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Effect of mobile phone radiation on heart rate variability

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Abstract

The rapid increase in the use of mobile phones (MPs) 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, and heaviness in the chest among MP users. This paper deals with the neurological effect of electromagnetic fields radiated from MPs, by studies on heart rate variability (HRV) of 14 male volunteers. As heart rate is modulated by the autonomic nervous system, study of HRV can be used for assessing the neurological effect. The parameters used in this study for quantifying the effect on HRV are scaling exponent and sample entropy. The result indicates an increase in both the parameters when MP is kept close to the chest and a decrease when kept close to the head. MP has caused changes in HRV indices and the change varied with its position, but the changes cannot be considered significant as the p values are high.

Keywords: Health; Heart rate variability; Mobile phone; Neurological effect; Sample entropy; Scaling exponent

1. Introduction

The use of mobile phone (MP) has increased rapidly all over the world since the early 1990s. In India it is increasing at the rate of 1.5–2 million a month. MPs operate on wireless technology, with communication via a 900–1800 MHz signal that is pulsed at 217 Hz with an approximate pulse width of 577 µs and duty cycle of 12.5% [1–3]. The signal carries essentially no power when the user is not talking or receiving, but when the user communicates, the power of this pulsed electromagnetic (EM) field reaches a maximum of 250 mW [4].

Although MP is an extremely useful device as it provides mobility, a concern was expressed about its potential biological effects due to the radiated EM field. There were complaints of headache, dizziness, numbness in the thigh, heaviness in the chest, etc. among some MP users. Studies were done to determine whether MPs affect human physiology. Survey studies showed that MPs may cause headache, extreme irritation, increase in carelessness, forgetfulness, decrease in reflexes, clicking sound in the ears, blurring of vision, inflammation in the eyes, and lacrimation [1,2]. Electroencephalogram (EEG) analysis suggests that MPs may affect brain activity, particularly when kept in close proximity to the head [3]. On the other hand, there were studies which could not establish any correlation between the observed neurological effects and the EM radiation from MP [5–7].

The autonomic nervous system (ANS) modulates the cardiac pacemaker and provides beat-to-beat regulation of the cardiovascular rhythm. Heart rate variability (HRV) is a useful signal for quantifying the activity of the ANS [8,9]. The present study attempts to find the neurological effect of EM radiation emitted from MPs, when MP is kept at different positions close to the body, by analysis of HRV.

2. Materials and methods

The sample studied consisted of 14 healthy co-operative male volunteers aged between 24 and 46 (mean = 31.5 years, SD = 6.6 years). Prior to electrocardiogram (ECG) recording, all participants were informed in detail about the purpose and procedure of the study. The ECG was recorded using Biopac® MP100 system, for 30 min under three conditions in the following order: (1) subject without MP, (2) MP kept in shirt's left pocket, so that it is in close proximity to the heart (on the chest), and (3) MP held close to left ear (on the head). The mean heart

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rates of the subjects during the three conditions were also noted.

During the recording duration, subjects sat in an easy chair listening to nonexciting music to avoid any external interference. A break of 30 min was given to subjects in between the three recording conditions. Steps were taken to ensure that no incoming calls or messages were received during the recording period, so that EM radiation from MP was minimum and the same throughout the recording period. The same MP was used for all the recordings.

2.1. HRV measures

The following measures were used for analysing heart rate variations under the three experimental conditions.

2.1.1. Detrended fluctuation analysis (DFA)

The DFA method was proposed to analyze long-term correlation in DNA nucleotides [10]. It has since been applied to various physiological time series [8,11–13]. The DFA method permits the detection of intrinsic self-similarity in nonstationary time series [13]. In the DFA method, the variation of each point in a time series from its mean value is treated as a step in a random walk. Integrating the steps gives the random walk time series. This time series is then divided into windows of size n and the local trends are removed. For a given box size, the root mean square (RMS) value $F(n)$ of this detrended series is obtained. This process is repeated for different window sizes, and a power-law relation between $F(n)$ and n indicates the presence of scaling, given by $F(n) \sim n^{\alpha}$. The parameter α is called the scaling exponent, and indicates the nature of the correlations present in the data. For example, uncorrelated white noise has a scaling exponent of 0.5, $1/f$ noise 1 and Brownian noise 1.5.

2.1.2. Sample entropy (SampEn)

Entropy is a thermodynamic quantity describing the amount of disorder in a system. When applied to time series data, it indicates the regularity of the time series. A number of different measures of entropy have been applied to EEG data. However, most of these measures require large data sets. Pincus [14] introduced the approximate entropy (ApEn) family of parameters for the analysis of short and noisy data sets, and it has since been applied to various physiological time series [15]. A related measure of complexity called sample entropy (SampEn) has been proposed that corrects the bias inherent in ApEn and is less dependent on the length of the time series [16].

$SampEn(m, r, N)$ is the negative natural logarithm of the conditional probability that two sequences within a time series of length N that are similar for m points remain similar for $m+1$ points, within a tolerance of r [15]. Thus, the higher the value of SampEn, greater the irregularity in the time series. Previous studies of physiological time series have used SampEn with values of $m = 2$, and r between 0.1 and 0.25 [16–19]. In this study values of $m = 2$ and $r = 0.2$ are used as they are suitable for HRV analysis.

3. Results and discussion

The results obtained under the three experimental conditions are shown in Tables 1 and 2. The mean heart rates under the three experimental conditions are shown in Table 3. Variation of scaling exponent and SampEn are shown in Figs. 1 and 2, respectively. The statistical significance of data is tested using the 't' test.

3.1. Scaling exponent

HRV analysis using the scaling exponent showed a decrease in SE (H) (scaling exponent with MP on the head) compared to SE (N) (scaling exponent without using MP) in nine subjects (Fig. 1). Also, 10 out of 14 subjects have higher SE (C) (scaling exponent with MP on chest) compared to SE (N).

Table 1
Range of scaling exponent (α)

Status	α	p Value
Without MP (mean ± SD)	0.8890 ± 0.0800	
MP at chest (mean ± SD)	0.9240 ± 0.0998	0.0970
MP at head (mean ± SD)	0.8711 ± 0.0638	0.8409

Table 2
Range of sample entropy (SampEn)

Status	SampEn	p Value
Without MP (mean ± SD)	1.5132 ± 0.3683	
MP at chest (mean ± SD)	1.6251 ± 0.2091	0.2585
MP at head (mean ± SD)	1.4501 ± 0.2684	0.4208

Table 3
Mean heart rates

Status	Mean heart rate	p Value
Without MP (mean ± SD)	74.28 ± 6.73	
MP at chest (mean ± SD)	74.64 ± 6.8	0.8902
MP at head (mean ± SD)	71.92 ± 6.93	0.3683

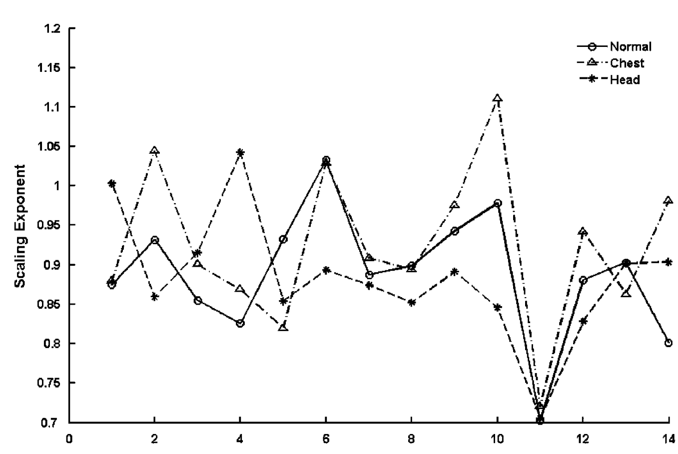

Fig. 1. Variation of scaling exponent.