# EFFECTS OF ELECTROMAGNETIC FIELDS EMITTED BY MOBILE PHONES ON HEART RATE VARIABILITY

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**Abstract: 26 healthy young volunteers were submitted to 900 MHz (2 W) cellular phone exposure and to sham exposure in separate sessions to assess potential changes on heart rate variability (HRV) during the exposure to low-intensity EMF. Each session consisted of 13 minutes in supine rest condition followed by 13 minutes in stand condition. The analyses of the data show that the most of the HRV parameters, both in time and in frequency domain, were no statistically different when recorded during a real or a sham exposure. However, a few statistically significant differences were found in the autonomic response to stand evidencing an increased sympathetic response to stand during exposure.**

## Introduction

With the increasing use of cellular telephones, the potential influence of radiofrequency electromagnetic fields (EMF) on human well-being is a focus of public interest.

Although there is no clear evidence to show harmful physiological effects of EMF at the levels used by mobile phones, there is widespread public concern that there may be potential for harm. Therefore, it is appropriate to conduct sensitive studies to allay any public concern.

The studies of mobile phones and of their possible health impact have been focused on different biological systems and functions [1, 2]. However, to date, there is only a limited knowledge on potential effects (adverse or not) of GSM cellular phones on the autonomic nervous system (ANS) functions controlling cardiovascular variables. Relatively few studies have been focused on the cardiovascular effects of the radiofrequency fields during mobile phone use, and their results have been controversial [3-7].

It is known that the analysis of fluctuations of RR intervals (RRI) around its mean values (the so called Heart Rate Variability (HRV)), is a powerful probe for assessing the ANS functions [8-9]. Several indexes may be derived from HRV analysis in both time and frequency domain and may be used to assess parasympathtic or sympathetic activity and to evaluate ANS state.

Aims of this study is to assess potential changes on time and frequency domain HRV parameters during the exposure to low-intensity EMF produced by GSM cellular phones at 900 MHz. To this purpose, a group of young healthy volunteers was analysed in rest and in stand condition, during real and sham exposures.

## Materials and Methods

Study Population. Participants are 26 healthy young adults, 14 males and 12 females, aged between 21 and 28 years, without any evidence of cardiac disorders. Absence of pre-existing cardiac disorder maximises the sensitivity of the study to detect small changes that may occur.

Recruitment of participants was based on absence of any clinical manifestations of cardiac or nervous system disease. In particular, subjects with obesity, cardiac or pulmonary diseases, stroke or neuro-psychiatric disturbances, and diabetes were not recruited. Subjects were not taking any medication or medical treatment known to affect cardiac and autonomic nervous system. In the twelve hours before the experiments, subjects were asked not to eat chocolates or drink teas, coffees, cola-containing or alcohol beverages. In addition they were instructed not to take a long cellular or wireless call (longer than 60 minutes) in the last 24 hours.

All the subjects were informed in details about the purpose of the study and the experimental procedure. The study was conducted in accordance with the Declaration of Helsinki.

Test Protocol The test protocols was designed to assess cardiac regulatory mechanism in different ANS states during exposure to EMF. The procedure is conducted twice in a double-blind design: once with a genuine EMF exposure and once with a sham exposure (at least 24 hours apart). Each session consists of 13 minutes in supine rest condition followed by 13 minutes in stand condition (sympathetic activation). The rest-to-stand protocol is a standard protocol used in clinical practice to elicit a sympathetic response. In the test subject were analysed during rest (vagal prevalence) and stand (sympathetic prevalence). All the tests were conducted in the morning (from 10 to 12 a.m.) to avoid influence of circadian modulation on the HRV results. The protocol phases are sketched in the following figure


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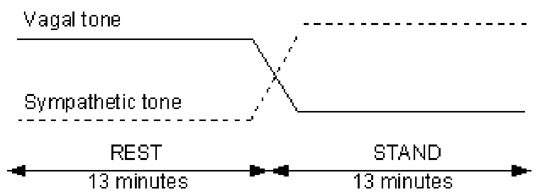


Figure 1. Sketch of the rest-to-stand protocol and the elicited ANS response.

<u>Data recording and exposure system.</u> During the test, electrocardiographic (ECG) leads were continuously recorded (250 Hz sampling frequency, 6.25 µV Least Significant Bit of resolution) using a commercially available Holter system (CLICK Holter, Cardioline, San Pedrino di Vignate Milano, Italy). The ECG leads were stored on the internal solid-state memory of the device. A notebook computer equipped with Cardioline Holter Analysis Software was used to download the ECG signals, store it and for the off-line analysis.

EMF exposure utilizes the normal output of a consumer mobile phone (NOKIA 6310i) at full power (2W) at 900 MHz. The phone is controlled by software to set the exposure parameters to the required frequency and power. The sham or genuine exposure was realised using a 50 Ω "load" or "dummy load", applied using the antenna connector output of the phone. The "load" intercepts the RF signal to the internal antenna on the phone and dissipates the RF in the load, while the "dummy load" looks identical but does nothing, allowing the RF to reach the antenna. In order to control the efficiency of the load a surface scanning of the phone by a near field measurements was performed. No radiated RF fields were measured using the RF load connected to the external antenna output.

To satisfy our experimental protocol, the phones had to emit the same RF power throughout the course of the 26-minute exposure. Since the phones have battery supply, the measurement of long term RF output stability was made by PC data acquisition of the output power during the whole discharge period of the battery. The phone RF power uncertainty during the whole period was below 1% using the highest power level at 900 MHz (2 W). In the first 10 minutes the uncertainty was below 0.4%.

To estimate the level of EMF exposure in the head and in the region of interest (hypothalamus and brainstem), measurements of absorbed radiofrequency power in the head, called Specific Absorption Rate (SAR, W/kg) were made in brain tissue equivalent liquid phantom (Antennessa GEL-900/1800, France). In these measurements 3D step motor robot system (Arrick Robotics, 3 Axis Positioning Table, USA), internal E-field probe (ER3DV4R, Schmid & Partner Engineering Ag., Switzerland) and non metallic phone positioning system were applied using the "touch position" of the phone, according to the EN 50361 CENELEC standard [10].

A system of phone fixation with the possibility of free head movement was designed (Figure 2). All parts of the positioning system were made of non-metallic plastic materials in order to avoid any perturbation of the EMF emitted by the mobile phone.

Figure 2: The positioning system. The phone holder is attached to an adjustable arm which may be adapted to control and reproduce phone positioning in different subjects.

The positioning system has three main parts: a headband, an adjustable arm and a phone holder. The headband allowed free movement of the head without any disturbance of the phone from the adjusted position. By using the adjustable arm the phone may be placed as required and may be adjusted according to the size of the subject under investigation. The phone holder was attached to a bracket glued to the battery pack of the phone.

During the exposure the phone was placed so that its longitudinal axis followed an imaginary line from the entrance to the ear canal to the corner of the mouth, in accordance with the CENELEC standard [10].

<u>Data Analysis</u> From the ECG recorded during the genuine and sham exposure in rest and in stand condition a series of HRV parameters both in time and in frequency domain were calculated according to [8]. Time domain indexes included RR mean, RR standard deviation (SDNN), RMSSD, PNN50, as well as geometric index computed on the RR histograms (TINN and triangular index).

The spectral analysis was performed using a parametric estimators based on autoregressive model [11]. The model order was automatically selected using Akaike Information Criterion [12] in a range between 8 and 15, being 8 the most frequently used. Spectral parameters included Low-Frequency (LF) and High-Frequency (HF) powers in absolute and normalized units and the LF/HF ratio.

In addition, reactivity to the sympathetic stimulus induced by standing was evaluated by computing, for each parameters, the difference between stand and rest values (this difference will be indicated as Δ in the text).

All the parameters were included in the statistical analysis which was performed by a repeated measures


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analysis of variance (ANOVA) comparing sham with exposure condition (p=0.05).

**Results**

*Dosimetry*: The measurements revealed a maximum SAR in the head below 2 W/kg, which is the limit of the European recommendation [13].

The maximum deepness of measurements inside the head allowed by the sensitivity of the system was 5 cm. Therefore an extrapolation to the interested deepness in the phantom (beyond 10 cm) was made by fitting the experimental data through an exponential curve (Figure 3).

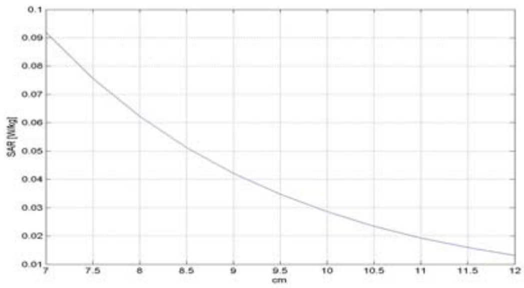


Figure 3: Local SAR (W/kg) extrapolated at the interested area (zoom from 7 to 12 cm of deepness).

The uncertainty from the extrapolation is ±10% while the total uncertainty of the measurement is ±26%. Local SAR values extrapolated in the area of interest were always below 0.02 W/kg.

*HRV results*: All the subjects completed the experimental procedure and the ECG signals could be recorded from all the subject during both of the recording sessions.

An examples of RRI series obtained during the text is shown in figure 4.

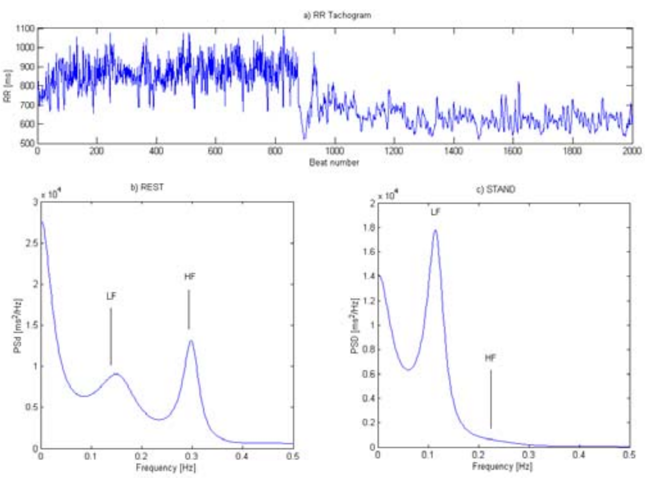


Figure 4. a) RR interval obtained during the rest-to-stand protocol. AR spectrum obtained in rest b) and stand c). The higher LF component in stand documented the augmented sympathetic activation.

The power spectrum or RRI evidence two main rhythms related to the activity of sympathetic and parasympathetic branches of ANS. A high frequency (HF) component, synchronous with respiration (0.3 Hz), is due to the respiration activity and is modulated by vagal tone; conversely, a low frequency (LF) component (centred around 0.1 Hz) is mainly modulated by sympathetic activity. Comparing the plot in figure 4(b) and (c) the increase of sympathetic activity induced by standing is evident.

The analysis of the data shows that the most of the HRV parameters were no statistically different when recorded during a real or a sham exposure (data not presented). However, a few statistically significant differences were observed in the autonomic response to stand. They are described in details in the following paragraphs.

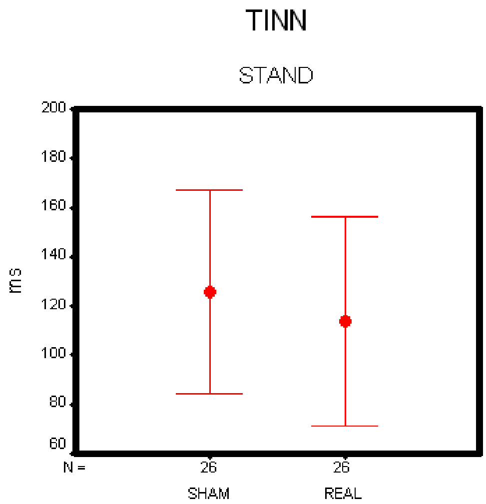


Figure 5: Mean and the standard deviation (over 26 subjects) of the TINN during stand condition evaluated for the sham and real exposure. A statistical difference was found.

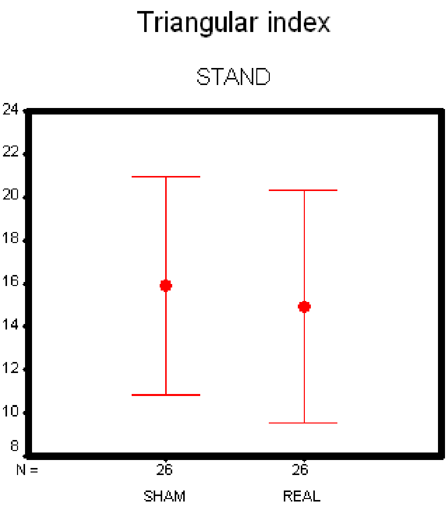


Figure 6: Mean and the standard deviation (over 26 subjects) of the triangular index during stand condition evaluated for the sham and real exposure. A statistical difference was found.


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In the time domain, significant reductions were observed in both the TINN and the triangular indexes (Figure 5 and 6, respectively) during stand condition.

In detail, a decrease of the mean value of 9.3% and of 6.3% for the TINN (Fig. 5) and for the triangular index (Fig. 6), respectively, was found under real exposure. Since these two parameters are both related to the magnitude of variability of cardiac cycle's length, these reduction may be interpreted to an augmented sympathetic activation.

In addition the $\Delta_{SDNN}$ was significantly higher (increase of 14.1%) during real than sham exposure. As SDNN is related to the variance of the RR series, the normal reduction of the variance of the RR intervals due to the reflexes activated by the standing and the consequent sympathetic fibres activation, seems to be accentuated under RF exposure.

As for the frequency domain parameters, the LF power during stand and the $\Delta_{LF}$ increased between real and sham exposure. Interestingly, the changes in stand LF power were gender dependent: in men, LF was higher during real exposure (2.98±0.38 vs. 3.13±0.30 $ms^2$- log values), while in women the parameter was lower during real exposure (2.91±0.43 vs. 2.74±0.35 $ms^{2-}$- log values). A similar trend, even if variations do not reach statistical significance, was observed for the LF/HF ratio. The changes in the spectral parameters confirm the observation derived by time-domain index. They reveal an increased sympathetic activation and a increased reactivity to the stimulus during exposure to low-intensity EMF produced by GSM cellular phones.

## Conclusions

The preliminary results of this study indicate that exposure to a cellular phone at 900 MHz at the maximum power for 26 minutes does not change the main measures of the autonomic regulation of heart.

However, a few indexes manifested a significant but quantitatively small differences when real and sham data are compared. The observed changes support the evidence of an increased sympathetic activation: this observation reveal an EMF effect which is consistent with previous studies [6-7].

Intrestingly, this activation is manifesting only during stand and in response to symphatetic stimulus, never during rest condition. The proposed hypothesis is that RF exposure influences the sympathetic activity, already increased by the standing, through a further activation of the sympathetic fibres that leads to an accellerated heart beat and a reduced variation of heart cycle's variability.

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