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Amelioration the Effect of Electromagnetic Field on Male Rats Using Glutathione Enhancer

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ABSTRACT

The possible biological effects of electromagnetic fields became an attractive public health concern, due to the wide use of mobile phones. Therefore, the present work was designed to study the effect of exposure in male albino rats to electromagnetic radiations(EMR), produced from a cellular tower for mobile telephone, on some redox elements (copper, iron, zinc and manganese), hepatic glutathione (GSH) and glutathione peroxidase (GSH-PX) in addition to the stress hormone ACTH (adrenocorticotrophic hormone), serum total proteins and total lipids with evaluation of the possible protective role of the antioxidant Glutathione Enhancer. The rats were arranged into three groups: the control unexposed, the exposed untreated and the exposed treated groups. Both exposed groups were subjected to electromagnetic field at frequency of 900–930 MHz, for 24h/day for 8 weeks, at the same time the third exposed group was supplied with oral injection of the antioxidant three times/week. Results showed that serum levels of zinc, copper, iron and hepatic tissue contents of reduced glutathione and glutathione peroxidase activity and serum total proteins were reduced while serum level of ACTH and manganese were increased in the exposed group compared to control unexposed. Most data of the studied parameters showed improvement after treatment supporting the suggestive protective role of Glutathione Enhancer against the effect of EMR emitted by mobile base station.

Key words: *Mobile Base Station, Glutathione, Glutathione Peroxidase,ACTH, Iron, Zinc, Copper, Manganese, Oxidative Stress.*

INTRODUCTION

Public exposure to electromagnetic radiation (radio frequency and microwave) is growing exponentially worldwide with the introduction and use

of cordless phones, cellular phones, pagers and antennas in communities designed to transmit their RF (radiofrequency) signals. Deteriorating effects include DNA breaks, chromosomal aberrations, increased free radical production, premature aging and changes in cell membrane function are found. Besides, other symptoms such as memory loss, learning impairment, headaches and fatigue, sleep disorders, neurodegenerative conditions**,** reductions in melatonin secretion, and cancer are encountered [(1)]. Electromagnetic radiation (EMR) or radiofrequency fields of cellular mobile phones caused these biological effects by increasing free radicals, which appear mainly to enhance lipid peroxidation, and by changing the antioxidant defense system of human tissues, thus leading to oxidative stress [(2-3)].

The ever increasing use of cellular phones and the increasing number of associated base stations are becoming a widespread source of nonionizing electromagnetic radiation [(4)]. Each base station covers phone use in a specific area as great as 10km in rural areas or as small as 0.2 – 0.5 km in towns where the demand is greater [(1)]. Therefore, electromagnetic pollution will no longer remain concentrated in population centers, nor will radio transmitters be confined to non-residential zones [(5)].

Trace elements including iron, copper, zinc and manganese are necessary for normal growth, development of animals and also required for reproduction [(6-7)]. Exposure to EMF may induce alterations in cell membrane activity, affect enzyme activities, protein and DNA synthesis [(8-9)], alterations in melatonin and hormone levels [(10)], Ca homeostasis [(11)] as well as changes in other important ions such as Cu and Zn which serve as co-factors for many biological reactions [(12)]. Superoxide dismutase enzymes contain the metal ion copper, zinc, manganese and iron cofactors that catalyses the breakdown of the superoxide anion into oxygen and hydrogen peroxide [(13-14)]. Cellular antioxidant defenses were evaluated by measuring manganese superoxide dismutase copper-zinc superoxide dismutase and glutathione peroxidase [(15)].

Glutathione peroxidase is an enzyme containing four selenium cofactor that catalyzes the breakdown of hydrogen peroxide and organic hydroperoxides[(16)]. The thiol tripeptide GSH (γ Glu-Cys-Gly) is also an abundant metabolite in plants, where it performs multiple functions, including transport and storage of sulfur, control of cell redox status, progression of the cell cycle, protection of protein thiol groups, and detoxification of heavy metals

and xenobiotics[17]. GSH is an important antioxidant and is also used as a substrate for glutathione reductase and glutathione peroxidase (GSH-PX) [18]. The toxicity of free radicals can be directly mitigated by free radical scavengers and by indirect antioxidants[19]. Molecules that directly scavenge radicals include the tocopherols (vitamin E) ,ascorbic acid (vitamin C), β-carotene and Glutathione [20-21].

The aim of the present study was to study Mobile Base Station-induced oxidative stress, which promotes production of reactive oxygen species (ROS), and to study the suggestive protective role of Glutathione Enhancer against the possible oxidative damage.

MATERIALS AND METHODS

Twenty four male albino rats (*Rattus rattus*), weighing about 120 – 150 g were used in the study. The rats were bred at the animal house of the Nuclear Research Center, caged in plastic cages, and were given food and water *ad-libitum.* Animals were randomly divided into three groups (8 rats each): control group, electromagnetic radiation (EMR) exposed group and EMR exposed+glutathione-treated group.

The exposed groups were subjected to electromagnetic radiation produced from a cellular tower (base station) for mobile telephone constructed on a building at frequency of 900-930 MHz, power density of 0.05 mW/cm^2 at the site of exposure with distance of 15 meters in front of the antenna, 24 hours/day for 8 weeks. The field strength levels emitted by the tower was measured with isotopic probe specified for measuring high frequency and the compartment shaped to standard IEEE C 95, 1995[22].

Antioxidant Glutathione Enhancer produced by International Business Establishment Co. (IBE Pharma) SPI, distributor Nova Pharm., Egypt. Each tablet (512.5 mg) contains 50 ng glutathione, 50 mg L-Cysteine, 100 mg N-acetyl cysteine, 50 mg L-methionine, 250 mg vitamin C, 12.5 mg selenium. Each two tablets were dissolved in 102.5 ml distilled water to obtain concentration of 10mg/ml and the suspension was given orally at dose 1ml/100 g/bwt. The treated group was given antioxidant orally using a stomach tube three times/week for two months.

At the end of 8weeks and after an overnight fasting the animals were decapitated, blood was centrifuged and sera were separated and kept frozen at

–20°C. Cu, Zn, Mn and Fe were assayed by atomic absorption/flame-emission spectrophotometer(Buck 210VGP) using acetylene flame and hollow cathode lamp. Serum levels of ACTH was measured by radioimmunoassay technique using commercial kits purchased from DPC (Diagnostic Products, Corporation, Los Angeles, USA). The calorimetric determination of serum total proteins and total lipids were based on the methods according to Tietz[23] and Kinght,*et al.*[24] respectively. Liver was frozen for estimation of hepatic tissue contents of GSH and GSH-Px activity [25-26].

Statistical Analysis

The data were analyzed by ANOVA test using MSTAT-C computer programme.

RESULTS

Results of serum iron, copper, zinc, cu/zn ratio and manganese are presented in Table 1 which showed that the mean values of serum copper and iron in the exposed group was significantly lower ($p<0.001$), compared to control and treated groups. Similarly, serum zinc in the exposed group was significantly lower ($p<0.01$) compared to control group. To the contrary serum manganese level was significantly higher ($p<0.01$) in the exposed group compared to control and treated groups. Copper/Zinc ratio was calculated and its mean value was significantly higher in exposed treated and untreated groups compared to control group.

Table 1. Mean ±S.D. of serum iron, copper, zinc, zn/cu and manganese in control and exposed groups (untreated and treated).

Parameters / Groups	Iron (µg/dl)	Copper (µg/dl)	Zinc (µg/dl)	Cu/Zn	Manganese (µg/dl)
Control: Mean ±S.D.	121.20±4.89 a*	106.84 ±4.08 a*	76.75±9.55 a*	1.41 b	2.39±0.46 b
Exposed : Mean ± S.D.	86.82 ±16.29 b	93.77 ± 2.48 b	44.89±8.09 b	2.15 a*	3.47±0.48 a*
Treated: Mean ± S.D.	128.42 ± 6.07 a*	103.04±4.74 a*	50.90±4.67 b	2.04 a*	2.62±0.54 b
L.S.D	11.71	4.36	8.66	0.33	0.5559

Means followed by the same letter(a or b) were not significantly different.
* (P<0.01highly significant).

The results of Table 2 showed reduced glutathione, glutathione peroxidase activity in the hepatic tissue, serum ACTH hormone, total lipids and total protein in control and exposed treated and untreated groups. The data illustrated that there was a significant decrease ($p<0.01$) of glutathione and glutathione peroxidase activity and serum total protein in exposed group compared to the control and treated groups. While serum ACTH hormone was significantly higher($p<0.01$) in both exposed and treated groups compared to the control one.

Table 2. Mean ± SD of glutathione, glutathione peroxidase in the hepatic tissue, ACTH total proteins and total lipids in serum of control and exposed groups (untreated and treated).

Parameters / Groups	Glutathione (mg/g)	Glutathione peroxidase (µmol min/g)	ACTH (pg/ml)	Total protein (gm/dl)	Total lipids (mg/dl)
Control: Mean ±S.D.	19.79 ±1.5 a*	90.14 ±3.25 a*	13.94 ±0.96 b	5.14 ±0.29 a*	248.67±8.97
Exposed : Mean ±S.D.	18.25 ±0.8 b	81.66 ±2.92 b	24.04±2.14 a*	4.27 ±0.54 b	259.83±13.14
Treated: Mean ±S.D.	19.80±1.01 a*	90.23±3.71 a*	22.41±2.38 a*	5.58 ±0.51 a*	249.29±7.04
L.S.D	1.28	3.72	2.17	0.521	0.0

* ($P<0.01$highly significant)

DISCUSSION

The number of people using cellular telephones has risen dramatically during the past decade, and the increasing is expected to continue. Non-ionizing electromagnetic sources can produce many hazardous effects on the biological system.

In the present study, EMF cause alteration in the levels of copper, zinc, manganese and iron**.** Decreased copper level could be attributed to the effect of EMF on the Cu-containing proteins as ceruloplasmin, while decreased Zn which acts as antioxidant trying to combat the effects caused by EMF free radicals or due to the effect of EMF on the antioxidant enzyme superoxide dismutase in which Cu and Zn acts as cofactors [13,14]. The results of the current study are consistent with those of Issa, *et al.*[27] who reported that workers exposed to EMF showed a decreased level of Cu, Zn. Decreased Fe serum level

is either due to decreased plasma protein by the impact of free radicals, or by the effect of EMR on the brain which contains magnetosomes (magnetite crystals,Fe_3O_4) these microstructures behave like small magnets and may be influenced by external electromagnetic fields changing their energy content, which finally results in a mechanical force[28], with effects on the hypothalamus and repercussions on immune and neuroendocrine functions [29], which may cause precipitation of iron leading to decreased its serum level. Increased serum iron after oral intake of antioxidant is probably due to scavenging free radical by glutathione and by ascorbic acid which keeps iron in ferrous state and promoting its absorption [20,21,30]. Results are consistent with those of Issa, *et al.*[27]. On the contrary, the results of Akdag, *et al.*[31] showed no statistically significant difference in serum levels of copper, zinc and iron of rats exposed to electromagnetic field this may be due to differences in the duration of exposure and/or type of animals. Meanwhile, results of Feyzan, *et al.* [32] showed no statistical significant difference in serum levels of copper and iron but showed significant increase of zinc level in EMF exposed rats. However, improvement which was noticed in serum copper and iron after antioxidant treatment is due to the effect of antioxidant on the free radicals. On the other hand, the increased serum level of manganese could be explained by the effect of EMF on the antioxidant enzyme Superoxide dismutase, in which Mn acts as a cofactor [13,14] also its increased level may be a compensatory mechanism for decreased serum levels of copper, iron and zinc which also acts as cofactors for the same enzyme or due to the increased manganese level in the brain as reported by Max, *et al.*[33]. Our results are in agreement with those found by Akdag, *et al.*[31] and Feyzan, *et al.*[32] who found increase of serum manganese level in EMF exposed rats.

Zinc deficiency has been shown to impair DNA, RNA and protein synthesis in the brains of rats [34], which may be related to decreased total protein in the present study, also zinc deficiency results in impaired incorporation of thymidine into brain DNA. Zinc deficiency affects hypothalamic pituitary thyroid function[34].

Because of the association of copper and zinc in many enzymes structures, and the important role of them in the immune system[35,36], the evaluations of the present study have considered ratio of copper and zinc together**.** In addition, the antagonistic action of Cu and Zn, the Cu/Zn ratio is an important marker showing the status of these two elements which was affected by exposure to

EMF in the present study and the increased Cu/Zn ratio in the exposed groups may be explained by an increase in Cu absorption and a decreased Zn absorption or competition of these two elements for binding to metallothionein or elimination of Zn in a trial to combat free radicals, which are consistent with the results of Issa, *et al.* [27].

In the present study, the high serum level of ACTH may point to that magnetic field exposure activated the pituitary gland to secrete more hormone. Some studies explained that EMF induced changes of trans-membrane Ca flux leading to altered metabolism and/or secretion of neurohormones including ACTH [37], the stimulation of the non–ionizing radiation to hypothalamic-hypophyseal-adrenal axis is an another suggestion offered by Nageswari [38]. Results are consistent with studies of Kunz, *et al.*[39], Librudy [40], Maisch, *et al.*[41] and Stagg, *et al.*[42] who revealed that EMF exposure was related to an increase in the level of stress hormone adrenocorticotropic hormone. Also, the results of this study are consistent with those of Imaida, *et al.* [43] who found increased serum level of ACTH in rats exposed to 1.439 GHzEMF for six weeks. To the contrary, results are inconsistent with those of Djeridane, *et al.*[44] and Bortkiewicz[45] who found that ACTH was not disturbed by the effect of EMF emitted by mobile phone. This discrepancy may be due to differences in the dose, duration of exposure and/or type of animals.

Improvement which was noticed after administration of antioxidants could be attributed to the protective role of antioxidants on biochemical mediators and endocrine system from the damaging effect of free radicals [20,21].

GSH-PXs are peroxidases that catalyze the reduction of H_2O_2, organic hydroperoxides, and lipid hydroperoxides to water by GSH[18].

To evaluate role of reactive oxygen species (ROS) in EMR-induced oxidative damage in rats, the changes in the antioxidant status in the EMR exposed group was studied. In the current study, EMF appeared to affect several parameters of oxidative stress in exposed group compared with the control group and treated group. While, hepatic tissue contents of glutathione and GSH-Px activities were reduced, the treatment with the antioxidant in group III reversed these effects. In this study, the decreased levels of glutathione and GSH-Px activities in exposed group demonstrate that exposure to 900 MHz mobile phone-induced oxidative damage, and Glutathione via its free radical scavenging and antioxidant properties, ameliorates oxidative stress in the

treated group. These results show that Glutathione exhibits a protective effect on mobile phone-induced and free radical mediated oxidative impairment in rats[2]. Therefore, toxicity of free radicals can be directly mitigated by free radical scavengers including ascorbic acid (vitamin C), and Glutathione [20,21]. These results are in accordance with those of Ilhan, *et al.*[46] who noticed improvement in glutathione and GSH–Px activities after treatment with the antioxidant Ginkgo biloba (Gb) on mobile phone-induced oxidative damage in brain tissue of rats. Also, Ozguner, *et al.*[2] and Ozguner, *et al.*[47] found decreased activity of GSH-Px in rats exposed to 900 MHz EMR and they also noticed that treatment of EMR exposed rats with melatonin or the antioxidant CAPE increased the activity of GSH-Px to higher level than those of control rats. Also, Oktem, *et al.*[48] who found that GSH-Px activity was reduced and melatonin treatment reversed this effect**.** Also, Guney, *et al.*[49] who found decreased activity of GSH-PX in EMR exposed animals while vilamins E and C caused a significant increase in the activity of antioxidant enzyme. Yurekli, *et al.*[4] found that GSH (reduced glutathione) concentration was found to decrease significantly ($p< 0.0001$) in rats exposed to EMF. Also, Meral, *et al.*[50] found decreased GSH level in the blood of EMF-exposed guinea pigs.

The present data revealed that serum level of total protein was reduced in the exposed group compared to control and improved after oral intake of antioxidant. This effect may be due to a reaction between EMF free radicals and animal proteins, which produce products that delay the initial protein synthesis. The decrease can be due also to mutation either in genes that encode proteins or in regions of DNA that control gene expression by the effect of free radical[51,52]. To less extent it could be also due to diminished formation due to the inhibition of liver function (the organ responsible for protein synthesis), or due to decreased levels of zinc and copper which stimulates catabolism of protein and limits the biosynthesis of protein[53]. The hypoproteinemic effect of EMF exposure in the present results are in support with Mohamed, *et al.*[54] who reported that chronic exposure for 2 months 4 and 8 hours daily produced a case like hypoproteinemia as a result of liver dysfunction. Also, results are consistent with those of Boguslaw, *et al.*[55] who found a significant decrease in serum level of protein in steel workers exposed to electromagnetic field and he explained that decrease on the base of disturbed protein synthesis in the liver, which is controlled by steroid hormones. Most of blood proteins are synthesized in the liver, several factors affect the rate of synthesis such as hormones (e.g

thyroxine and cortisol), liver function, nutritional and environmental factors[55]. Then, improvement which was noticed in the treated group confirms the suggestion of the protective role of antioxidants which can remove free radicals developed by the effect of EMF which can damage protein[51].

In the current study, although serum total lipids was increased in the exposed group the increase did not reach the level of significance compared to other groups. Results are inconsistent with those of Boguslaw, *et al.*[55] who found significant decrease in serum level of total lipids of steel workers exposed to electromagnetic field which may be attributed to the change of race and type of diet.

It is possible to conclude that exposure to EMR of cellular tower for mobile telephone produced some biological disturbances, and thus the present study suggests that protection against oxidative damage is best served by the variety of antioxidants which can behave synergistically and can exert a protective role to prevent oxidative stress.

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مجلة البحوث الإشعاعية والعلوم التطبيقية

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تحسين تأثير المجال الكهرومغناطيسي على ذكور الجرذان باستخدام محفز الجلوتاثيون

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تعتبر الموجات الكهرومغناطيسية والناتجة عن محطات تقوية المحمول احد مصادر التلوث البيئى الهامة وذلك نظرا لزيادة استخدام أجهزة الهاتف المحمول وأنتشار محطات تقوية المحمول فوق اسطح المنازل.

لذلك كان الهدف من البحث هو دراسة تأثير المجال الكهرومغناطيسى على عناصر الأكسدة والأختزال والجلوتاثيون المختزل والجلوتاثيون بيروكسيداز في الكبد وهرمون ACTH والبروتين الكلى والدهون الكلية لمعرفة الأثار الصحية الضارة والناتجة عنها وكذلك معرفة الدور الوقائى لمضاد الأكسدة المحفز للجلوتاثيون ضد هذه التغيرات على ذكورالجرذان.

لتقييم تأثير التعرض على الجرذان استخدم عدد 24 من ذكور الجرذان قسموا إلى ثلاث مجاميع متساوية المجموعة الأولى الضابطة التى لم تتعرض للمجال الكهرومغناطيسى وعرضت المجموعة الثانية والثالثة للجرعة من المجال المغناطيسى بتردد حوالى 900– 930 ميجا هرتز عند موقع التعرض وذلك طوال اليوم لمدة ثمانية اسابيع، استخدم العقار المحفز للجلوتاثيون كمضاد للأكسدة وأعطى للمجموعة الثالثة 3 مرات أسبوعيا لمدة ثمانية اسابيع اثناء فترة التعرض وأسفرت النتائج عن التالي:

أن التعرض للمجال الكهرومغناطيسى قد سبب زيادة معنوية فى مستوى مصل الدم فى هرمون ACTH، وذلك في المجموعة المعرضة مقارنة بالمجموعة الضابطة غيرا لمعرضة ولم يحدث فرق معنوى فى المجموعة المعرضة مقارنة بالمجموعة المعرضة المعالجة وفى الدهون الكلية قد حدثت زيادة غير معنوية في المجموعة المعرضة، وحدث نقص معنوى فى الجلوتاثيون المختزل والجلوتاثيون بيروكسيداز في الكبد، وذلك في المجموعة المعرضة مقارنة بالمجموعة الضابطة غيرا لمعرضة والمجموعة المعرضة المعالجة. وقد حدث نقصا معنويا فى عنصر الحديد والزنك و النحاس, وكذلك في البروتين الكلى وزيادة معنوية في المنجنيز وذلك في المجموعة المعرضة مقارنة بالمجموعة الضابطة، وبعد المعالجة قد حدثت زيادة معنوية فى عنصر الحديد والنحاس والبروتين الكلى, ولم يحدث فرق معنوى فى الزنك وذلك في المجموعة المعرضة المعالجة مقارنة بالمجموعة المعرضة غير المعالجة وفى المنجنيز لم يوجد فرق معنوى بين المجموعة الضابطة غير المعرضة والمجموعة المعرضة المعالجة .

وأخيرا يمكن أن نستنتج أن التعرض للمجالات الكهرومغناطيسية لمحطات المحمول والذى ينتج عنه بعض الشوارد الحرة والتى تسبب تغيرا فى بعض عوامل التوتر التأكسدى وبعض التغييرات البيولوجية مما ينتج عنها أثار صحية ضارة وقد يمكن الحد من اضرارها بإستحدام مضادات الأكسدة كوقاية.