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Research Article

Ameliorative Effect of Zinc on Oxidative Stress Induced by Electromagnetic Fields Emitted from Computers

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ABSTRACT

Background: A personal computer (PC) is a device with wide existence and use in modern societies. A PC user is exposed to a wide range of electromagnetic fields (EMFs). Objectives: This work aimed to investigate the possible effects of radiation emitted from computer monitor on the oxidant/antioxidant status of workers. Potential ameliorative effects of zinc (Zn) on antioxidant status was considered. Three groups were included in this work. Group B comprised 42 computer workers. The same workers were given zn tablets in a dose of 25 mg/day orally. They were termed group A. A control group composed of sixty-three subjects were included. They were matched for age and socioeconomic status. The study lasted for fifty-six days. Malondialdehyde (MDA) and reduced glutathione (GSH) levels and superoxide dismutase (SOD), glutathione peroxidase (GPx), and catalase (CAT) activities were measured in serum of all participants. We found that serum levels of MDA were significantly increased while zinc concentration, GSH level and (CAT, SOD, and GPx) activities decreased significantly in group B compared with group C. In group A, all parameters were improved when compared with group B. Conclusion: Our results demonstrated that chronic exposure to EMRs emitted from computer induced oxidative stress. Zn supplementation can safeguard against resultant oxidative stress.

Keywords: Electromagnetic field, Computer, Oxidative stress, Zinc, antioxidant enzymes, reduced glutathione, malondialdehyde.

INTRODUCTION

Electromagnetic fields (EMFs) are one of the most dangerous types of pollution. They affect different functions of body cells. There is a wide variety of electromagnetic sources. Power lines, radio and TV broadcasting stations, cellular phones, house appliances and computer monitors are popular sources. A personal computer (PC) user is exposed to a wide range of electromagnetic fields. Ultraviolet and visible light, radio-range waves, and extremely low frequency (ELF) (50 Hz) fields are examples of such fields. Preliminary studies showed that radiation from a monitor can lead too deleterious biological consequences[1]. Many studies have shown that ELF–EMFs (0–300 Hz) increase the average concentration of free radicals, or reactive oxygen species (ROS), extend their lifetime, promote the chance of radical reactions with cellular ingredients, and alteration of antioxidants or ROS scavenging enzymes[2]. Many ways are adopted by cells to alleviate the effects of oxidative stress, either by rectifying the harm or by immediately diminishing the occurrence of oxidative damage by means of some antioxidant enzymes such as superoxide dismutase (SOD), glutathione peroxidase (GPx) and catalase (CAT) and non-enzymatic antioxidants (low-molecular weight molecules such as reduced glutathione (GSH)[3]. Free radicals, such as superoxide ($O^{-}2\bullet$) and hydroxyl (OH^{-}) anions, that are created by the electrical stimulus present high chemical reactivity and hence have a relatively short lifespan in the free state. Extreme production of free oxygen radicals can lead to oxidative stress, which is a serious component inclusive in the mechanism of the EMF, DNA damage and cell death. Time-varying electric and magnetic fields can increase the production of some types of free oxygen radicals[4]. Lipid peroxidation is considered a good parameter of oxidative stress as its concentration increases during oxidative stress. Ergüder & Durak[5] found that MDA levels was elevated in the salivary samples obtained from volunteers after computer use. They deduced that radiation emitted from computers alters enzymatic antioxidant defense mechanism, and causes oxidant stress in salivary samples obtained from participants. Zinc is a component of more than three thousand zinc-related transcription factors, including DNA-binding proteins with zinc fingers, and more than three hundred enzymes, including copper/zinc superoxide dismutase and several proteins involved in DNA repair. Thus, zinc plays an important role in protecting cellular components from oxidation and damage of DNA. Accordingly, zinc deficiency lead to an increases in oxidative stress[6]. The study aimed to investigate the impact of EMF exposure on oxidant and antioxidant status of computer workers and zinc concentration.

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SUBJECTS AND METHODS

The study was carried out in the internet unit of the National Research Centre. Forty-two computer workers (group B) were included. They were subdivided into 23 males and 19 females. Mean duration of work was 8±1.2hrs daily for 5 days weekly. The mean duration of exposure to computer was (14.3 ± 8) years. Zn supplementation was given to the computer workers who were willing to continue the study (group A) in the form of Octazinc tablets (containing zinc sulphate 120 mg equivalent to 25mg zinc). One tablet / day was given for 8 weeks. A comparable group of 63 persons matched for age and socioeconomic status were recruited as a control group (group C). It consisted of 33 males and 30 females. Their work does not require using computers. But they use computers for purposes other than work. They used computer for a mean duration of (4 ± 0.8) hours/day for 5 days weekly. They are exposed to electromagnetic radiation for a lower duration (7.2 ± 2.0) years. Subjects with histories of liver diseases, exposure to toxic substances and shift work were excluded from the sample. Written consents were taken from all participants. Approval of the Ethical Committee of Medical research of the National Research Centre was obtained in advance.

Environmental Measures

Work was carried out in closed rooms with appropriate humidity, ventilation and temperature. EMFs was measured at the work place using the Digital electrostress analyzer device ME 3030B (frequency range 5 Hz to 100 kHz, EF range: 1 V/m – 1999 V/m and MF range: 1 nT-1999 nT or 0.01 mG-19.99 mG). The device was purchased from Gigahertz Solutions Company, Germany

Biochemical Parameters

A venous blood sample of about 5 ml was obtained and placed in heparinized test tubes. Blood samples were taken from each worker before zinc supplementation (on Thursday) at 12 a.m. (2 h after the start of work) and from control subject. After eight weeks of Zn intake, another sample was obtained from computer workers. Blood was centrifuged (3000 rpm; 10 min, 4°C) then serum was separated and stored in the refrigerator until analyzed. After separation of serum, the red blood cells (RBCs) were rinsed 3 times with cold 0.9% NaCl. The following parameters were measured in serum by spectrophotometric method; zinc concentration[7], malonedialdehyde (MDA) level[8], and catalase acitivity (CAT)[9]. The level of GSHwas measured in whole blood by spectrophotometric method[10]. The activities of Superoxide dismutase (SOD)[11] and Glutathione peroxidase (GPx)[12] were measured in the RBCs by spectrophotometric method.

Statistical analysis

The obtained results were expressed as mean ± SD. The statistical difference between various groups was analyzed by the one-way ANOVA and the significance was set at $p \leq 0.05$. Relations between variables were studied using Pearson Correlation.

RESULTS

Electromagnetic radiation released from control processing unit (CPU) plus computer monitor was measured when computers are turned on. Measurements were obtained at frequency fifty Hz. The mean value of magnetic field was 0.167±0.042 and 0.151±0.039 µT at distances thirty and fifty cm respectively. The electric field mean value was 386±58 and 253±51 m/v at distances thirty and fifty cm respectively. The mean age of the computer workers was 37.1 ± 9.6 years. The mean age of the control group was 36.95 ±8.4 years with no statistical significance. Table (1) represented the values of zinc, GSH and MDH in

Table 1: Comparison of Zn, MDA and GSH concentration and CAT, SOD and GPx activities between groups C, B, and A.

Parameters	Group C (No. 63) (Mean ± SD)	Group B (No. 42) (Mean ± SD)	Group A (No. 42) (Mean ± SD)
Zn(µg/dl) PC < PB <	138.8 ± 24.1	124 ± 19 <0.05	138.5 ± 18.7 (NS) <0.05
MDA (nmol/ml plasma)	11.00 ±1.37	12.57±3.11	11.03±1.11
PC <		< 0.05	(NS)
PB <			< 0.05
GSH (mg/dL)	27.05 ± 2.96	24.54 ± 2.86	26.74 ± 3.04
PC <		< 0.01	(NS)
PB <			< 0.05
CAT (U/ml)	602.7 ± 101.7	509.5± 69. 6	563.5 ± 79.5
PC <		= 0.001	(NS)
PB <			< 0.05
SOD (U/gmHb)	24.73 ± 2.37	21.65 ± 2.99	24.19 ± 2.82
PC <		= 0.001	(NS)
PB <			< 0.01
GPx (mlU/dL)	62.76 ± 24.93	56.40 ± 29.26	62.47± 25.78
PC <		< 0.05	(NS)
PB <			< 0.05

Zn: Zinc. MDA: malondialdehyde.GSH: reduced glutathione.SOD: superoxide dismutase.GPx: glutathione peroxidase. CAT: catalase

Table 2: Comparison of oxidative stress and antioxidant enzymes between A, B, and C groups according to gender.

ANOVA		Group A (42)				Group B (42)				Group C (n= 63)				parameter
		Female		Male		Female (22)		Male (20)		Female (30)		Male (33)		
P-value	F-ratio	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD	Mean	±SD	Mean	
NS	1.765	1.11	11.1 (BF)	1.17	11 (BF)	2.97	12.9 (CF, AM, AF)	3.37	12.1 (–)	1.59	10.7 (BF)	1.13	11.3 (–)	MDA
														LSD
0.01	3.382	2.35	26.7 (BF)	3.8	26.8 (BF)	2.5	23.3 (CM, CF, BM, AM, AF)	2.69	25.9 (BF)	3.16	28.1 (BF)	2.49	26.1 (BF)	GSH
														LSD
< 0.05	2.765	76.5	581 (BF)	86.3	543 (–)	55.7	504 (CM, CF, AF)	85.3	514 (CM, CF)	90.9	592 (BM, BF)	114	612 (BM, BF)	CAT
														LSD
NS	1.577	8.84	63.1 (BF)	9.18	61.8 (–)	9.18	54.8 (CF, AF)	9.67	58.1 (–)	11.4	64.7 (BF)	7.1	61 (–)	GPx
														LSD
0.005	3.804	3.24	23.8 (BF)	2.36	24.6 (BF)	2.64	20.8 (CM, CF, AM, AF)	3.24	22.5 (CM)	2.84	24 (BF)	1.74	25.4 (BM, BF)	SOD
														LSD

the studied groups and the activities of antioxidant enzymes (CAT, SOD and Gpx). There was significant increase in the values of MDA of group B compared to the control group (C) ($P< 0.05$), while Zn, CAT, SOD, GPx and GSH showed significant decrease in the group B when compared with the group C. After administration of Zn tablets, MDA showed significant decrease in group A. Also significant increase in (CAT, SOD and GPx) activity and GSH concentration were observed in group A when compared with group B. There was a significant decrease in Zn level on compared group B with group C and was improved after zinc supplementation (group A), no significant difference between group A and group C was present as shown in Table (1). As shown in table (2) there was a significant difference in MDA level among group B female and group C female where there was no significant difference in group B male when compared with group C male. And this increase in MDA level in group B female was corrected after supplementation. Also a significant decrease was observed in GSH and GPx in group B female when compared with group C male or female and this decrease in GSH level in group B female was elevated after supplementation. Moreover, CAT and SOD levels in group B male and female demonstrated significant decrease when compared with group C male and female respectively. MDA correlated negatively with zinc level in Group B. Moreover, significant negative correlation was detected between MDA and measured antioxidant enzymes. It is clear from table (4) that there was a significant negative correlation between all parameters listed in this table and duration of exposure. Reduction of working hours using computers may help to minimize hazards of EMFs emitted from PC monitors.

DISCUSSION

Metabolism, that "produce oxidants and antioxidants" can be affected by environmental factors as EMFs. High EMFs exposure can disturb the cellular balance by creating free radical or ROS[13]. Several studies pointed to the effect of magnetic fields and electric fields on free radical production and antioxidant systems. Various models of EMFs exposure could affect the biological system[2-4]. Hence, excessive formation of free radicals or ROS lead to harmful effects as a result of the imbalance between free radical production and the capability of antioxidant for defense, termed "oxidative stress". and the peroxidation of membrane lipids was one of its important consequences[14]. Our results showed that computer workers exposed to EMFs are subjected to increased oxidative stress as shown by significant increases in their serum MDA levels before Zn supplementation compared with the control group. This was consistent with previous reports which suggested that radiation emitted from computer-monitor causes "oxidative stress" in the corneal and lens tissues of rats[1]. Also**,** Ergüder & Durak[5] found that MDA levels increased in the saliva samples obtained from volunteer subjects after computer use. They reported that radiation released from computers causes changes in enzymatic antioxidant defense system, leading to "oxidative stress" in saliva samples. Several biochemical studies indicated that EMFs

of various frequencies (which PC can emit from its different parts) caused changes in lipid peroxidation (LPO) and antioxidant enzymes in different tissues or plasma of experimental animals and in plasma or blood of human volunteers or workers[4,15,16]. Moreover, it has been documented that EMFs caused LPO and increased MDA in various tissues such as lung, plasma, brain, and liver[17]. MDA is a reliable parameter of oxidative stress-mediated LPO in biological system as its concentration increases during oxidative stress[18]. Our results agreed with Canseven et al.[20] who studied the effect of 1, 2, and 3 mT (50 Hz) in male guinea pigs. They applied EMFs of the previously mentioned intensities for 4 hours/day in one group and 8 h/day in another group for a duration of five days. They reported that MDA levels in liver tissue were enhanced in the first group. The authors concluded that the effects were

Table 3: Correlation between MDA and Antioxidant Enzymes and Zinc concentration in Group (B).

Parameter	Correlation Coefficient (r)
Reduced glutathione (GSH)	- 0.386*
Catalase (CAT)	- 0.336*
Superoxide dismutase (SOD)	- 0.427**
Glutathione peroxidase (GPx)	- 0.380*
Zinc	- 0.473**

* significant at p<0.05, ** significant at p<0.01

Table 4: Correlation between duration of exposure (hrs/ day) and MDA, Zinc and antioxidant enzymes in group (B).

Parameter	Correlation coefficient (r)
MDA	- 0.435*
Zinc	- 0.317*
Reduced glutathione (GSH)	- 0.467**
Catalase (CAT)	- 0.470**
Superoxide dismutase (SOD)	- 0.320*
Glutathione peroxidase (GPx)	- 0.477**

* significant at p<0.05, ** significant at p<0.01

independent on the intensity of ELF- EMF used in the study. Furthermore, Coskunet al.[21] found that exposure to 50 Hz, 1.5 mT for four days elevates MDA, nitric oxide (NO) levels and myeloperoxidase activity in guinea pigs while GSH levels were reduced. The current study found a positive significant correlation between MDA and duration of exposure (hours/day) in group B as shown in table 4. Goraca et al.[3] proved that rats' exposure to ELF–EMF (40 Hz, 7 mT, 30 min/day for 2 weeks) did not significantly alter tissue Thiobarbituric acid research substance (TBARS), hydrogen peroxide (H_2O_2) and total antioxidant capacity of plasma. On contrast, ELF-MF with the same frequency and induction but used for 60 min/day for 14 days caused significant increase in TBARS and H_2O_2 concentration (P<0.01) in heart homogenates. Moreover, exposure of rats to ELF-EMF (40 Hz, 7 mT, 60 min/day for 2 weeks) resulted in the decrease of plasma antioxidant capacity. It could be deduced that effects of ELF–EMF on ROS generation in tissue or plasma and antioxidant capacity of plasma depend on duration of exposure. Erdal et al.[24] revealed no statistical significant difference in MDA between control male (CM) and control female (CF) rats. In the male and female rat's groups exposed to ELF–EMF, MDA level of the liver tissue were found to have increased non significantly when compared with CM and CF rats also, no statistical significant difference was found in MDA between female and male exposed rats. Our results also revealed a significant decrease in serum MDA in computer worker after Zn supplementation (25 mg Zn/d during 8 weeks) (group A) when compared with pre- Zn supplementation as shown in Table (1). Concerning lipid peroxidation, our results are in contradiction with those of Bediz et al.[2] who observed a significant difference in plasma MDA between pre- and post-Zn supplementation "injection of 3 mg/kg/d for six months" in rat exposed to ELF–EMF (50 Hz – 5 minutes/ day for 6 months). EMFs exposure is accompanied by a reduction in antioxidant defenses, and more specifically, by a progressive oxidation of reduced glutathione (GSH).[15] In the present study, blood GSH concentrations were significantly lower in computer worker before Zn treatment (group B) than control group which might indicate a reduction in antioxidant defenses. Also, we found an improvement in GSH levels in computer worker after zinc supplementation when compared with GSH levels in group B and also found non-significant increase when compared with group C as observed from Table (1). This study also found a significant negative correlation between GSH and MDA. So, depletion of GSH could be due to its involvement in the detoxification of the noxious effects of elevated free radical within the cell, which are highly generated by lipid peroxidation after exposure to the magnetic field[26]. However, severe oxidative stress may lower GSH levels with loss of adaptive mechanisms and the oxidation of GSH to GSSG[27]. Our findings are in agreement with results obtained by Ozturke et al[25]. They found a decrease in GSH levels in rats after exposed to EMFs which was improved after zinc supplementation, indicating that added zinc activated the antioxidant defense system and prevented lipid peroxidation induced by the EMFs. In addition, Goraca et al.[3] found that rat exposure to ELF-MF "40 Hz, 7 mT, 30 min/day for 2 weeks"did not significantly alter tissue total free -SH groups, and reduced glutathione (GSH). On contrast, ELF-MF with the same frequency and induction applied for 60 min/day for 14 days caused significant decrease in the concentration of GSH (P<0.05) and total free -SH groups in heart homogenates. This study was agreement with our results which found significant negative correlation between GSH and duration of exposure in years and between GSH and duration of exposure (hours/day) in the group B as shown in table 4. Table (1) showed that the SOD, CAT, and GPx activities in erythrocytes were significantly lower in group B than group C, the decrease in the activity of those enzymes may be considered an indicator of increased ROS production occurring during the exposure period and may reflect the pathophysiological process of the exposure, and this deleterious effect was improved after Zn supplementation as shown in group A. We concluded that the reduced catalase activity might be due to its slight

consumption in detoxifying these peroxides. The decrease in the SOD activity that was found in workers exposed to EMFs results in the accumulation of superoxide radicals in red blood cells, but details of the mechanism remain obscure. Our results are in agreement with reports of other workers, which suggest that EMFs exposure in experimental animals causes depression of their antioxidant enzymes due to increased lipid peroxidation and formation of free radicals and this may be attributed to disruption in the antioxidase mechanisms that neutralize free radicals[2,15,28]. It was also observed that when free hydroxyl radicals increased, the activities of antioxidant enzymes decreased causing a decrease in GSH/GSSG ratio. This was associated with a rise in the content of lipid peroxidation resulting in oxidative stress. This might be due elevation of the level of oxidized form of GSSG which inhibits the glucose monophosphate pathway. The latter is responsible for the continuous supply of GSH within the cell[3]. On the other hand, some other studies declared increased activity of antioxidant system after exposure to magnetic field. They suggested that the level of antioxidant enzymes may rise as a compensatory mechanism to eliminate this oxidative stress[1,4]. Also our study observed that the antioxidant enzymes SOD, CAT, and GPx activity significantly increased after Zn supplementation when compared between pre- and post-Zn intakes. Few studies examined the effect of dietary zinc intake on CAT, SOD and GPx activity, and data are equivocal. Some studies demonstrated an improvement in CAT, SOD and GPx activity following zinc supplementation[3]. Also, Amara et al.[6] found that zinc supplementation in SMF-exposed rats restored the activities of GPx, CAT and SOD in the liver to those of control group. However, only CAT activity was restored in the kidney. Moreover, zinc administration was able to lower the elevated levels of MDA in the liver but not in the kidney. Balci et al.[2] demonstrated that SOD activity was higher in the PC monitor users given vitamin C than in the control group. They also detected a significant lowering of MDA levels in the lens tissue with the administration of vitamin C in the PC monitor group, compared to the PC monitor alone group. This pointed to the possible fact that the antioxidant supplementation can improve the deleterious effect of prolonged use of computer. However, other studies have observed no changes in SOD activity after zinc supplementation in EMFs exposure group compared with control group[29,30]. Those discrepancies could be related to the differences in the doses administrated in the different studies, we used nutritional and moderate supplementation while higher doses of Zn (more than 25 to 50 mg/d) were given in other cited studies. We also detected a significant negative correlation between MDA and Zn, GSH and antioxidant enzymes (SOD, CAT, and GPx) in the group B as shown in table 3 and a significant negative correlation between duration of exposure (hours/day) and [MDA, Zn, GSH and antioxidant enzymes (SOD, CAT, and GPx) activities] in the group B as shown in table 4**.** In contrast to our study, Sharifian et al.[28] found no correlation between employment period and SOD and GPX activities. They explained their results by short employment period (mean employment period = 3.8 years and median = 3 years) or periodical relocation of workers.

CONCLUSION

Chronic exposure to EMFs emitted from computer induced oxidative stress and decreased antioxidant enzyme activities. Zn supplementation can protect computer workers from such hazard.

Conflict of interest: The authors declare that there is no conflict of interest.

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