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Biological Effects of Power Frequency Magnetic Fields on Serum Biochemical Parameters in Guinea Pigs

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Abstract: There are several reports that indicate a linkage between exposures to power frequency (50-60 Hz) magnetic fields with abnormalities in the serum biochemical parameters. The present study was designed to understand whether power frequency magnetic fields could act as an environmental insult and invoke any biochemical changes in Guinea pigs. Male Guinea pigs were randomly divided into four groups each comprising of 36 animals. Group 1 as control was found sham-exposed animals. Groups 2 to 4 exposed to 50 Hz (0.0207 μT) in three different times (1, 2 and 4 h), respectively for 5 consecutive days. We found significant decreases in the levels of total protein, β- and y-globulins and in the activities of γ-glutamyltranspeptidase and malate dehydrogenase. The activity of aspartate aminotransferase decreased, but the activity of alanine aminotransferase was unchanged. Total lipid, cholesterol, triglycerides and pre-β-lipoproteins decreased, but α-lipoproteins, glucose and cortisol levels increased. The most pronounced changes in the biochemical parameters studied were found in workers with the longest exposure to an electromagnetic field.

Key words: Magnetic field, glucose, cortisol, blood serum, serum enzymes, serum lipids, Guinea pigs

INTRODUCTION

Over the past few years, considerable attention has been given to the potential bio-effects of Magnetic Field (MF). Epidemiological studies have suggested that MF may increase the risk of various types of cancer, including leukemia, brain and breast tumours. The characteristic biological effects of MF appear to be functional changes in the central nervous system, endocrine and immune systems (Ahlbom, 2001; Blank *et al*., 1995; Kula, 1985, 1987).

Numerous biochemical studies have been carried out to evaluate the effects of electric and magnetic fields on the metabolism of cell cultures, animals and humans. The studies showed significant disturbances in the metabolism of carbohydrate, lipid and protein reflected by altered blood glucose levels and by accelerated glycolysis and glycogenolysis with a metabolic block of conversion of pyruvic acid to acetylocoenzyme A (Kula, 1985; Kula, 1987, 1988, 1990, 1992; Kula and Wardas, 1988; Kula *et al*., 1991; Kula and Drozdz, 1996a, b). The levels of total protein and its fractions were also changed. The Krebs cycle was disturbed probably due to a metabolic block of conversion of alpha-ketoglutaric acid to succinyl-coenzyme A. It is likely that the disturbances lead to adaptative changes, which in turn result in altered lactate dehydrogenase activity and accelerated transamination processes (Kula and Drozdz, 1996a, b; Kula, 1993; Berg, 1993; Duda *et al*., 1991; Gobovich and Kozyrion, 1979; Kozyrion, 1981; Sroczynski *et al*., 1988; Tuhackova and Cenkova, 1992).

Magnetic fields penetrate the animal and human body and act on all organs, altering the cell membrane potential and the distribution of ions and dipoles (Kula and Drozdz, 1996a, b; Berg, 1993; Duda *et al*., 1991). These alterations may influence biochemical processes in the cell, thus changing both biochemical parameters and enzyme activities of serum. Data on the effects of electric and magnetic fields on animal and human health are inconsistent probably due to differences in the exposure conditions, populations and parameters studied.

The aim of this study, which was a part of research into the effect of magnetic fields on some male Guinea pigs, was to evaluate the levels of proteins lipids, glucose, cortisol and the activities of some enzymes in serum from exposed to magnetic fields.

MATERIALS AMD METHODS

Animals: Male Guinea pigs (Pasteur Institute, Iran) weighing 350-400 g at the time of experiments were housed at 25°C in a cage under a 12-12 h light/dark cycle, with free access to food and water. Animals were randomly divided into four groups each comprising of

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Table 1: Weight and exposure differences between the groups studied

Group	Exposured time (h)	Weight	No. of Animals
Control	0	360±21.34	36
1	1	377±10.04	36
2	2	380±45.34	36
3	4	356±21.55	36

36 animals. Group 1 as control was found sham-exposed animals. Groups 2 to 4 exposed to 50 Hz (0.0207 μT) in three different times (1, 2 and 4 h), respectively for 5 consecutive days (Table 1)

Magnetic field exposure: All procedures does base on Kula (1985). The sinusoidal, 5 and 50-Hz MF was generated by a pair of double-wound coils connected to an internally developed, stabilized AC-current generator. The coils were embedded in molded epoxy resin to avoid vibration. The inner diameter of the coils was 42 cm. The distance between the two parallel coils, mounted horizontally above and below the mouse cage, was 32 cm. The orientation of MF was vertical. The magnetic flux density was measured with a Hall detector-type MF sensor and monitor (Lakeshore M420).

Biochemical parameters: All procedures in this study done in Biology Laboratory of Faculty of Science (Urmia University) from Feb to Sep., 2005. All biochemical parameters were measured in serum. Serum samples were collected at the 6th day; twelve serum samples were taken from each test and control animals. The following parameters were measured:

- Total serum protein (Kula *et al.*, 1991; Mauer, 1968).
- Serum protein fractions by polyacrylamide-gel electrophoresis (Kula and Drozdz, 1996a, b).
- Aspartate aminotransferase activity (AspAT; EC.2.6.1.1.) (Reitman and Frankel, 1957).
- Alanine aminotransferase activity (ALAT; EC.2.6.1.2.) (Reitman and Frankel, 1957).
- Malate dehydrogenase activity (EC. 1.1.1.37) (Sevela and Tovorek, 1969).
- Sorbite dehydrogenase activity (EC. 1.1.1.14) ((Sevela and Tovorek, 1961).
- y-glutamyltranspeptidase activity (GGTP; EC. 2.3.2.2) (Orlowski and Szewezuk, 1962).
- Total lipid level (Zoellner and Kirsch, 1962).
- Triglyceride level by an enzymatic method with Boehringer reagents.
- Total cholesterol by an enzymatic method with Boehringer reagents.
- Lipoprotein separation by agar-gel electrophoresis with an ERJ-65 Zeiss Jena densitometer (Orlowski and Szewezuk, 1962; Lowry *et al.*, 1951).
- Serum cortisol was measured by radioimmunoassay technique (RIE) using the cortisol coat-A-count kit, DPC (USA) (Sroczynski *et al.*, 1988)
- Glucose level measured by the glucose oxidase method using the PAPglucose kit-Labtest Diagnostic-Iran.

Statistical analysis: The results were analyzed with Student's t-test. Differences were considered significant when p<0.05.

RESULTS

In group 2 (2 h exposure), there was a statistically significant decrease in total serum protein content (Table 2). None of the groups showed changes in albumin levels. The levels of β-globulin decreased in all groups and γ-globulin decreased in group 1 and 2 (Table 2).

Serum ALAT activity did not show any significant change in any group, but AspAT activity increased 35% in group 3 (Table 3). GGTP activity decreased significantly only in group 3 and so did malate dehydrogenase activity. Sorbite dehydrogenase activity did not change in any group studied (Table 3).

Total serum lipid and cholesterol levels significantly decreased in groups 2 and 3 (Table 4). Triglyceride levels significantly decreased only in group 3, where

Table 2: Total serum protein and its fractions in male Guinea pigs exposed to a magnetic field in different times

Parameters	Control	Group 1	Group 2	Group 3
Total protein (g%)	6.18±0.44	6.13±0.5	6.25±0.75	6.15±1.21
Albumins (g%)	2.48±0.21	2.43±0.21	2.51±1.21	2.44±0.44
α1-globulins (g%)	0.33±0.021	0.32±0.026	0.34±0.033	0.39±0.056
α2-globulins (g%)	0.58±0.025	0.52±0.026	0.55±0.032	0.61±0.011
β-globulins (g%)	1.03±0.023	0.95±0.025[a]	0.90±0.043[c]	0.94±0.056[a]
γ-globulins (g%)	1.25±0.32	1.10±0.023[b]	1.06±0.044[b]	1.24±0.068

[a]p<0.05, [b]p<0.01 and [c]p<0.001 - data shown as mean±SD

Table 3: Serum enzyme activities in male Guinea pigs exposed to a magnetic field in different times

Parameters	Control	Group 1	Group 2	Group 3
AspAT (UJ)	24.1±3.34	31.3±4.2	30.2±5.2	36.2±6.3[a]
ALAT (UJ)	20.2±3.6	21.4±2.8	22.3±4.22	21.4±5.6
γ-Glutamyl-transpeptidase GGTP (UJ)	1.47±0.21	1.75±0.46	1.44±0.23	1.05±0.26[a]
Malate dehydrogenase (UJ)	1.24±0.152	1.02±0.102	1.05±0.300	0.61±0.143[a]
Sorbite dehydrogenase (UJ)	0.10±0.023	0.11±0.022	0.10 ±0.021	0.11±0.030

[a]p<0.05 - data shown as mean±SD

Table 4: Serum lipid parameters, cortisol and glucose levels in male Guinea pigs exposed to a magnetic field in different times

Parameters	Control	Group 1	Group 2	Group 3
Total lipids (g L^{-1})	6.85±1.22	7.3±1.34	5.2±1.4[b]	6.0±2.4[b]
Cholesterol (mmol L^{-1})	4.12±1.22	4.68±0.95	4.00±0.88[a]	3.84±0.44[b]
Triglycerides (mmol L^{-1})	1.51±0.88	1.55±0.77	1.44±0.45	1.05±0.26[b]
α-lipoproteins (%)	19.0±8.8	20.1±11.4	21.3±9.7	27.1±6.5[b]
Pre-β-lipoproteins (%)	15.0±8.5	18.0±9.3	15.5 ±8.9	13.1 ±7.3[a]
β-lipoproteins (%)	40.2±11.4	36.8±12.8	37.4±8.7	41.6±9.3
Cortisol (pg mL^{-1})	4.44±0.15	4.55±0.10	4.58±0.22	4.93±0.14[a]
Glucose (pg mL^{-1})	78.2±11.34	79.1±12.12	81.0 ±10.23	110.12±10.54[c]

[a]$p<0.05$, [b]$p<0.01$ - data shown as mean±SD

we also found a significant increase in the levels of α-lipoproteins cortisol significantly increased only in group 3, where we also found a significant increase in the levels of glucose. In contrast, None of the groups showed changes in the level of β-lipoproteins (Table 4).

DISCUSSION

Many previous studies of the effect of magnetic fields on living organisms showed that the initial effect of an electromagnetic field is the triggering of key biochemical processes in various metabolic pathways (Kula, 1985, 1989, 1993; Kula and Drozdz, 1996a, b; Duda *et al.*, 1991). The effect of a magnetic field on the living organism is a complex phenomenon. The initial mechanism is physicochemical in nature and afterwards biological effects develop. The physicochemical action of a magnetic field consists in electron, ion and dipolar, macro structural and electrolytic polarization. Other factors may also play a role, such as molecular excitation, biochemical activation, generation of radicals, chemical bond weakening, hydration change, altered relaxation time of atom vibration and altered spin of dipoles (Kula and Drozdz, 1996a, b; Berg, 1993; Duda *et al.*, 1991). These physicochemical changes may affect the biochemical parameters of serum. Many studies showed changes in protein levels *in vivo* (Kula, 1985, 1987, 1989; Kula *et al.*, 1991; Kula and Drozdz, 1996a, b). The changes occurred in all electrophoretic protein fractions of serum; but the levels of albumins and γ-globulins were most affected.

In this study, we observed a decrease in β- and γ-globulins. The decreases may have resulted from disturbed protein synthesis in the liver, which is controlled by steroid hormones. The availability of tissue proteins, release of amino acids and their metabolism in the liver are triggered by the katabolic action of glucocorticoids (Wilson *et al.*, 1981; Bellosi, 1996), but the changes observed in steelworkers cannot be attributed to glucocorticoids only. The action of glucocorticoids is also determined by the function of the liver and nutritional status.

It is likely that the 30% increase in aspartate aminotransferase activity observed in group 3 resulted from the intensification of transamination processes. This intensification, noted in animals exposed to magnetic fields, seems to be caused by increased glycogenesis (Kula, 1988, 1989). Glucocorticoids also enhance transamination processes. In such cases, the activation of aminotranferases most probably consists in substrate induction. The fact that the activities of serum GGTP, malate dehydrogenase and sorbite dehydrogenase were not diminished suggests the normal function of liver parenchyma. The decreased malate dehydrogenase activity in group 3 suggests adaptative changes in the metabolism of fumaric acid to oxaloacetic acid.

The decreased total lipid and cholesterol levels in groups 2 and 3 suggest decreased energetic demand. The findings concerning fat metabolism may be of some importance with respect to the early development of atherosclerosis, especially in group 2, which showed significant changes in the level of lipoproteins that prevent the development of atherosclerosis. Lowered cholesterol and triglyceride levels were also found in the serum of rats exposed to electromagnetic radiation (Wilson *et al.*, 1981; Bellosi, 1996).

The reason for measuring the cortisol serum concentration in this experiment was because the cortisol is well known as being a stress indicator (Marti and Armario, 1997; Radon *et al.*, 2001). In this study was observed an increase statistically significant in cortisol serum concentration at the exposed animals when compared to control group.

In this study the serum glucose concentration also had a significant increase on the exposed group when compared to control group, in accordance with Marti and Armario (1997), which shows that repeated stress is associated with the sensitivity of glucose, inducing hyperglycaemia. Obtained data in this experiment make us to believe that the EMF of 60Hz, in spite of being a low frequency EMF, activates the hypothalamic-hipophyse-adrenal axis with consequent increase on cortisol and glucose release what characterises an immune depression patient's condition of immune system.

In conclusion, the most significant changes in serum enzyme activities and lipid parameters were found animals with the longest exposure time to magnetic fields. We believe that many experiments are still necessary, with the purpose of explaining which frequency, intensity, exposure time and other parameters involved with the EMF, to protect us from harms that life can cause to us.

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