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Evaluation of heart rate variability, blood pressure and lipid profile alterations from dual transceiver mobile phone radiation exposure

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Abstract

Objectives: Electromagnetic fields have been reported to alter electrical activities in the brain and heart. However, there is paucity of information on the potential functional alterations that magnetic fields from mobile phone could cause to the heart. This study investigated heart rate variability (HRV), blood pressure (BP) and lipid profile in Wistar rats exposed to electromagnetic field radiation from a dual transceiver mobile phone (DTrMP).
Methods: Twenty-one male albino Wistar rats (140–180 g) were randomly assigned to two major groups positioned 5 m apart as follows: control: no phone (n=7) and treatment group (n=14) continuously exposed to electromagnetic field from Tecno T312 DTrMP 900/1800 MHz set in silence mode. Experimental treatment consisted in 10 min calls/day, directed to this device for a period of six weeks. Seven animals from the treatment group were allowed to recover for a period of two weeks after exposure. HRV, systolic, diastolic and mean arterial BP were noninvasively investigated, while serum lipid profile and heart tissue nitric oxide (NO) activities were determined using standard procedures.
Results: There was significant ($p<0.05$) increase in systolic, diastolic, mean arterial BP and a decrease in HRV. Serum high density lipoproteins decreased, while total cholesterol, atherogenic indices, and heart NO levels increased significantly in the radiation exposed animals. The alterations observed in exposed animals remained unchanged even after the recovery period.
Conclusions: These results suggest that exposure to electromagnetic radiation from dual transceiver mobile phones could be a risk factor to increase in blood pressure.

Keywords: blood pressure; heart rate variability; lipid profile; mobile phone electromagnetic radiation.

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Introduction

The use of multiple transceiver mobile phones has become rampant in our society with little or no concern about their potential health risks, especially on the cardiovascular system [1]. Mobile phone subscription rate is about 7.8 billion worldwide as at December 2018 [2]. The increase in subscription rate is probably related to the emergence of dual transceiver mobile phones. Unlike the conventional mobile phones meant to house a single subscriber identification modules (SIM), multiple transceiver phones offer more flexibility to users owing to their increased SIM capacity [1, 3]. The dual transceivers mobile phones (DTrMP) are known to emit higher electromagnetic energies than their single transceiver prototype [1, 3, 4].

Electromagnetic fields have been reported to alter the electrical activities in the brain [5] and heart [6]. The alterations in the autonomic nervous system are known to induce changes in blood pressure variability [7]. Previous studies have revealed that radiofrequency energies emissions similar to mobile phone radiations can alter biological responses, and references were made to oxidative stress effects [1, 3, 8, 9]. Recently, exposure to electromagnetic fields from multiple transceiver mobile phones has been reported to induce anxiolitic behavior, oxidative stress in the serum, brain and heart tissue in rodents [1, 3]. Furthermore, chronic exposure to this device with at least 10 min/day exposure rate has also been reported to cause disturbance in sleep cycle. This could lead to alterations in cardiovascular system responses [1, 3, 10].

High levels of lipid in the serum have been reported to be a very strong risk factor to cardiovascular system dysfunctions. The alterations in some of the lipid profile variable can cause elevation of blood pressure [11, 12]. Nitric oxide (NO) as endothelial tissue relaxing signaling factor had also been reported to exert some role in the regulation of lipid metabolism and blood pressure by dilating blood vessels [11–13]. Inhibition of this signaling agent (NO) could lead to accelerated atherosclerosis [11, 14]. Therefore, the current study investigates the effects of exposure to electromagnetic radiation from dual transceiver mobile phones on heart rate variability (HRV), blood pressure (BP) and lipid profile in Wistar rats' model.

Materials and methods

Materials

Plastic cages (24″×18″×15″), 900/1800 MHz Tecno T312 DTrMP with whole body SAR values of 0.851 W/kg, mobile phone fitted sized wooden box (4.5''×2''×0.7''), electrocardiography heart rate variability machine by Edan Scientific®, China and blood pressure machine by Kent Scientific®, USA were used.

Experimental protocol

Twenty-one (21) 7–8 weeks old male albino Wistar rats (140–180 g) were randomly assigned to two major groups as follows: Control: no phone (n=7 animals) and treatment group: with electromagnetic field radiation exposure from DTrMP (n=14 animals). The animals were kept freely at room temperature (25 °C) and humidity of 40±10 % at 12 h light/dark cycle condition. They were fed with standard chow and water *ad libitum* in their respective cages positioned at a distance of 5 m apart. Animals in the treatment group were continuously subjected to electromagnetic field radiation from a Tecno T312 DTrMP set in silence mode. The phone works on a 900/1800 MHz GSM network with body SAR value of 0.851 W/kg, and the actual emission during the experiments were not measured. The phone was placed beneath their cages in a fitted sized wooden box [1] as shown in Figure 1.1 below. In order to facilitate comparison with previous studies [1, 3], exposure lasted for 6 weeks with at least 10 min calls/day. After 6 weeks of exposure, seven animals each from the DTrMP electromagnetic field radiation exposed and control groups were assessed for blood pressure and heart rate variability (HRV) as described below. Thereafter, the animals were humanely sacrificed and their tissues were collected for biochemical analyses. The mobile phone was removed from the cage, and the remaining seven animals in the DTrMP electromagnetic field radiation exposed group were kept in the same conditions of initially sacrificed animals for two weeks, after which they were assessed for the experiments listed above. This aspect of the experiment was meant to ascertain whether potential changes due to exposure would be reversed during this period.

Blood pressure (BP) measurement: Blood pressures (BP) of the animals were measured non-invasively using a rat tail cuff connected to volume pressure sensor on a CODA blood pressure machine. Each animal was confined in a cone restrainer, and placed on a

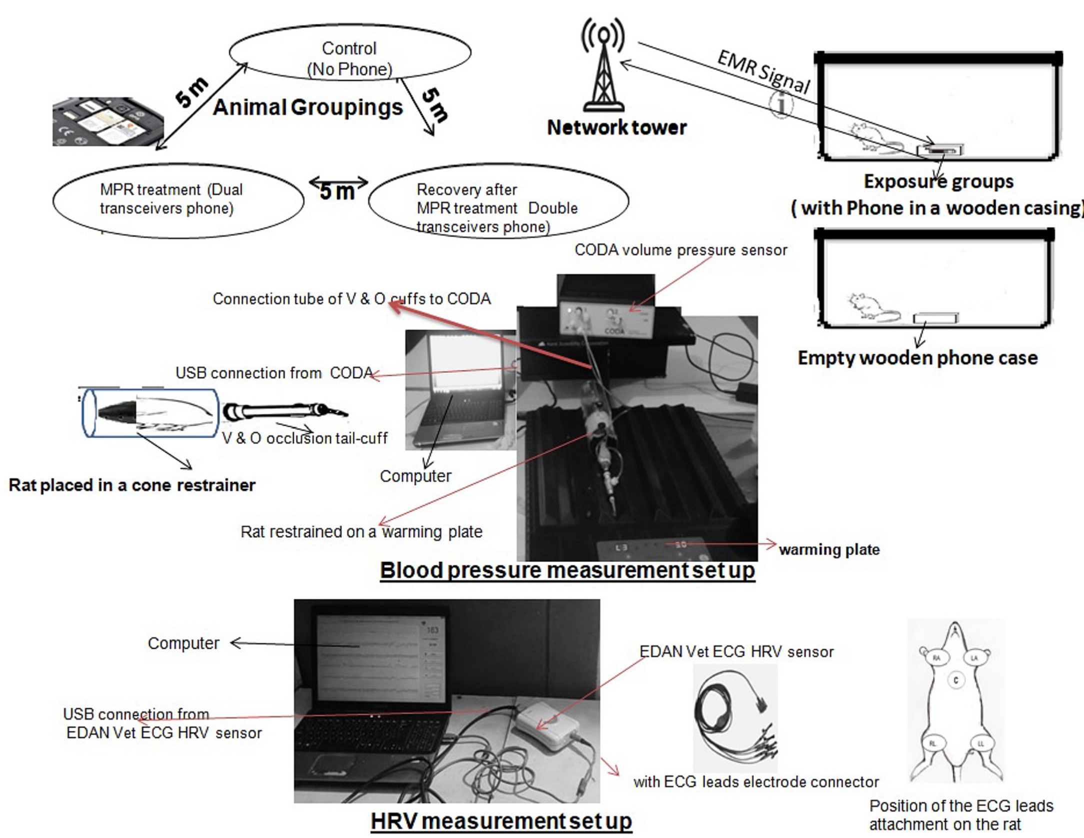

Figure 1.1: Experimental protocol.

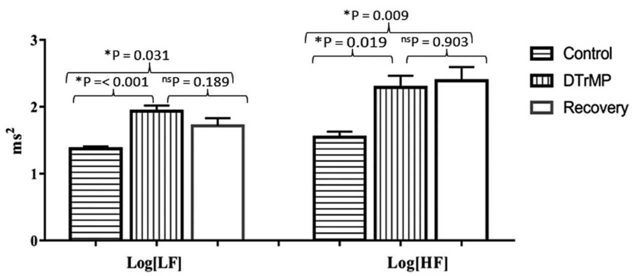

Figure 1: Frequency domain of HRV results of Wistar rats after 6 weeks of exposure to electromagnetic field radiation from a DTrMP. DTrMP: Dual transceiver mobile phone electromagnetic field radiation; *p<0.05; ^{ns}p>0.05.

manually-controlled warming plate with their tail inserted into the V and O cuff of the machines' transducer. Diastolic BP, systolic BP and mean arterial BP were monitored through a transducer connected to computer via data acquisition system (CODA 2095). Blood pressure variables (mmHg) were recorded trice/session and mean value per session was taken [11].

Electrocardiographic heart rate variability (ECG HRV) studies: Animals from each group were anesthetized with intraperitoneal injection of 0.1 ml/100 g 40 mg/ml xylazine and 25 mg/ml of ketamine hydrochloride (1:1). ECG HRV lead electrode of the ECG HRV machine were placed in their respective position on the chest, right arms, right legs, left arms and left legs of the animals. The HRV data were monitored electrocardiographically for 5 min on a computer connected to the ECG HRV transducer as described in Figure 1.1 below. The variable measured in the frequency domain of the HRV were low frequency variation of RR intervals (LF) and high frequency variation of RR intervals (HF), while average time between consecutive R waves (RR interval), ratio of maximum to minimum values of RR interval (Max/Min ratio) and root mean square of successive difference between adjacent RR intervals (RMSSD) were recorded on the time domain [15].

Serum lipid profile studies: Blood samples were collected through intracardiac puncture into plain sample bottles and centrifuged for 10 min at 5000 rpm. The serum was decanted for high density lipoprotein (HDL), triacylglycerol (TG) and total cholesterol (TC) biochemical assay using the procedure highlighted in the commercially available kits by Fortress diagnostics, Antrim, UK. Low-density lipoprotein cholesterol (LDL) concentration was estimated using LDL = TC - (HDL) - (TG/5), while atherogenic indices was calculated using (AI)=[TC-HDL]/[HDL] [16].

Heart tissue nitric oxide (NO) assay: The heart of each animal was dissected and homogenized (1 g of tissue per 4 ml) in 0.1 M phosphate buffer of pH 7.4 at 4 °C. The homogenized tissue was centrifuged using a cold centrifuge machine at 10000 rpm to get a clear tissue fluid for the NO biochemical assay. Griess reagent method was used to quantify nitrites/nitrates activities in the homogenate [1, 17].

Statistical analysis

Data were subjected to analysis of variance (ANOVA) using GraphPad Prism 7. Mean comparison was done using Tukey HSD test (p<0.05). Results was expressed as mean±SEM.

Results

Blood pressure results

Systolic BP, diastolic and mean arterial BP increased significantly in animal exposed to DTrMP electromagnetic field radiation and recovery group compared to their control (p<0.05). Heart rate values were not significantly different when animals of the DTrMP electromagnetic field radiation exposed and recovery groups were compared to control. Systolic BP, diastolic BP, mean arterial BP and heart rate values of animals in the recovery group were not significantly different from the values of the DTrMP electromagnetic field radiation exposed group (Table 1).

Heart rate variability results

Time domain of HRV

RR interval and RMSSD values of animal in both the DTrMP electromagnetic field radiation exposed and recovery groups were not significantly different from their control

Table 1: Systolic, diastolic, mean arterial BP (mmHg) and heart rate (beats/min) results of Wistar rats after 6 weeks of exposure to electromagnetic field radiation from a DTrMP.

	Control	DTrMP	Recovery	p-Value control vs DTrMP	p-Value control vs recovery	p-Value DTrMP vs recovery
Systolic BP	128.70±2.80	186.30±8.41	201.00±12.52	0.002*	<0.001*	0.488^{ns}
Diastolic BP	91.38±3.64	136.30±6.42	122.5±9.62	0.002*	0.021*	0.374^{ns}
MABP	103.50±2.82	152.60±6.06	148.00±2.24	<0.001*	<0.001*	0.712^{ns}
Heart rate	396.10±11.73	421.70±24.14	328.00±38.80	0.794^{ns}	0.232^{ns}	0.081^{ns}

DTrMP, Dual transceiver mobile phone electromagnetic field radiation; BP, Blood pressure; MABP, Mean arterial blood pressure; *p<0.05;^{ns} p>0.05

values. A significant decrease was observed in the max/min values of RR interval ratio (RR Max:Min) of animals exposed to DTrMP electromagnetic field radiation compared to control (p=<0.001), while no significant differences were observed in the values of RR max:min of the recovery group compared to control. RR max:min values significantly increase (p=<0.001), while no significant changes was observed in the RR interval and RMSSD when their values in animals from the recovery group were compared to the DTrMP electromagnetic field radiation exposed group (Figure 2).

Frequency domain of HRV

Values of LF and HF increased significantly in animals exposed to DTrMP electromagnetic field radiation and recovery groups when compared to their controls. LF and HF values of animals in the recovery group were not significantly different from the values of the DTrMP electromagnetic field radiation-exposed group (Figure 1).

Lipid profile

Serum high density lipoprotein (HDL) and total cholesterol (TC) levels decreased significantly, while atherogenic indices (AI) increased significantly when their values in animals exposed to DTrMP electromagnetic field radiation were compared to the control. TG and LDL levels were not significantly different in the DTrMP electromagnetic field radiation exposed animals and the recovery group compared to control. TC and HDL levels were not significant, while AI increased significantly when their values in animals of the recovery group were compared to control. HDL, LDL, TC, TG and AI levels in animals of the recovery group were not significantly different from the values of the DTrMP electromagnetic field radiation exposed group (Figures 3, 4, and 5).

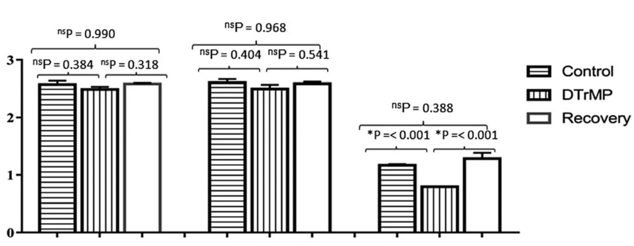

Figure 2: Time domain of HRV results of Wistar rats after 6 weeks of exposure to electromagnetic field radiation from a DTrMP. DTrMP: Dual transceiver mobile phone electromagnetic field radiation; *$p<0.05$; $^{ns}p>0.05$.

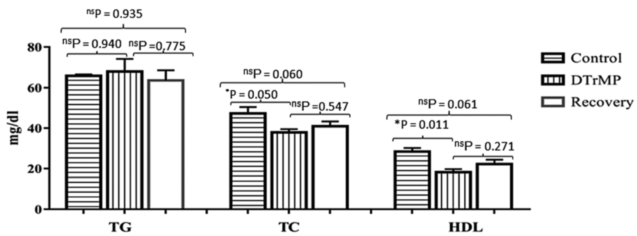

Figure 3: Serum high density lipoprotein (HDL), triglycerides (TG) and total cholesterol (TC) results of Wistar rats after 6 weeks of exposure to electromagnetic field radiation from a DTrMP. DTrMP: Dual transceiver mobile phone electromagnetic field radiation; *$p<0.05$; $^{ns}p>0.05$.

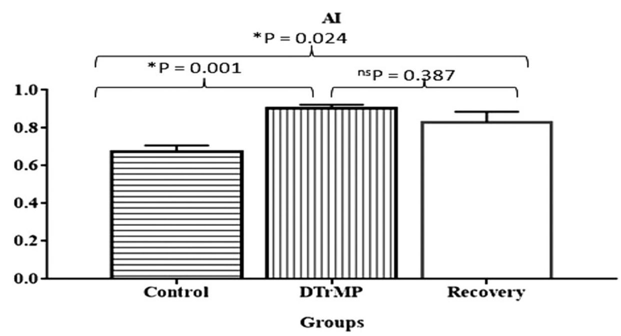

Figure 4: Serum atherogenic indices (AI) results of Wistar rats after 6 weeks of exposure to electromagnetic field radiation from a DTrMP. DTrMP: Dual transceiver mobile phone electromagnetic field radiation; *$p<0.05$; $^{ns}p>0.05$.

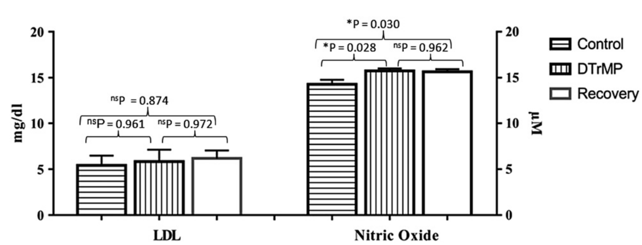

Figure 5: Serum low density lipoprotein (LDL) and nitric oxide activities results of Wistar rats after 6 weeks of exposure to electromagnetic field radiation from a DTrMP. DTrMP: Dual transceiver mobile phone electromagnetic field radiation; *$p<0.05$; $^{ns}p>0.05$.

Nitric oxide (NO) activity

Heart tissue nitric oxide from animals in both the DTrMP electromagnetic field radiation-exposed and recovery groups significantly increased compared to control ($p<0.05$), while it values in animals of the recovery group were not significantly different from that of DTrMP electromagnetic field radiation exposed group (Figure 5).

Discussions

Findings from this study present that exposure to electromagnetic field radiation from dual transceiver mobile phone significantly increased the level of systolic, diastolic and mean arterial blood pressure. This could be as result of increase in serum lipid profile that resulted into increased level of atherogenic indices which can potentially increase peripheral resistance, or increase in the sympathetic drive to the heart musculature that could possibly cause an increase in the stroke volume. Variations in the systolic, diastolic and mean arterial blood pressures had been reported in previous studies to be directly proportional to variation in the stroke volume and tissue peripheral resistance [18, 19]. This report on blood pressure is also consistent with the findings of Saili et al. [20] who reported an increase in the arterial blood pressure in rabbits exposed to 2.45 GHz of wireless fidelity (WIFI) radiations. However, they associated the observed increase in blood pressure to the direct action of radiofrequency on Ca^{2+} and Zn^{2+} homeostasis alterations, rather than the increase in lipid profile as observed in the current study. Braune et al. [21] have also observed that 35 min exposure to Global System for Mobile communication simulated signal increased blood pressure by 10 % in volunteer individuals, while Thomas and Tenforde [22] illustrated a rise in the blood pressure of individuals working under magnetic field environment.

The present study also showed that electromagnetic field exposure from dual transceiver mobile can alter some variables in heart rate variability (HRV) via changes in the electrical activities of the heart. In the time domain of the HRV, the average time between consecutive R waves (RR interval), ratio of maximum to minimum values of RR interval and RMSSD in heart electrocardiogram decreased in the radiation-exposed group. These observations were similar to the report of Bortkiewicz et al. [23] investigating radio and TV transmission workers. Increased LF and HF levels obtained in our study agree with the findings of Andrzejak et al. [24] and Havas et al. [25] on the effects of radiofrequency electromagnetic field exposure in humans.

High levels of serum HDL and atherogenic indices in the present study suggest dyslipidemia [29]. These observations are similar to the reports of Luo et al. in their study of electromagnetic fields exposure to rats [27]. The nonsignificant increase in serum LDL observed is concordant with the study of Güler et al. [28] where they exposed guinea pigs to different intensities and duration of electromagnetic fields.

The variation of serum lipids observed in the present study can be as a result of electromagnetic field ability to penetrate and act on cells by changing their membrane potential, which leads to alterations in the serum biochemical processes [29, 30], or alterations through oxidative stress mechanism and inflammatory cells responses [1]. High (35 GHz) or low (50 Hz) frequency electromagnetic field radiations have been reported to also trigger inflammatory response of macrophages from the bone marrow of rats [31, 32]. The responding inflammatory cells can enter the blood vessel and take up cholesterol with other fatty substances to build up plaques forming arteriosclerosis [33], thereby causing an increase in the blood pressure observed. The increased level of NO activities in the heart can be due to compensatory response to increase in blood pressure [11] or inflammatory response in the cardiomyoctes [31].

Inability of the blood pressure to recover despite the decrease in heart rate and increased levels of NO activity in the heart could be as a result of increased peripheral resistant resulting from increase in lipogenesis and atherogenic indices, or due to increase level of stroke volume resulting from increase in the force of myocadial contraction which are factors known to cause increase in the arterial blood pressure [18] observed in the present studies. More so, it could also result from loss in the sensitive complex neurocardiac control [34] resulting from the increased level of LF, HF and decreased RMSSD values that leads to decrease in the heart rate variability reported in the present work. Thus, this enhanced sympathetic drive caused by direct interaction of electromagnetic fields radiated from mobile phone with the electrical activities of the heart [1, 35]. The enhanced sympathetic activities could also be as a result of increased oxidative stress and anxiety as previously reported [1, 3, 36].

The limitation to present study was the inability to measure energy density inside the cages where the animals were placed with the mobile phone. However, all experiments were performed in a quite laboratory with zero interference to charges from other electric appliances. Furthermore, energy density in a space, room or the laboratory environment, where the experiment were conducted in reality would be too difficult to monitor. This situation emanates from fluctuations in the strengths of signal transmissions all the time of the day from communication towers of the network provider to transceivers on the mobile phone.

Conclusions

This study suggests that exposure to radiation from dual transceiver mobile phones electromagnetic fields could be a risk factor to rise in blood pressure in cardiovascular system dysfunction of unknown pathology.

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