EFFECT OF MOBILE PHONE AND BTS RADIATION ON HEART RATE VARIABILITY

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Abstract

The exponential increase in the use of mobile phone in recent years raised problem associated of health risk with electromagnetic field exposure (EFE).The electromagnetic field emitted by mobile phone and base station transceiver (BTS) may causes biological effects as they are designed to operate in 900-1800MHz with 12.5% duty cycle. These radiation is non-ionizing type which may have long term biological effect. There are enormous numbers of known and unknown problems due to EFE few known problems are headaches, heaviness in chest, dizziness etc. This paper deals with cardiovascular effect in relation with EFE by analysis on Heart rate variability (HRV) of 19 healthy male volunteers of age group 23±4.3 years in three different condition of EFE level. The ECG was recorded for twenty minutes in order to access all the parameters of HRV. As HRV is not only the best representative of autonomic nervous system (ANS) but also used to access the pathological and physiological conditions. The parameters used in the HRV analysis are frequency domain parameters, sample entropy and scaling exponent. The results clearly show that scaling exponent decreases when higher radiation level is experienced. Mobile phone radiation has caused change in HRV parameters and the change varied with radiation level along with the change in few HRV parameter significance as the p values is ≤ 0.05. The significant change in the scaling exponent of DFA promises there is shift of RR time series towards higher HRV at the elevated radiation exposure.

Index Terms: *Autonomic nervous system, Effect of wireless network radiation, Electromagnetic field exposure, Heart rate variability, Scaling exponent, Sample entropy, Frequency domain parameter.*

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1. INTRODUCTION

Heart rate variability (HRV) is a non-invasive clinically significant physiological and psychological marker of cardiac and autonomic nervous system (ANS) [1, 2]. Linear and non-linear techniques can be used to analyze HRV [3, 4]. Controversial results have been obtained from last few studies. Some are claiming no significant effect of mobile phone on ANS [5], and some studies shows there was change in ANS activity with reference of HRV parameters [6-7]. Electromagnetic fields (EMF) generated from the either mobile phones or base station transceiver (BTS) referred to wireless network radiation in communication, effect were examined on the basis of HRV parameters.

The Mobile Phones (MP) are low power radio devices which work on electromagnetic fields (EMFs) , in the frequency range of 900-1800MHz signal pulsed at 217 Hz with pulse width of 577 µs and duty cycle of 12.5% [3,21-23] . Radiation Power of MP is much higher at the beginning of communication and changes from 2W to 100mW after the beginning of communication. The output power of MP is at minimal when the MP is at standby mode. The increase in number of electro sensitivity with year in different part of the world is also reported [8-10].

Exposition to high power RF energies may lead to negative thermic effects and cause skin burns, cataracts. With increase in use of MP in day today activities, studying the effect of exposure to EMF has become important. Survey studies have shown that MPs may cause headache, extreme irritation, forgetfulness, blurring of vision, lacrimation , affects brain activity. Some studies suggest electromagnetic fields emitted by cellular phones may affect working of implantable pacemakers [11-14].

Generally MP are held close to head, this might affect Autonomic nervous system (ANS) by close brain heart connection which modulates the cardiac pacemaker and provides beat to beat regulation of cardiovascular rhythm [15]. The aim of present study is to analyze and determine the effect of MP and BTS radiation on ANS using HRV. Since ANS is a non linear system, therefore HRV signal has been analyzed using non linear method Detrended Fluctuation Analysis (DFA) along with Sample Entropy. The study was carried out on nineteen subjects in three different conditions.

2. DATA ACQUSITION

In the present study the Electrocardiogram (ECG) of 19 healthy male volunteers in the age group of 23±4.3 years, under three different test conditions namely i) 800 meters from nearest BTS without mobile phone ii) 50 meters from nearest BTS without mobile phone iii) 800 meters from nearest BTS with mobile phone near chest in calling mode are recorded for 20 min using Zephyr BioharnessTM physiological monitoring system. Additionally, in case iii) the maximum EMF or RFR exposure was observed i.e. power density 1.65±.32 W/m2 (watt per meter square) so, this case named as calling mode exposure period. In case ii) the RFR exposure i.e. power density 2.08±.27 mW/m2 (milliwatt per meter square) in less than calling mode exposure but greater than case i so case ii) named as moderate exposure. In case i) the minimal RFR exposure i.e. power density 0.49±.12 mW/m2 (milliwatt per meter square) was minimal named as least exposure. Volunteers are selected based on having no genetically diseases and any addiction prior to the ECG recording.

In order to make the experiment reliable, the following issues were considered. During recording duration, the volunteers are in easy sitting mode and they are advised to neither make any bodily movement [16, 17] nor try to speak anything even in 3rd condition in order to avoid any recording artifacts. The same environmental conditions were observed along with same mobile phone having specific absorption rate (SAR) 1.2 W/kg [18],which is within the ICNIRP[19] limit used during recording.

The radiofrequency radiation (RFR) was measured at the testing sites using Radio Frequency Electromagnetic Field (RF EMF) strength meter (50MHz to 3.5GHz) in watt per square. However, the cardiovascular effect may depend on the degree of acceptance of RFR exposure by the living body species not on the RFR exist in space [13].

3. METHOD

The recorded data set of 19 volunteers in three different conditions were used to evaluate cardiac behavior during RFR exposure by HRV estimation using Detrended Fluctuation Analysis (DFA), Sample Entropy and Power Spectral Density (PSD) computation which is called also called spectral analysis of HRV.

4. HRV ANALYSIS

The recorded data set of 19 volunteers in three different conditions were used to evaluate cardiac behavior during RFR exposure by HRV estimation using Detrended Fluctuation Analysis (DFA), sample entropy and power spectral density (PSD) computation which is called also called spectral analysis of HRV.

The RR time series were preprocessed by automatic filters which exclude some samples of original RR time series which differs 20% from previous samples [1]. As replacing the samples manually may cause undesirable effects [5].

4.1 Spectral Analysis

The PSD analysis deals with periodic oscillation of heart rates for different frequencies and amplitudes relative power in heart's sinus rhythm [20]. The PSD can be computed using parametric and non-parametric methods. Both methods provide comparable results while non-parametric analysis uses autoregressive estimation gives smoother easy calculation of spectral components but needs to verify the suitability and complexity, in contrast the non-parametric method uses simple algorithm Fast fourier Transform (FFT) having high computation speed and easy in implementation. In this paper we use the non-parametric based estimation of spectral components [21]. The result of FFT of RR times series is complex number its squared modulus gives the spectral power. The PSD consist of frequency band 0-.5 Hz as this study deals with short term recording the spectral components can be visualizes are very low frequency (VLF), low frequency (LF), high frequency (HF). The spectral components are evaluated in range of frequency but the amplitude is the area under that frequency band called power spectral density as represented in table 1. The unit of spectral components are squared millisecond (ms2) or can be represented by normalized unit (n.u) according to following normalizing equation 1 [1].

$$LF\ or\ HF(n.u) = \frac{LF\ or\ HF(ms^2)}{total\ power - VLF(ms^2)} \times 100 \quad (1)$$

Table-1 spectral components of HRV

Variable	Unit	Description	Frequency range
Total power	ms2	Variance of all RR intervals	approximately <0·4 Hz
VLF	ms2	Power in the very low frequency range	<= 0.04 Hz
LF	ms2	Power in the low frequency range	0.04–0.15 Hz
HF	ms2	Power in the high frequency range	0.15–0.4 Hz

LF consist of both sympathetic along with parasympathetic activity behavior. While HF give the measure of efferent nature of vagal activity [2]. HF having information about parasympathetic activity. LF/HF ratio was also calculated which provides the information about the symptho-vagal balance.

4.2 Deterend Fluctuation Analysis (DFA)

As the RR time series is non-stationary signal non linear analysis is recommended for better results DFA is one of nonlinear method for HRV, so the DFA calculates root mean square fluctuation of detrended time series [22]. DFA is used to simulating for various biological and physiologic time series and it also permits to calculate the self-similarity of RR-time series [23]. In the method of DFA the RR time series is integrated as equation 2 and then vertical characteristic scale was measured.

$$y(k) = \sum_{i=1}^{k} [RR(i) - RR_{avg}] \quad (2)$$

For measurement of vertical characteristics the time series was divided in boxes of equal length n which represents the trend in that box and local trend are removed by subtraction of yavg.(average value of integrated time series in that box) [24]. In each box a least square fit to data is used to represent the trend, yn(k) represent the straight line in particular box. The root mean square of integrated fluctuation and detrended RR times series is given by following equation, which will be calculated for every window [22].

$$F(n) = \sqrt{\frac{1}{N}\sum_{k=1}^{N}[y(k) - y_n(k)]^2} \quad (3)$$

N is the overall length of RR series and F(n) will increase with the box size. The slope of line relating log(F(n)) to log(n) give the value of scaling exponent (α). An α of 0.5 corresponds to white noise, α = 1 represents l/f noise and α = 1.5 indicates Brownian noise or random walk. Scaling exponent having potency for diagnostic and prognostic abilities with various type of cardiac diseases.DFA method gives superior results with respect to spectral analysis for analysis of HRV in patient with sleep apea [13].

4.3 Sample Entropy (Sampen)

Entropy basically deals with randomness, when applied to time series it calculates the dynamics of time series. Approximate entropy (ApEn) was introduced and calculated for regularity measurement for same predefined time window and compare other group for same time length [28]. ApEn, for regular series is expected to having low value while complex signal having higher ApEn values [29]. As ApEn's having self its dependence on the data size make its application limited and alternative ,which more robust amenable to short data size sample entropy (SampEn) was introduced by Richmann and Moorman [26,29].

Time series complexity can be measured using sample entropy with less computation time as data set is low and applied to physiological signal. The negative natural logarithm of the conditional probability that two sequences similar for m points at the next point with a tolerance r, where self-matches are excluded [27] was calculated for time series. For sample entropy analysis, the parameter (m,r) were set according to literature[25]. Where, N is the length of the time series. In this, we computed SampEn by the values of 2 for m and 0.2 for r.

5. RESULT AND DISCUSSION

Maximum, mean and minimum instantaneous heart rate did not change significantly in either of least exposure to maximum exposure the values are tabulated in table 2, which confirms the previous study [6,25]. The paired student-t test was carried out to evaluate the statistical significance. The results obtained using DFA which is a nonlinear HRV gives the statistically significant result p-value (p<.05) in contrast to the reference [25] because of they considered as the mobile phone is in standby mode in this paper the experimentation was carried out in thousand times higher level RFR exposure exposure which is the general case i.e. mobile phone in calling mode.

Table 2: Instantaneous heart rate in three conditions

Heart rate	Least exposure	Moderate exposure	Calling mode exposure	p-value
Mean	80.67±8.1	81.29±7.9	80.99±8.1	ns
Maximum	94.78±7.2	97.16±10.4	93±6.5	ns
Minimum	71.26±8.7	73.11±11.1	72.42±7.8	ns

ns= not significant

When the RFR exposure is moderate the scaling exponent (α) is showing the same behaviour as in Ahamed et al.'s study being statistically insignificant [25].

The mean value of scaling exponent (α) in table 2 is low in case of least exposure case, highest in the case of maximum RFR exposure and low in moderate case as well. The above study indicates that α value of HRV increases with statistical significance, when mobile phone sited near chest in calling mode with respect to least radiation and also α value of HRV is not significant if the living got exposed by wireless transmitter station, BTS was considered in this paper. This can be well justified by statistical analysis as p-value is $\leq$0.05 for calling mode exposure condition.

Table 3: HRV parameters in three conditions

parameters	Least exposure	Moderate exposure	Calling mode exposure	p-val1	p-val2
LF (n.u)	43.99± 16.79	46.56± 15.79	45.19± 18.3	0.21	0.39
HF (n.u)	56.01± 16.79	53.44± 15.79	54.81± 18.4	0.20	0.38
LF/HF	0.96±.64	1.09±.41	1.05±.74	0.24	0.31
Sample entropy	1.66±.24	1.58±.40	1.68±.25	0.21	0.42
α	0.91±.09	0.92±.11	0.96±.09	0.53	0.02

n.u = normalised unit, α = scaling exponent in DFA, p-val1 = statistical comparison between least and moderate exposure, p-val2 = statistical comparison between least and calling mode exposure

The mean value of sample entropy in table 2 was low in 11 subjects in case of maximum RFR exposure and was high in 9 subjects when it was compared with the least RFR exposure. The statistical significance sample entropy value was not made because of higher p-value.

The mean value of LF component increases in normalized unit indicated in table 2 which shows that with exposure RFR of either moderate or maximum exposure which is calling mode exposure in this paper also increase in parasympathetic and sympathetic tone. LF is marker of both parasympathetic and sympathetic activity [1-3]. But the change in LF component is selective in 8 volunteers it increases in calling mode case were as in 13 volunteers it decreases in moderate exposure case.

The mean value of HF component decreases in normalized unit indicated in table 2 which shows that with exposure RFR decrease in parasympathetic behaviour of ANS.

The HF is marker of efferent vagal activity [1-4]. But the change in HF component is not stabilized in all the volunteers as it decreases in 11 volunteers during calling mode RFR exposure where as it decreases in 13 volunteers during moderate RFR exposure mode.

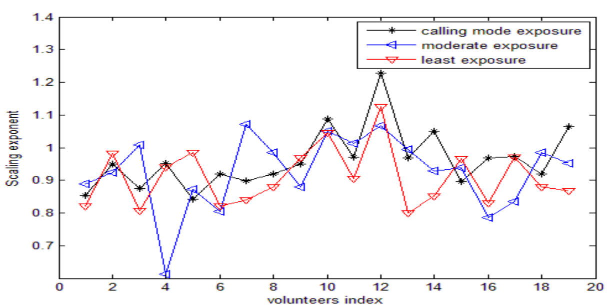

Figure 1: Change in the Scaling exponent.

Overall, HF decreases and LF increases indicating that there is reduction in vagal activity and increase in sympathetic behaviour of ANS. Obviously there will be increase in mean value of LF/HF ratio which can be interpreted as the sympathetic modulation increases with respect to parasympathetic activity. But statistical significance was not observed in either of exposure case.

It can be seen that scaling exponent show significant change during high RFR exposure as mobile phone emit highest power during calling mode, rest in other conditions the low RFR exposure does not having significant impact on HRV parameters.

CONCLUSIONS

The potency of RFR exposure by wireless network on cardiac behaviour based on non linear HRV scaling exponent was examined. The parameters namely, DFA scaling exponent α increases with p-value <0.05 when maximum RFR exposure was recorded, otherwise at low level RFR exposure the α value loses its statistical significance.

This study was limited to the volunteers in least exposure considered as control group. Which mean no additional control group comparison was made. In order to come up with more detailed cardiological effect of wireless network radition more experimentation should be conducted on more number of subject along with more number different of RFR exposure levels..

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