

Effects of sub-acute exposure to magnetic field on blood hematological and biochemical parameters in female rats

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ABSTRACT

The present work was undertaken in order to investigate the effects of magnetic field (MF) on hematopoiesis and fuel metabolites in female rats. At thermoneutrality (25°C), the exposition of rats 1 hour/day for 10 consecutive days to a MF of 128 mT (m Tesla) induced an increase in hematocrit and hemoglobin compared to controls. Exposure to MF also induced an increase in blood glucose levels but had no effect on triglyceride concentrations. Moreover, serum alanine aminotransferase activity remained unchanged in treated rats, while aspartate aminotransferase and lactate dehydrogenase activities increased by about 22% and 33%, respectively, following MF exposure. It was concluded that sub-acute exposure to MF induced elevations in hematocrit, hemoglobin, plasma fuel metabolites and tissue enzymes release within the blood. Key words: Magnetic field, hematology, glucose, triglycerides, plasma enzymes, rat.

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INTRODUCTION

Over the past few years, considerable attention has been given to the potential bio-effects of magnetic field (MF). Previous data showed that MFs are of minor importance in controlling heart rate, blood pressure, and biochemical parameters^[1,2], and have no effects on the circadian rhythms in humans^[3, 4].

In a recent report, Schenck^[5] reviewed the literature concerned with the influence of static fields upon human physiology for magnets with fields strengths up to 8 Tesla (T). He concluded that, in the absence of ferromagnetic foreign bodies, there is no replicated scientific study showing a health hazard associated with MF exposure and no evidence for hazards associated with cumulative exposure to these fields. Kanal *et al.*^[6] conducted an epidemiological study to assess the possible deleterious effects of magnetic resonance imaging (MRI) on the reproductive health of female MRI technicians. There were no significant effects of the MRI on the rate of miscarriage, stillbirth, spontaneous abortion, or ectopic pregnancy among the women responding to the survey. In addition, no effects on the rate of premature delivery, fertility, or low birth weight were found. Studies measuring the effects of MRI upon human cell development (fetal lung fibroblasts) have also failed to find evidence of abnormalities attributable to MRI^[7, 8]. The exposure of rats to a 9.4 T static MF during 10 weeks had no significant effects on spatial memory, incidence of death, changes in heart rate, body weight, or food and water consumption^[9].

The resurgence of interest in the interaction between electromagnetic fields and biological systems has mainly focused on time-varying fields. However, studies have shown that static MF can also interact with living systems at various levels. Effects on *in vitro* biochemical reactions have been reported^[10]. The exposure to a 50 mT static MF also alters the structure of poly-L-lysine^[11].

Behavioral effects of static MF have been previously noted. Static MF was avoided by rats, mice and worker ants^[12]. Static MF induced changes in hematological parameters in mice and rats^[9,13] and disruption of the mammalian menstrual cycle^[14]. Moreover, MF exerts a preponderant controlling influence on the thermoregulation, metabolism and hematology in rats^[2,15]. The exposure of mice to 5 T for 48h suppresses eating and drinking behavior and increases blood urea nitrogen, glucose and creatinine concentrations^[16]. MF is

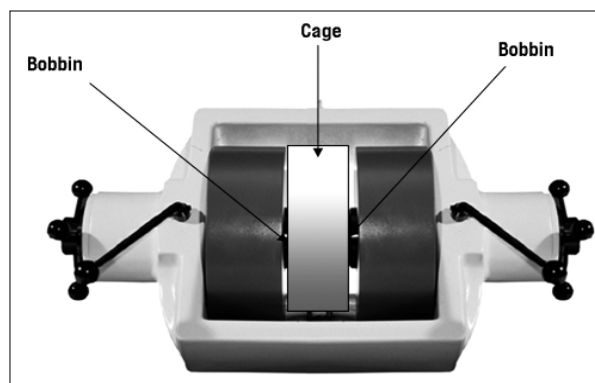


Figure 1. Lake Shore Electromagnets (Lake Shore Cryotronic, Inc, Westerville, Ohio, USA)

known to be strongly lipolytic and glycogenolytic in rats^[17,18], inducing a prominent increase in blood glucagon, cortisol and thyroxin levels.

The aim of the present study was to investigate the effect of sub-acute exposure to static MF on blood hematological and biochemical parameters in adult female rats, a fact that is probably indicative of hypoxia-like status in treated rats.

MATERIALS and METHODS

Animals

Female Wistar rats (Pasteur Institute, Tunisia) weighing 100-150g 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. Treated rats (n=6) were exposed to a static MF (128 mT; 1h/day) for 10 consecutive days. The control group (n=6) rats were not exposed to static MF. The cage in the Lake Shore contained two female rats for each exposure (Figure 1). The fractional concentrations of the O₂ (FiO₂ = 0.21) were the same between the Control and the MF groups. MF and control rats were kept under similar conditions under room air. The animals were housed in an air-conditioned room within 4m at sea level (P=760 mmHg) (Faculté des Sciences de Bizerte, Bizerte Tunisia). Control and treated animals were sacrificed under light anesthesia (halothane 2.5%, in air).

Exposure system

Lake Shore Electromagnets (Lake Shore Cryotronic, Inc, Westerville Ohio, USA) are compact electromagnets suited for many applications such as magnetic resonance demonstrations (Figure 1). For the present experiment, we used an air gap of 15 cm. Water-cooled coils provide an

excellent field for stability and uniformity when high power is required to achieve the maximum field capability for the electromagnet. We have an accurate pole alignment by precise construction of the air gap adjustment mechanism^[15].

Blood sampling protocol

We used a Lake Shore system measurement for biochemical and hematological investigations. Female rats were positioned in the Lake Shore System 1h/day (between 9 a.m. - 12 p.m.) over 10 days at a static MF (128mT). To obtain steady metabolic state, the rat was left sitting in the cage for an initial 120 min adjustment period before the experiment was begun.

Blood samples were collected via the Biotrol sampling catheter. Blood samples (0.5ml approximately/sample) were collected in vials containing EDTA for hematological investigations or heparin for biochemical studies.

Blood chemistry

Blood collected in heparinized chilled tubes was immediately centrifuged. Aliquots of plasma were frozen and stored at -80°C prior to biochemical analysis. Plasma glucose was measured using enzymatic method (Sigma). Plasma alanine aminotransferase (ALT), aspartate aminotransferase (AST), lactate dehydrogenase (LDH) and triglycerides were measured using the enzymatic methods according to manufacturer instructions (ChronoLabo, France). Hematological parameters were assayed by Medonic-precision instruments for hematology research (CA620).

Temperature

Ambient (Ta) and body (Tb) temperatures were measured using a Copper-Constantan thermocouple and recorded on a chessel model 320 recording potentiometer (accuracy $\pm 0.2^\circ\text{C}$). Tb was obtained from the thermocouple inserted into the rectum. The Tb was determined before and after the treatment (1h/day over 10 days at 0 mT for Control group and 1h/day over 10 days at 128mT for MF group).

Data presentation and statistical analysis

Data are reported as the mean \pm SEM. Differences between means were evaluated by one-way analysis of variance (ANOVA). Statistical significance of the differences between means was assessed by Student's *t*-test. The level of significance was set at $p < 0.05$.

Table 1. The effect of sub-acute exposure to magnetic field (MF) on body weight (BW) and body temperature (Tb)

| | Control | MF |
|-------------------------|-------------------|-------------------|
| BW (g) | 133.91 \pm 2.16 | 129.03 \pm 3.88 |
| Tb ($^\circ\text{C}$) | 36.50 \pm 0.60 | 36.98 \pm 0.41 |

Values are means \pm SEM of six determinations.
 $p > 0.05$ compared to control (Student's *t*-test).

Table 2. Effect of sub-acute exposure to magnetic field (MF) on the blood parameters

| | Control | MF |
|----------------------------|--------------------|---------------------|
| WBC ($10^9/\text{L}$) | 7.81 \pm 0.73 | 9.12 \pm 0.91 |
| RBC ($10^{12}/\text{L}$) | 7.26 \pm 0.31 | 8.09 \pm 0.58 |
| Hb (g/dl) | 12.10 \pm 0.58 | 13.59 \pm 0.61* |
| Ht (%) | 35.27 \pm 1.84 | 38.15 \pm 2.33* |
| PLT ($10^9/\text{L}$) | 536.10 \pm 36.92 | 783.02 \pm 53.78* |

WBC: White blood cells. **RBC:** Red blood cells. **Hb:** Hemoglobin. **Ht:** Hematocrit, **PLT:** Platelets.

Values are means \pm SEM. Calculated from $n=6$ in each group.

* $p < 0.05$ compared to control (Student's *t*-test).

Table 3. Effect of sub-acute exposure to magnetic field (MF) on plasma glucose and triglyceride concentrations

| Parameter | Control | MF |
|-----------------------|-----------------|------------------|
| Glucose (g/L) | 1.02 \pm 0.04 | 1.22 \pm 0.05* |
| Triglyceride (mmol/L) | 1.36 \pm 0.09 | 1.27 \pm 0.03 |

Values are means \pm SEM of six determinations.

* $p < 0.05$ compared to control (Student's *t*-test).

RESULTS

The temperature of the Lake Shore was similar to the ambient temperature, which was about 25°C . No significant differences in the temperature of the Lake Shore system at 0 mT ($24.98 \pm 0.40^\circ\text{C}$) or at 128 mT (25.82 ± 0.30 ; $p > 0.05$) were observed. Body temperature (36.50 ± 0.60 vs $36.98 \pm 0.41^\circ\text{C}$; $p > 0.05$) and body weight (BW) (133.91 ± 2.16 g vs 129.03 ± 3.88 g; $p > 0.05$) also remained unaltered following sub-acute exposure to static MF (Table 1). However, MF exposure significantly increased the hematocrit (Ht) by 8% ($38.15 \pm 2.23\%$ vs $35.27 \pm 1.84\%$; $p < 0.05$), the amount of hemoglobin (Hb) by 12% (13.59 ± 0.61 g/dl vs 12.10 ± 0.58 g/dl; $p < 0.05$) and platelet count by 41% (783.02 ± 53.78 $10^9/\text{L}$ vs 536.10 ± 36.92 $10^9/\text{L}$; $p < 0.05$) compared to

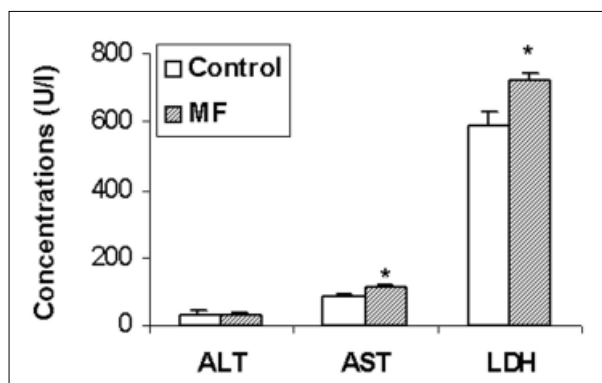


Figure 2. Effect of sub-acute exposure to magnetic field (MF) on serum enzymes activities. **LDH:** Lactate dehydrogenase. **AST:** Aspartate aminotransferase. **ALT:** Alanine aminotransferase.

control values (Table 2). The number of red and white blood cells remained unchanged.

MF exposure also induced an increase in blood glucose levels (1.22 ± 0.05 g/L vs 1.02 ± 0.04 g/L; $p < 0.05$) but had no effect on triglycerides concentration (Table 3). Following 10 days of MF treatment, serum ALT activity remained unchanged in treated rats, while AST and LDH activities increased by about 22% and 33%, respectively (Figure 2).

DISCUSSION

In this present study, we show that static MF applied to female rats produced alteration in hematological and biochemical parameters, whereas BW and temperature remained stable.

Numerous studies indicate that static MF exerted a preponderant controlling influence on the thermoregulation and metabolism in rats^[2,15]. Our data demonstrated that 10 days of MF exposure was associated with a high level of Ht, Hb and platelet count compared to controls, while red and white blood cells numbers were not altered.

It is well known that Hb is the blood transporter of oxygen within the mammal's body. Oxygen is bound to the iron atoms of the Hb^[19]. Lino^[20] stated that Hb is sensitive to MF. Other studies also showed that erythrocytes orient with the applied MF^[21]. These data are probably associated with the change in the conformation of Hb under MF action^[22]. Indeed, the increase in Hb and Ht levels may be explained by the hypoxia-like status induced by the static MF^[23] resulting probably from the oxygen-binding impairment of Hb.

On the contrary, Dacha *et al.*^[24] did not observe any significant modification in human erythrocytes exposed *in vitro* to power frequency fields.

MF exposure did not alter serum triglycerides levels. This result is in disagreement with the data reported by Bellossi *et al.*^[25] showing that MF exposure (6mT, 24h) induced a decrease in plasma cholesterol and triglycerides concentrations. The fact that serum triglycerides concentrations were not affected by MF exposure suggests that lipid metabolism remained insensitive during this period of treatment.

The plasma glucose concentrations were markedly elevated in MF-treated rats, in accordance with previous studies^[17,26]. This effect may be attributed to the release of the hyperglycemic hormone (glucagon) and/or the inhibition of the hypoglycemic hormone (insulin) as previously shown by Gorczynska^[18].

Indeed, in MF-exposed rats, physiological adaptation to hypoxia might alter endocrine systems^[18,27]. MF exposure caused a large increase in serum LDH activity. Pietruck *et al.*^[28] reported that hypoxia provoked a rapid loss of cellular adenosine 5'-triphosphate (ATP), followed by tissue functional and structural alterations revealed by an increase in LDH release. Thus, the high level of this enzyme activity following sub-acute exposure to static MF could indicate an adaptation for the anaerobic production of ATP in MF rats as previously reported by numerous authors in hypoxia status^[29,30]. The elevation in tissue enzymes within blood serum is indicative of cell injury or of functional impairment of cells^[31] probably resulting from the hypoxia environment caused by MF. In mammals, the LDH enzyme occurs in two isomeric forms: the M subunit, which is indicative of skeletal muscle-derived enzyme, and the H subunit, which derives from heart muscle^[31]. Serum LDH increase may result from the release of both muscle and heart-type LDH isozymes. Furthermore, the separation and quantification of LDH isozymes levels in blood may reveal a possible specific organ toxicity of the MF.

Serum transaminases, specifically AST and ALT, have been widely utilized in mammalian toxicology as biomarkers of specific organ dysfunction^[32]. In general, increased serum transaminases activity is usually associated with hepatocyte damage. Thus, the great increase in serum AST compared to unchanged ALT found

under MF suggested that the liver was not the only organ leaking the AST or that this enzyme was released to a higher degree than ALT from the liver. The heart, with a relatively high AST content, could provide a significant portion of the serum AST^[32].

In conclusion, sub-acute exposure to static magnetic field induced an elevation in hematocrit,

hemoglobin, fuel metabolites and tissue enzymes within the blood, a fact that is probably indicative of the hypoxia-like status in treated rats.

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