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Letter to Editor

Effect of Low Frequency Electromagnetic Fields on [^{3}H]Glucose Uptake in Rat Tissues

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Abstract

The aims of this study were to evaluate the influence of an extremely low-frequency electromagnetic field (ELF-EMF) on [^{3}H]glucose uptake in the peripheral tissues and organs of rats. Rats were exposed to ELF-EMF (frequency-10 Hz, induction -1.8-3.8 mT) one hour daily for 14 consecutive days. Control animals were sham exposed. On the 15th day (24 hours after last exposure) rats were injected with D-[^{3}H]-6-glucose 500µCi/kg IP. Fifteen minutes later animals were sacrificed by decapitation and peripheral tissues were excised and examined for radioactivity (desintegrations per minute, DPM/100 mg wet tissue weight), which expressed [^{3}H]glucose uptake. In most of the examined tissues and organs, such as liver, kidney, heart muscle, cartilage, connective tissue, tendon and skin, [^{3}H]glucose uptake in ELF-EMF-exposed animals was significantly higher as compared to that in the sham control. Exposure to ELF-EMF did not influence [^{3}H]glucose uptake in the thoracic aorta and the skeletal muscle. It is concluded that ELF-EMF impacts tissue glucose uptake by facilitating glucose transport via cell membranes, dependent and probably also independent of its role in increasing insulin action in insulin-dependent tissues.

Keywords: extremely low frequency-electromagnetic field, [^{3}H]glucose, tissues, rats

Introduction

Alternating extremely low frequency magnetic fields (ELF-EMF) are an element of our environment. Changes in concentration of neurotransmitters of the autonomic nervous system, stimulation of activity of numerous enzymes and hormones, stimulation of oxidation-reduction processes, and cellular synthesis suggest a possibility that these fields influence carbohydrate metabolism as well as endocrine and exocrine function of the pancreas [1, 2]. Previously our team has found that ELF-EMF attenuate Parkinson's-like behavioral symptoms in animal's models of this sickness [3]. In addition, we presented evidence that ELF-EMF influenced behavior of animals [4] and increased turnover of dopamine and 5-hydroxytryptamine in rat brain [5]. Long-term exposure to an ELF-EMF (10 Hz, 8 mT and 50 Hz, 20-50 mT) [6, 7] led to a decrease in glucose concentration in the serum of experimental animals. A hypoglycemic effect of ELF-EMF (50 Hz and 3.4 mT) has been confirmed by clinical studies on healthy volunteers and diabetics [8].

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Previously, we showed that there was increased secretion of insulin from pancreatic Langerhans islets and decreased glucose concentration in the blood of rats exposed 1 h daily for 14 days to ELF-EMF [1]. It was concluded that the above result was a consequence of ELF-EMF influence on pancreas endocrine activity.

Therefore, the aim of this study was to evaluate the influence of long-term exposure to ELF-EMF on [^{3}H]glucose uptake in peripheral organs and tissues of rats.

Material and Methods

Adult Wistar male albino rats, about 220 g, were housed in the University's Animal Department (three animals per cage) at 22±1°C under a 12 h light-dark cycle (light on at 7 AM) with free access to tap water and pellet food (Murigran, Motycz, Poland). The local Bioethics Committee of the Medical University of Silesia for Animals approved the experiment (permission No. 06/2001 issued on May 15th, 2001). All animal testing was conducted according to NIH regulations on animal care, as described in the "Guide for the Care and Use of Laboratory Animals" (National Institutes of Health, 1996).

Animals were randomly divided into two groups. Rats from the first group (6 animals) were exposed to a 10 Hz ELF-EMF generated inside the cylindrical applicator of a device for magnetic therapy "Ambit 2000", manufactured in Poland. Magnetic field induction values within the applicator measured by a "Magnet Physik" gauss meter FH 35 (Germany) with a Hall effect probe were in the range of 1.8-3.8 mT. The diameter of the solenoid was 51 cm and its height was 16 cm. The parameters of ELF-EMF (shape of impulse, induction and frequency) were set up by means of a computer system. Rats were placed in a specially designed plastic chamber which fit tightly inside the applicator, and the whole body of the animals was exposed for 1 h each day for 14 consecutive days, beginning at 10 AM.

Rats from the second group (6 animals) were subjected to sham exposure in which applicator connectors received no voltage, and therefore the applicator solenoid did not generate a magnetic field.

On the 15th day, 24 h after last ELF-EMF or sham exposure, all rats were injected IP with D-[^{3}H]-6-glucose (Amersham Radiochemicals, Pittsburg, PA, USA; specific activity, 1.15 TBq/mmol, 31.0 Ci/mmnol, aqueous solution; 500μCi/kg BW IP), and 15 minutes later, animals were sacrificed by decapitation. Peripheral organs and tissues (i.e., heart muscle, thoracic aorta, liver, kidney, connective tissue [mesenterium], cartilage [sternum], skeletal muscle, tendon and skin lacking hair) were then excised in "blind" fashion to prevent the identities of animal grouping.

All samples (50-100 mg) were placed in a large Petri dish with ice, then dried on blotting-paper, weighed and transferred into 20-ml scintillation vials. One ml of Soluene-350 (Packard Inc., Downers Grove, IL, USA) was

Table 1. Effect of low frequency electromagnetic fields (ELF-EMF) on [^{3}H]glucose uptake in rat tissues (x ± SEM; n = 6).

Group	Radioactivity: DPM / 100 mg of wet tissue								
	Tissue								
	Liver	Kidney	Heart muscle	Connective tissue	Skin	Cartilage	Tendon	Skeletal muscle	Thoracic aorta
Control (Shame)	45772± 8600	37623 ± 3249	41264± 1634	41146± 3753	44692 ± 7986	27874 ± 1548	24460 ± 5792	39263± 4155	41725± 5768
ELF-EMF	59444± 2464*	51493± 3030*	55409 ± 8482*	67922 ± 8326*	82799 ± 11185*	57152 ± 9514*	35336 ± 2093*	42177± 8261	42356± 3287

Explanation: * $p < 0.05$ as compared to the control

added to each vial, and the tightly-closed vials were incubated at 37°C for 48 hr, until the tissues were completely dissolved. Then, 10 ml of scintillation cocktail (Dimilume-350, Packard Inc., Downers Grove, IL, USA) was added, the vials were briefly centrifuged, then placed in a scintillation counter (Liquid Scintillation Counter, DSA 14091, Wallac, Finland) for two minutes, and counted twice. Then, after taking into account the background and efficiency of the counter, the final results were presented as DPM (Disintegrations Per Minute) per 100 mg of wet tissue. Mean values ± S.D. were calculated for each group of 6 rats [9].

The results from each group were presented as mean and standard deviation. Statistical analysis was performed with use of STATISTICA 6.0 PL software. Shapiro-Wilk's test was used to verify normality, and Levene's test was employed to verify the homogenity of variances. Statistical evaluations were made by means of t-test, t-test with separate variance estimation, and Mann-Whitney U test. A value of $p<0.05$ was considered to be significant.

Results and Discussion

In this study [^{3}H]glucose uptake, expressed as DPM/100 mg tissue wet weight, was significantly greater in the liver of rats exposed to ELF-EMF vs. sham controls (Table 1). [^{3}H]glucose uptake was also significantly increased by ELF-EMF exposure in kidney, heart muscle, connective tissue, skin, cartilage and tendon, but not in skeletal muscle nor in thoracic aorta (Table 1).

In the present study we showed that exposure to ELF-EMF has an impact on modulated glucose uptake in different tissues and organs. The greatest increase in [^{3}H]glucose, expressed as DPM/100 mg tissue wet weight, was observed in the cartilage and skin of the ELF-EMF group (105% and 85%, respectively) as compared to the respective controls. Increases in [^{3}H]glucose uptake were also found in the liver, kidney, heart muscle, connective tissue and tendon of the ELF-EMF group (30%, 36%, 34%, 65% and 44%, respectively), as compared to those tissues in the sham control.

Glucose, the major energy source for nearly all mammalian organs, is derived primarily from systemic circulation, and insulin is the critical hormone regulating active glucose transport across the cell membrane. Insulin binding to receptors activates an intracellular enzymatic cascade which in turn leads to glucose transporter translocation and glucose uptake. Some tissues (neurons, red blood cells) accumulate glucose independent of insulin.

There is scarce information concerning the effect of ELF-EMF on glucose metabolism in mammalian organisms. ELF-EMF was previously found, by histochemical methods, to induce activity of SDH, LDH and ATP-ase in liver [8, 10]. Earlier, we showed that long-term exposure of rats to ELF-EMF (1 hr daily for 14 days) produced changes in the ultrastructure of β-cells in pancreatic islets, leading to increased synthesis and secretion of insulin and secondary hypoglycemia in the initial phase of exposure [1].

The above ELF-EMF-induced alterations in pancreatic function can account for improvement of clinical status of human diabetics [1, 8]. From the present experiment we can additionally hypothesize that ELF-EMF increases glucose uptake not only via increased pancreatic secretion of insulin, but also by increasing affinity of insulin receptors and/or increasing signal transduction in the target cells, and insulin transporter function. Also, others found that ELF-EMF decreased glucose-stimulated insulin secretion by increases in cellular adenosine 5'-triphosphate/adenosine 5'-diphosphate, membrane depolarization, and cytosolic free calcium ion concentration [11]. Decrease of plasma glucose levels in male mice exposed to electromagnetic fields (5 microT, 50-Hz for 109 days) was also noticed [12]. It must be added that there are contradictory findings indicating that ELF-EMF exerted no effects on glucose level in the blood or increased it [13, 19].

From the above we confirmed previous data [1] by different method in experimental rats, that ELF-EMF facilitate glucose transport via cell membrane probably both in dependent and independent also from insulin way in insulin-dependent tissues and organs.

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