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(RESEARCH ARTICLE)

The effect of electromagnetic waves of mobile phones on DNA, RNA content and kidney function in rats before, during and after pregnancy and their offspring

Amira Abd El Raouf and Shenouda M Girgis *

Department of Cell Biology, Biotechnology Research Institute, National Research Centre, 33 El-Bohouth St. (former ElTahrir St.)- Dokki, Giza, P.O.12622, Egypt.

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Abstract

Increasing use of mobile phones in daily life with increasing adverse effects of electromagnetic radiation cause many concerns about their effects on human health. This study was designed to investigate the effect of exposure to a 900-MHz electromagnetic waves (EMW) produced by mobile phones on nucleic acids (DNA and RNA), protein content, kidney function (levels of urea and creatinine) and oxidative stress (malondialdehyde, MDA level) in rats before, during and after pregnancy periods and their offspring. A total of 32 Wistar albino female rats were divided into 4 equal groups (8 each): 1- unexposed (control group); 2- pre-pregnancy (2 h/d for 21 d) EMW-exposed group; 3- during pregnancy (2 h/d for 21 d) EMW-exposed group; 4- during and after pregnancy (2 h/d for each period) EMW-exposed group. Dams, new born and young rats (40-50 g) of all groups were sacrificed and kidney tissues were harvested for determination of parameters under investigation. A high significant decrease in DNA, RNA and protein levels were found of all periods in exposed groups compared to control. No difference in protein, DNA and RNA content in new born and young rats of pre-pregnancy EMW exposed rats, however these parameters were increased significantly in new born and young rats of both during and during and after pregnancy exposed groups compared to control. There was no difference in new born kidney function and oxidative stress of all exposed groups compared to control. However, these parameters were increased significantly in young rats of both during and during and after pregnancy exposed groups as well in all exposed groups compared to control. In conclusion, the EMW propagated from mobile phones have harmful effects on DNA, RNA and protein content as well kidney function and oxidative stress of exposed rats and their offspring. Therefore, people may use various antioxidants and avoid exposure to EMW for a long periods to prevent the potential adverse effects of exposure to EMW.

Keywords: EMW; Mobile phones; DNA; RNA; Protein; Kidney function; Rat and offspring

1. Introduction

Increasing use of mobile phones in daily life with increasing adverse effects of electromagnetic waves (EMW)on some biological and biochemical processes, cause many concerns about their effects on human health. Measurements and exposure calculations have shown that a radiofrequency field exposure is dominated by mobile phone use [1]. According to WHO, EMW pollution is defined one of the most common problems of human and environmental health [2; 3]. In fact, studies have shown that the exposure to EMW can affect liver, kidneys and nervous system [3-5].

The biological impacts of EMW can be classified as thermal and non-thermal. Thermal effects are associated with the heat created by EMWs in a certain area of the body resulting in a rise in temperature [6]. Nonthermal mechanisms are

* Corresponding author: Shenouda M Girgis
Department of Cell Biology, Biotechnology Research Institute National Research Centre, 33 El-Bohouth St. (former ElTahrir St.)- Dokki, Giza, P.O.12622, , Egypt.

some other changes in the tissues in association with the amount of energy absorbed [7; 8]. It has been observed that this effect is mediated by generation of reactive oxygen species (ROS) [9], thus resulting in oxidative stress [10].

Some studies suggested that low energy EMW emitted from a cellular phone may cause biological effects, such as DNA damage and changes on oxidative stress in exposed rats [11]. EMW is able to induce a genotoxic response in rat offspring exposed to EMW during the embryogenesis [12]. Exposure to mobile phone (900–1800 MHz) during pregnancy induced oxidative stress (increase in malondialdehyde; MDA level) in tissues of dams and their offspring [13; 14]. MDA is a biomarker for lipid peroxidation, it is a highly toxic molecule and it has been implicated in a range of disease pathologies by producing oxidative damage that promotes production of reactive oxygen species (ROS) on renal tissue [15-17].

Moreover, other studies have reported that exposure to EMW results in oxidative stress in many tissues of the body. Exposure to EMF is known to increase free radical concentrations or reactive oxygen species (ROS). These ROS can damage cellular components such as proteins, lipids and DNA [18; 19]. In addition, EMW was found to induce a significant DNA damage and oxidative stress (increase in MDA) in whole body exposed adult female pregnant rats [20; 21]. Further studies revealed a significant elevation in MDA level, a reduction in protein amounts and mRNA expression in pregnant female rats and their new born [22].

Investigations in Wistar and Sprague-Dawley rats provided consistent evidence for oxidative stress occurring after EMW exposure in the brain and testes and some indication of oxidative stress in the heart. Observations in Sprague-Dawley rats also seem to provide consistent evidence for oxidative stress in the liver and kidneys [23].

Human and animals studies have shown that exposure to EMW during pregnancy and/or their offspring during their neonatal life may exhibit some changes in biochemical parameters [24; 25], increasing oxidative stress with a significant elevation in MDA level [26]. It was found that EMW might produce impairments in some biochemical changes including a significant increase ($p < 0.05$) in urea and creatinine, and MDA levels in brain, liver and renal tissue of albino rats [27].

Therefore, the aim of this study was to investigate the effects of whole body exposure of albino female rats before, during and after pregnancy periods and their offspring (new born and young of 40- 50 gm) to a 900-MHz EMW produced by mobile phones on DNA, RNA and protein content, kidney function (urea and creatinine) and MDA level as a marker of oxidative stress.

2. Material and methods

2.1. Animals

A total of 32 Wistar albino mature female rats obtained from the Animal house of the National Research Centre, Dokki, Giza, Egypt were used in the study. The animals were housed in a controlled environment of temperature (22 °C ± 3). All animals were received normal rat food and tap water ad libitum and left 1 week for adaptation. Experiments complied with the ARRIVE guidelines and was carried out in accordance with the National Institutes of Health guide for the care and use of Laboratory animals (NIH Publications No. 8023, revised 1978) .

2.2. Experimental design

Whole-body exposure for 2h/day at average specific absorption rate of 0.974 W/Kg used signal generators with horn antenna. Rats were divided into 4 equal groups (8rats/group): 1- unexposed (control group); 2- pre-pregnancy (2 h/d for 21 d) EMW-exposed group; 3- during pregnancy (2 h/d for 21 d) EMW-exposed group; 4- during and after pregnancy (2 h/d for each period) EMW-exposed group. The experimental groups were exposed to mobile phone (900-MHz) during all periods of exposure. At the end of each period, dams and their offspring (40-50 gm) of all groups were sacrificed and kidney tissues were harvested for determination of DNA, RNA and protein content as well some biochemical analysis (urea and creatinine levels) for kidney function examination and MDA for oxidative stress were accomplished.

2.3. Methods

2.3.1. Determination of DNA, RNA and protein content

Determination of Nucleic acids (DNA and RNA) were determined using a simplified method for determination of specific DNA and RNA using quantitative PCR and an automatic DNA sequencer [28]. Total proteins were estimated using the Biuret method [29].

2.3.2. Biochemical examinations

Analysis of oxidative enzyme malondialdehyde (MDA)

Kidney tissues were homogenized in 20mm Tris-HCI (pH 7.4). Homogenates were centrifuged at 6000g for 30 min. MDA levels in the supernatants were determined using a spectrophotometric assay kit according to the manufacturer's instruction. The absorbance of the resultant pink product was measured at 534 nm according to [30]. Tissue MDA levels were calculated as nmol MDA/g tissue.

Kidney Function

Urea and creatinine concentration of control and exposed rats of each group were determined using commercial kits (Architect c 16,000, Autoanalyzer, Abbott Diagnostics, Waltham, MA).

2.4. Statistical analysis

All results were expressed as mean ± standard errors (SE). Comparison between mean values of control and other exposed groups was carried out using one-way analysis of variance (ANOVA) using SAS program (SAS, 2012). *P* values of <0.05; < 0.01 and < 0.001 were considered to indicate statistical significance. Duncan's test was used for intergroup comparisons [31].

3. Results

The results of the present study revealed a high significant decrease in DNA, RNA and protein level of pre-pregnant period exposed dams and a very high significant decrease in DNA, RNA and protein levels for dams either during or during and after pregnancy periods exposed groups compared to control group (Table 1A).

Table 1A Effect of mobile phone radiation on protein, DNA and RNA content of pregnant female rats

Groups	Protein (mg/g)	DNA (mg/g)	RNA (mg/g)
Control	9.992 ±0.2388	0.345 ±0.0046	0.225 ±0.005
pre-pregnancy exposure	0.721±0.376**	0.321 ±0.005	0.2089 ±0.0046**
During pregnancy exposure	6.859 ±0.210***	0.254±0.007***	0.2006 ±0.003***
During and after pregnancy exposure	6.032 ±0.163***	0.2487±0.011***	0.1957 ±0.0049***

Values represent means± standard errors (n=8).

Table 1B Effect of mobile phone radiation on kidney function and oxidative status of pregnant female rats

Groups	Urea (mg/dl)	Creatinine(mg/dl)	MDA (nmol/g)
Control	15.789 ± 0.0934	0.5833 ± 6.0086	7.9 ± 0.73
Pre-pregnancy exposure	15.8808 ± 0.1016	0.6886 ± 0.0114	9.3 ± 1.1**
During-pregnancy exposure	18.7649 ± 0.142**	0.8543 ± 0.0264**	9.95 ± 1.15***
During and after–pregnancy exposure	19.2565 ± 0.1887***	0.9087 ± 0.0246***	10.1 ± 1.39***

Values represent means± standard errors (n=8).

Concerning the effect of mobile phone radiation on kidney function and antioxidant of pregnant female rats (Table 1B), there was no increase in urea and creatinine level in pre-pregnancy exposed group but the MDA level was significantly high compared to control group. In addition, it was found a high significant increase in urea, creatinine and MDA level in the exposed group during pregnancy period. In addition, a very high significant increase in these levels was found for group exposed during and after pregnancy periods compared to control group.

The results presented in Table (2A), revealed no difference in protein and RNA content in new born of pre-pregnancy EMW exposed rats, however, DNA content was increased significantly compared to control. Protein, DNA and RNA levels were increased significantly in new born rats of both during and during and after Pregnancy exposed groups compared

to control. For kidney function examination (urea and creatinine levels) and analysis of oxidative stress (MDA level). There was on difference in new born kidney function of all exposed groups compared to control in regard to these parameters (Table 2b).

Table 2A Effect of EMW on protein, DNA and RNA levels in new born rats of exposed dam's pre and during pregnancy periods

Groups	Protein (mg/g)	DNA (mg/g)	RNA (mg/g)
Control	4.363± 0.314	0.177 ± 0.004	0.147± 0.016
New born of Pre- pregnancy exposed dams	2.313± 0.054***	0.128 ± 0.005***	0.106± 0.0039**
New born of during pregnancy exposed dams	2.115 ± 0.021***	0.12± 0.015***	0.10± 0.004***

Values represent means± standard errors (n=25).

Table 2B Effect of EMW on Kidney function and oxidative stress in new born rats of pre and during pregnancy exposed dams

Groups	Urea (mg/dl)	Creatinine (mg/dl)	MDA (nmol/g)
Control	10.569 ± 0.718	0.333 ± 0.024	5.616± 0.315
New born of Pre- pregnancy exposed dams	11.184±1.130	0.359 ± 0.012	6.827± 0.381
New born of during pregnancy exposed dams	11.844 ± 0.583	0.37± 0.013	7.065 ± 0.393

Values represent means± standard errors (n= 25). MDA: malondialdehyde.

No difference in protein, DNA and RNA content in young rats of pre-pregnancy exposed rats compared to control. However, protein, DNA and RNA levels were increased significantly in young rats of both during and during and after pregnancy exposed groups compared to control (Table 3A).As well, No difference in urea, creatinine and MDA content in young rats of pre-pregnancy exposed rats compared to control. However, those levels were increased significantly in young rats of both during and during and after pregnancy exposed groups compared to control (Table 3B).

Table 3A Effect of EMW on protein, DNA and RNA content of young rats of pre- and during pregnancy exposed dams

Groups	Protein (mg/g)	DNA (mg/g)	RNA (mg/g)
Control	6.228 ± 0.250	0.306 ± 0.0075	0.194± 0.008
Young rats of pre-pregnancy exposed dams	5.034± 0.373**	0.258 ± 0.043***	0.164± 0.009***
Young rats of during pregnancy exposed dams	4.387± 0.101***	0.215± 0.143***	0.156 ± 0.016***

Values represent means± standard errors (n= 25).

Table 3B Effect of EMW on kidney function and oxidative stress in young rats of pre and during pregnancy exposed dams

Groups	Urea (mg/dl)	Creatinine (mg/dl)	MDA (nmol/g)
Control	15.447 ± 0.201	0.584 ±0.021	7.51±0.484
young rats of pre-pregnancy exposed dams	16.814± 0.227**	0.625 ± 0.0184**	8.946± 1.063**
young rats of during pregnancy exposed dams	17.1904±0.3417***	0.814±0.015***	10.569±0.718***

Values represent means± standard errors (n=25).

4. Discussion

To our knowledge a limited number of studies have investigated the effects of EMW on nucleic acids, protein and MDA levels as well kidney function in female rats during different periods of pregnancy. Therefore, this study was designed to investigate the effects of EMW produced by mobile phones (900-MHz) exposure in Wistar albino female rats before,

during and after pregnancy periods and their offspring (new born and 40- 50 gm pups) on DNA, RNA and some biochemical parameters such as protein content and kidney function (urea and creatinine levels) and antioxidant status (MDA) as a marker of oxidative stress.

The results revealed a high significant decrease in DNA, RNA and protein level of all pregnancy periods in female rats exposed groups compared to control. That coincide with [21] Al-Chalabi (2017) who found an increase in the level of DNA damage in EMW whole body exposed adult female pregnant rats.

The increase in lipid peroxidation (increase in MDA level) in EMW exposed rats in our study is a result of increased ROS production, which in turn leads to excessive peroxidation of polyunsaturated fatty acids, causing tissues damage [10]. This in the same line with [13;14], who found that exposure to mobile phone (900–1800 MHz) during pregnancy induced oxidative stress (increase in MDA level) in kidney tissues of dams and their offspring

It was previously reported that EMW produces an abundance ROS which are directly involved in oxidative damage to cellular macromolecules, such as lipids, proteins, and nucleic acids (DNA and RNA) in the tissues [32]. The increase in MDA levels of renal tissue demonstrated the role of oxidative mechanism induced by 900-MHz mobile phone exposure in rats [16]. It was proposed that EMF might cause increased activity in free radicals, such as superoxide anion and hydrogen peroxide in living organisms, and can affect the antioxidant activity of living cells [33]. Furthermore, as a result of energy transfer in the tissue by EMF, molecular O_2 is transformed to free radicals, and as a result of increased levels of O_2 radicals, MDA content in those tissues have increased [34].

In addition, the oxidative stress occurred in the brain, liver, and kidney of adult Albino rats exposed to the effect of 900-MHz EMW was investigated [27]. A significant increases in tissue MDA and in urea and creatinine levels in kidney tissues in the exposed groups compared to control was reported. The author suggested that 900-MHz EMF may exacerbate oxidative stress and impair kidney functions, which support our findings. A very high significant increase in urea and creatinine levels was found in young rat of exposed dams in our study. However, it was found that no difference in urea and creatinine levels in young rat whose mothers were exposed to 900-MHz of EMW during pregnancy [35].

It has been reported that exposure to electromagnetic field in Sprague-Dawley rats caused a decrease in the total protein concentration [36]. The decrease in total protein concentration may be related to the decrease of their synthesis and may indicate a diminished antioxidant protection and that coincide with our findings. No difference in DNA and RNA content in new born of pre-pregnancy EMW exposed rats, however these parameters were increased significantly in new born rats of both during and during and after pregnancy exposed dams compared to control. In consistent to our results, EMW was able to induce a genotoxic response such as DNA damage during the embryogenesis in rat [12].

No difference in protein, DNA and RNA content in young rats of pre-pregnancy exposed dams. However, these parameters were increased significantly in young rats of both during and during and after pregnancy exposed dams compared to control. The same findings were found regarding urea, creatinine and MDA content in all exposed groups compared to control. That may due the withdrawal of EMW during and after pregnancy periods from the pre-pregnancy exposed dams, which correct the oxidative stress and some biochemical changes induced in kidney tissues of pre-pregnancy albino rats exposed to 900 MHz of EMW [27].

5. Conclusion

Our study showed that the EMW propagated from mobile phones have harmful effects on DNA, RNA and protein content as well kidney function and triggers oxidative stress (increased in MDA level) of exposed rats and their offspring. Therefore, as reported in many studies, people may use various antioxidants such as vitamin E, melatonin, selenium and ferulic acid and avoid exposure to EMW for a long periods especially in pregnancy and early childhood periods to prevent the potential adverse effects of exposure.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors declare no conflict of interest.

Statement of ethical approval

This study conform the ethical requirement and animals health and care guidelines of our Institute. In addition, experiments complied with the ARRIVE guidelines and was carried out in accordance with the National Institutes of Health guide for the care and use of Laboratory animals (NIH Publications No. 8023, revised 1978) .

Statement of informed consent

This study doesn't involve information about any individual e.g. case studies; survey; interview etc.

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