total = 95). Mean age of the subjects was 19.34 ± 1.04 years. Mean weight was 60.89 ± 14.48 kg, mean height was 166.2 ± 9.81 cm, and mean body mass index was 21.89 ± 3.8 kg/m^2.

Table 1: Participants data (n=95)

Parameter	Values
Age (years)	19.34±1.04
Gender (M/F)	49/46
Mobile phone use (min)	64.21±75.81
Weight (kg)	60.89±14.48
BMI (kg/m^2)	21.89±3.80

BMI: Body mass index

The whole-group analysis showed that there was a statistically significant difference in mean HR between 3 phases of test, $\chi^2(2) = 62.075$, $P = 0.000$. *Post-hoc* analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied. There were a significant differences between Phase 2 and Phase 1 ($Z = -6.912$, $P = 0.000$), between the Phase 3 and Phase 1 ($Z = -5.718$, $P = 0.000$), and between Phase 2 and 3 ($Z = -4.108$, $P = 0.000$).

There was a statistically significant difference in mean RR interval between 3 phases of test, $\chi^2(2) = 58.099$, $P = 0.000$. *Post-hoc* analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied. There were significant differences between Phase 2 and Phase 1 ($Z = -6.436$, $P = 0.000$), between the Phase 3 and Phase 1 ($Z = -5.366$, $P = 0.000$), and between Phase 2 and 3 ($Z = -3.983$, $P = 0.000$).

SDNN did not show any difference ($P = 0.966$) between the 3 test phases, but there was a statistically significant difference in RMSSD between 3 phases of the test, $\chi^2(2) = 22.989$, $P = 0.000$. *Post-hoc* analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied, resulting in a significance level set at $P < 0.017$. There were significant differences between Phase 2 and Phase 1 ($Z = -4.907$, $P = 0.000$) and between the Phase 3 and Phase 1 ($Z = -4.358$, $P = 0.000$), but there was a no statistically significant difference between Phase 2 and 3 ($Z = -0.585$, $P = 0.559$).

There was a statistically significant difference in LF component of HRV between 3 phases of test, $\chi^2(2) = 15.411$, $P = 0.000$. *Post-hoc* analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied. There were significant differences between Phase 2 and Phase 1 ($Z = -2.474$, $P = 0.013$) and between the Phase 3 and Phase 1 ($Z = -4.417$, $P = 0.000$), but there was a no statistically significant difference between Phase 2 and 3 ($Z = -1.654$, $P = 0.098$).

There was a statistically significant difference in high-frequency (HF) component of HRV between 3 Phases of test, $\chi^2(2) = 16.063$, $P = 0.000$. *Post-hoc* analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied. There were significant differences between Phase 2 and Phase 1 ($Z = -2.658$, $P = 0.008$) and between the Phase 3 and Phase 1 ($Z = -4.415$, $P = 0.000$), but there was a no statistically significant difference between Phase 2 and 3 ($Z = -1.622$, $P = 0.105$).

There was a statistically significant difference in LF: HF ratio of HRV between 3 phases of test, $\chi^2(2) = 16.063$, $P = 0.000$. *Post-hoc* analysis with Wilcoxon signed-rank tests was conducted with a Bonferroni correction applied. There were significant differences between Phase 2 and Phase 1 ($Z = -2.604$, $P = 0.009$) and between the Phase 3 and Phase 1 ($Z = -4.330$, $P = 0.000$), but there was a no statistically significant difference between Phase 2 and 3 ($Z = -1.665$, $P = 0.096$).

Gender-specific results are depicted in Tables 2 and 3. In males, mean HR, mean RR, and RMSSD were significantly different

between baseline and mobile phone use either directly or with the use of earphones. SDNN did not show any difference. LF, HF, and LF:HF were significantly different between Phase 1 and Phase 3 (Table 2). In females, statistically significant differences were noted between all the 3 phases with respect to mean HR and mean RR. Changes in SDNN were insignificant. RMSSD was significantly different between baseline and mobile phone use either directly or with the use of earphones. LF and HF did not showed any difference, whereas LF: HF ratio showed difference only between Phase 1 and Phase 3 (Table 3).

DISCUSSION

The present study was conducted in 95 young adults to find out immediate effects of mobile phone radiations on HRV. Our results reveal that there are considerable changes in HRV parameters which are in contrast to the study findings of Tamer et al. who showed that mobile phone placed on the chest does not have any effect on hemodynamic and cardiac electrical activity parameters.[21] Our study participants had a very wide range of duration (5 min to 6 h per day) of mobile phone use during active call as well as the total duration of exposure to mobile phones in years. Ekici et al. concluded that HRV may be influenced by long-term mobile phone usage.[22] In our study, SDNN parameter did not show any significant difference between the 3 phases. While recording HRV time domain parameters, we found that RMSSD values were significantly reduced during direct contact of mobile phone to the ear and by use of earphones in comparison to baseline recording. The HF component values of Phase 2 and 3 were also significantly reduced. The above findings were consistent with a previously done study by Vegad et al.[23] HRV was lower during direct contact of mobile phone than by the use of earphones, but this difference was not statistically significant (Table 4). In our study, we found that LF and LF/HF ratio were significantly increased while HF was significantly reduced when mobile phone was in direct contact and when earphones were used in comparison to baseline values. The LF component value of Phase 2 was significantly increased in comparison to the baseline recording, and this finding is consistent with the study conducted by Andrzejak et al.[24] The LF/HF ratio was also increased significantly during Phase 2 and 3, but there was no significant difference between Phase 2 and 3 which is consistent with the study by Vegad et al.[23] In contrast to our study, LF/HF ratio was decreased in the study by Andrzejak et al.[24] There was a significant decrease in the mean RR interval in Phase 2. The decrement in Phase 3 was less than the Phase 2. Thorat and Shelke.[25] showed that there was no significant change in RR interval after the mobile phone ring. We also found a significant increase in the HR in Phase 2. This finding is consistent with the study conducted by Andrzejak et al.[24] The increment was less in Phase 3 when compared to Phase 2. Mann et al.[26] conducted a study on effects of pulsed high-frequency EMF generated by a mobile phone in lower micro frequency range on HRV at the time of sleep and concluded that no significant effects were noted on HR parameters.

Barutcu et al. also concluded no effects on HRV.[18] The studies conducted by Yilmaz and Yildiz,[27] Andrzejak et al.,[24] and

Table 2: Differences in HRV parameters between different phases in males

Parameters	Phase 1	Phase 2	Phase 3	Wilcoxon signed-rank tests
Mean HR	79.76±11.64	84.78±11.73	83.43±10.45	P=0.000*† P=0.017‡ P=0.000*#
Mean RR	0.76±0.11	0.72±0.10	0.72±0.09	P=0.000*† P=0.039‡ P=0.000*#
SDNN	47.58±16.87	45.77±14.40	47.23±19.28	P=0.124† P=0.557‡ P=0.922#
RMSSD	43.85±21.81	36.66±17.76	36.68±20.67	P=0.000*† P=0.831‡ P=0.000*#
LF	53.02±19.68	62.30±13.26	65.37±12.56	P=0.031† P=0.092‡ P=0.000*#
HF	46.97±19.68	37.70±13.26	34.62±12.56	P=0.031† P=0.092‡ P=0.000*#
LF:HF	1.52±1.06	1.96±0.98	2.24±1.03	P=0.044† P=0.057‡ P=0.000*#

†Difference between Phase 1 and 2, ‡difference between phase 2 and 3, #difference between Phase 3 and 1, P=Significance value, *statistically significant at $P \leq 0.017$ (after Bonferroni correction 0.05/3=0.017). HRV: Heart rate variability, HR: Heart rate, RMSSD: Root of the mean of the sum of the squares of differences, SDNN: Standard deviation of all normal-to-normal intervals, HF: High frequency, LF: Low frequency

Table 3: Differences in HRV parameters between different phases in females

Parameters	Phase 1	Phase 2	Phase 3	Wilcoxon signed-rank tests
Mean HR	85.63±9.29	89.41±10.35	87.91±8.87	*P*=0.000*† *P*=0.000*‡ *P*=0.002*#
Mean RR	0.69±0.10	0.67±0.08	0.69±0.07	*P*=0.000*† *P*=0.000*‡ *P*=0.008*#
SDNN	39.00±12.42	41.71±12.72	41.71±13.87	*P*=0.229† *P*=0.756‡ *P*=0.270#
RMSSD	35.27±15.99	30.10±11.70	32.11±15.33	*P*=0.002*† *P*=0.227‡ *P*=0.007*#
LF	56.16±18.33	61.93±14.67	64.00±14.27	*P*=0.183† *P*=0.544‡ *P*=0.019#
HF	43.83±18.33	37.98±14.24	35.99±14.27	*P*=0.102† *P*=0.544‡ *P*=0.019#
LF:HF	1.67±1.03	1.98±1.01	2.11±0.95	*P*=0.085† *P*=0.604‡ *P*=0.016*#

†Difference between Phase 1 and 2, ‡difference between Phase 2 and 3, #difference between Phase 3 and 1, *P*=Significance value, *statistically significant at *P*≤0.017 (after Bonferroni correction 0.05/3=0.017). HRV: Heart rate variability, HR: Heart rate, RMSSD: Root of the mean of the sum of the squares of differences, SDNN: Standard deviation of all normal-to-normal intervals, HF: High frequency, LF: Low frequency

Table 4: Time-domain and frequency-domain parameters between different phases (all participants)

Parameter	Phase 1	Phase 2	Phase 3
Mean HR (bpm)	82.60±10.92	87.02±11.27	85.60±9.93
Mean RR (ms)	0.73±0.11	0.70±0.09	0.71±0.08
SDNN (ms)	43.43±15.42	43.81±13.69	44.56±17.02
RMSSD (ms)	39.70±19.59	33.49±15.41	34.46±18.33
LF (nu)	54.54±19.00	62.12±13.88	64.71±13.36
HF (nu)	45.45±19.00	37.83±13.67	35.28±13.36
LF:HF	1.59±1.04	1.97±0.99	2.18±0.99

HR: Heart rate, RMSSD: Root of the mean of the sum of the squares of differences, SDNN: Standard deviation of all normal-to-normal intervals, HF: High frequency, LF: Low frequency

Al-Hazimi.[28] showed that there is an increased parasympathetic activity associated with some changes in HRV indices. Whereas Vegad et al.[23] demonstrated increase in sympathetic tone and decrease in parasympathetic tone in females while male subjects demonstrated no significant change. In our study, we noticed differences in various parameters in both the genders (Tables 2 and 3). Our study is in contrast with that conducted by Roggeveen.[1] where HR decreased when dialing mobile phone was placed on the chest and also in contrast to the study conducted by Thorat and Shelke.[25] and Devasia et al.,[29] where there were no significant changes.

Limitations of the Study

During the data acquisition, subjects were required to listen and talk which will have effect on HRV. We minimized the effect of talking and emotions associated with speech by asking standard neutral, non-exciting questions which they had to answer in one word.

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.

ACKNOWLEDGMENTS

The authors thank all the subjects who participated in this study.

REFERENCES

1. Roggeveen S, van Os J, Gielissen J, Mengelers R, Golombeck K, Lousberg R. Effects of mobile phone radiations on heart rate: A radiation detector controlled pilot study. Peer J Preprints. 2014;2:e485v1.
2. Guidelines for Limiting Exposure to Time-varying Electric, Magnetic, and Electromagnetic Fields (up to 300 GHz). International Commission on Non-Ionizing Radiations Protection. Health Phys. 1998;74(4):494-522.
3. Comité Européen de Normalisation Électrotechnique (CENELEC) (English: European Committee for Electrotechnical Standardizations). Basic Standard for the Measurement of Specific Exposure Rate Related to Human Exposure to Electromagnetic Field from Mobile Phones (300MHz-3GHz) (Document No. EN 50361: 2001E); 2001. Available from: http://www.standards.globalspec.com/std/532912/cenelec-en-50361. [Last accessed on 2017 Jun 28].
4. Stringent Mobile Radiations Standards Come into Force from Tomorrow. New Mobile Handsets to Comply with SAR Value of 1.6 W/Kg. Penalty, Random Check Introduced for Enforcement. Press Information Bureau, Government of India; 2012. Available from: http://www.pib.nic.in/newsite/mbErel.aspx?relid=87152. [Last accessed on 2017 Jun 28].
5. Malaric K, Bartolic J, Malaric R. Measurement of GSM Phone Emission. Instrumentation and Measurement Technology Conference. IMTC 04. Proceedings of the 21st IEEE, At Como, Italy;Vol.1. May; 2004. p. 263-6. DOI: 10.1109/IMTC.2004.1351041.
6. Ahamed VI, Karthick NG, Joseph PK. Effect of mobile phone radiation on heart rate variability. Comput Biol Med. 2008;38(6):709-12.
7. Pal GK, Pal P. Textbook of Practical Physiology. 3rd ed. Hyderabad, India: Universities Press; 2013. p. 291-7.
8. Altamura G, Toscano S, Gentilucci G, Ammirati F, Castro A, Pandozi C, et al. Influence of digital and analogue cellular telephones on implanted pacemakers. Eur Heart J. 1997;18(10):1632-41.
9. Barbaro V, Bartolini P, Bellocci F, Caruso F, Donato A, Gabrielli D, et al. Electromagnetic interference of digital and analog cellular telephones with implantable cardioverter defibrillators: *In vitro* and *in vivo* studies. Pacing Clin Electrophysiol. 1999;22:626-34.
10. Hayes DL, Carrillo RG, Findlay GK, Embrey M. State of the science: Pacemaker and defibrillator interference from wireless communication devices. Pacing Clin Electrophysiol. 1996;19(10):1419-30.
11. Maier M, Blakemore C, Koivisto M. The health hazards of mobile phones. BMJ. 2000;320(7245):1288-9.
12. Heynick LN, Merritt JH. Radiofrequency fields and teratogenesis. Bioelectromagnetics. 2003;Suppl 6:S174-86.
13. Foster KR. The mechanisms paradox. In: Ayrapetyan SN, Markov MS, editors. Bioelectromagnetics Current Concepts. NATO Security through Science Series. Dordrecht: Springer; 2006. p. 17-29. DOI: 10.1007/1-4020-4278-7_2.
14. Pickard WF, Moros EG. Energy deposition processes in biological tissue: Nonthermal biohazards seem unlikely in the ultra-high frequency range. Bioelectromagnetics. 2001;22(22):97-105.
15. Saini BS, Pandey A. Effect of mobile phone and BTS radiation on heart rate variability. Int J Res Eng Technol. 2013;2(4):662-6.
16. Barker AT, Jackson PR, Parry H, Coulton LA, Cook GG, Wood SM. The effect of GSM and TETRA mobile handset signals on blood pressure, catechol levels and heart rate variability. Bioelectromagnetics. 2007;28(6):433-8.
17. Kwon MK, Nam KC, Lee DS, Jang KH, Kim DW. Effects of RF fields emitted from smart phones on cardio-respiratory parameters: A preliminary provocation study. Conf Proc IEEE Eng Med Biol Soc. 2011;2011:1961-4.
18. Barutcu I, Esen AM, Kaya D, Turkmen M, Karakaya O, Saglam M, et al. Do mobile phones pose a potential risk to autonomic modulation of the heart? Pacing Clin Electrophysiol. 2011;34(11):1511-4.
19. Tsuji H, Venditti FJ Jr, Manders ES, Evans JC, Larson MG, Feldman CL, et al. Reduced heart rate variability and mortality risk in an elderly cohort. The Framingham Heart Study. Circulation. 1994;90(2):878-83.
20. Chinagudi S, Badami S, Herur A, Patil S, Shashikala GV, Ankad R. Immediate effect of short duration of slow deep breathing on heart rate variability in healthy adults. Natl J Physiol Pharm Pharmacol. 2014;4(3):233-5.
21. Tamer A, Gündüz H, Ozyildirim S. The cardiac effects of a mobile phone positioned closest to the heart. Anadolu Kardiyol Derg. 2009;9(5):380-4.
22. Ekici B, Tanindi A, Ekici G, Diker E. The effects of the duration of mobile phone use on heart rate variability parameters in healthy subjects. Anatol J Cardiol. 2016;16(11):833-8.
23. Vegad MA, Kacha YK, Varu MS, Mehta HB, Shah CJ. Effects of mobile phone radiation on heart rate variability of healthy young subjects. Int J Clin Exp Physiol. 2015;2(1):23-8.
24. Andrzejak R, Poreba R, Poreba M, Derkacz A, Skalik R, Gac P, et al. The influence of the call with a mobile phone on heart rate variability parameters in healthy volunteers. Ind Health. 2008;46(4):409-17.
25. Thorat KD, Shelke V. Effects of mobile phone radiation on heart rate variation in healthy volunteers. Res J Pharm Biol Chem Sci. 2013;4(1):840-5.
26. Mann K, Connemann B, Roschke J. Cardiac autonomic activity during sleep under the influence of radiofrequency electromagnetic fields. Somnologie. 2005;9(4):180-4.
27. Yilmaz D, Yildiz M. Analysis of the mobile phone effect on the heart rate variability by using the largest Lyapunov exponent. J Med Syst. 2010;34(6):1097-103.
28. Al-Hazimi A. Effects of the call with the mobile phone on heart rate variability parameters of healthy young people. J Chem Pharm Res. 2011;3(4):734-40.
29. Devasia T, Nandra A, Kareem H, Manu MK, Thakkar AS. Acute effect of mobile phone on cardiac electrical activity in healthy volunteers. In t J Clin Med. 2014;5(5):167-70.

How to cite this article: Yasmeen J, Arifuddin MS, Khatoon N, Mahveen U, Hazari MAH. Immediate effects of mobile phone radiations on heart rate variability in college going students. Natl J Physiol Pharm Pharmacol 2018;8(1):56-61.

Source of Support: This study was partly supported by Indian Council of Medical Research-Short-term studentship 2016 (ICMR STS Reference ID: 2016-02412) (Crossref funder ID: http:// dx.doi.org/10.13039/ 501100001411)., **Conflict of Interest:** None declared.