Effects of the Electromagnetic field, 60 Hz, 3 μT, on the hormonal and metabolic regulation of undernourished pregnant rats

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(With 5 figures)

Abstract

Epidemiological studies have implicated maternal protein-calorie deficiency as an important public health problem in developing countries. Over the last decades, a remarkable diffusion of electricity and an increased level of the electromagnetic field (EMF) in the environment have characterized modern societies. Therefore, researchers are concerned with the biological effects of 50-60 Hz, EMF. The aim of this paper is to show the effects of EMF of 60 Hz, 3 μT, exposure for two hours per day in the regulation of the hormonal and metabolic concentrations in pregnant rats, which were fed by Regional Basic Diet (RBD) during their pregnancy as compared with pregnant rats fed a standard diet. Pregnant rats exposed to EMF of 60 Hz, 3 μT, over the pregnancy and fed with RBD presented an increase in glucose release when compared with the Group subjected only to the RBD ration. Rats fed RBD presented a decrease in their insulin and cortisol serum levels when compared with the Group fed with casein. The T_3 and T_4 concentrations presented the greatest variation among the Groups. The relation T_4:T_3 was much exaggerated in the Group subjected to RDB and exposed to EMF when compared to the others. In conclusion, the group subjected to the association of EMF and undernutrition suffered a decrease in its serum concentration of T_4 and T_3 when compared to the well-nourished group and the relationship T_4:T_3 in the former group was almost eighteen-fold the later one.

Keywords: casein, electromagnetic field, metabolism, hormone, regional basic diet, undernourished pregnant rats.

Efeitos do campo eletromagnético, 60 Hz, 3μT, na regulação hormonal e metabólica de ratas prenhes desnutridas

Resumo

Estudos epidemiológicos têm mostrado que a deficiência proteico-calórica é um importante problema nos países em desenvolvimento. Durante as últimas décadas, a sociedade moderna tem sido caracterizada pelo aumento no número de equipamentos elétricos e como consequência um aumento no nível do campo eletromagnético (CEM) no ambiente. No entanto, os pesquisadores estão preocupados com os efeitos biológicos dos CEM de 50-60 Hz. O objetivo deste artigo é mostrar os efeitos do CEM de 60 Hz, 3 μT, nas concentrações hormonais e metabólicas de ratas prenhes, expostas duas horas por dia ao CEM, alimentadas pela Dieta Básica Regional (DBR) comparando com ratas submetidas às mesmas condições, mas alimentas com dieta padrão. Ratas prenhes expostas ao CEM de 60 Hz, 3 μT, durante a prenhez e alimentadas com a DBR apresentaram um aumento na liberação de glicose quando comparadas com o grupo alimentado pela DBR sem CEM. As ratas alimentadas pela DBR apresentaram uma diminuição nos níveis de insulina e cortisol quando comparadas com o grupo alimentado pela caseína. As concentrações de T_3 e T_4 apresentaram a maior variação entre os grupos. A relação T_4:T_3 foi muito exagerada no grupo alimentado pela DBR e exposto ao CEM quando comparado com os outros. Conclusão, os animais que foram submetidos à desnutrição e ao CEM sofreram uma diminuição na concentração sérica de T_4 e T_3 quando comparados com os animais bem nutridos e a relação T_4:T_3 no primeiro grupo foi quase 18 vezes a relação de T_4:T_3 no grupo bem nutrido.

Palavras-chave: caseína, campo eletromagnético, metabolismo, hormônio, dieta básica regional, ratas prenhes desnutridas.

1. Introduction

Over the last decades, a remarkable diffusion of electricity and an increased level of electromagnetic fields (EMF) in the environment have characterized our society. Recent epidemiological studies of occupational and residential exposure to EMF are concerned with the biological effects of 50-60 Hz fields (extremely low frequencies or ELF), particularly with determining an increase in cancer incidence in individuals exposed to these types of radiation (Galloni and Marino, 2000). A milestone in epidemiological research on ELF is the study of Wertheimer and Leeper (1979): it links the presence of power lines (60 Hz) near homes with the development of childhood leukaemia in Colorado, USA.

The main efforts of researchers have been focused on the possible link between electromagnetic fields and cancer development; different endpoints have been assessed (Galloni and Marino, 2000). The ELF field influences pineal gland activity and decreased melatonin production (Ubeda et al., 1995). Besides the major role of the pineal in the regulation of the circadian rhythm of various physiological functions and seasonal adaptation through the cyclic production of melatonin (Reiter, 1981), this organ was found to be closely associated with the hypothalamic-pituitary-gonad-thyroid-adrenal axis (Kappers, 1976). Most probably, the pineal gland converts the environmental photic, thermic and magnetic signals into information that affects the neuroendocrine system (Jankovic et al., 1993).

In accordance with Marino (2005), in order to understand the relationship between environmental factors and disease in terms of an internal state variable called stress, (for instance: death of a loved one, loss of job, an unhappy marital situation, poor diet, etc.), it is helpful to understand the influences of environmental EMFs.

Epidemiological studies have implicated maternal protein-calorie deficiency as an important public health problem in developing countries (Olubodun, 1992). Experimental studies have shown that pre- or postnatal nutritional manipulation may program adult size, metabolism, blood lipids, diabetes, obesity, blood pressure, glomerular hypertrophy, arteriosclerosis, behaviour, and learning (Lucas, 1998).

In North-Eastern Brazil, the diet that is consumed by the population living in the area of sugar-cane cultivation in coastal Pernambuco is known as "Regional Basic Diet" or RBD (Teodósio et al., 1990). The RBD was prepared by Teodósio et al. (1990), according to data from food consumption surveys in the Pernambuco coastal forest strip (Teodósio et al., 1990). The RBD is made with the most frequent foods and in the same proportion consumed by the population as detected by the surveys.

When this diet is compared with the standard one, it is noticed that it is deficient in proteins (content and quality) calories, fat, vitamins and minerals (Pessoa et al., 2000). Pioneer studies have indicated that this experimental diet, RBD, produces in rats a type of undernutrition similar to that prevalent among children from this region of Brazil, namely an association with nutritional dwarfism, with some clinical signs of marasmus Teodósio et al. (1990).

In light of the fact that pregnancy is a period of increased metabolic demands mainly due to changes in the woman's physiology and the requirements of the growing fetus (King, 2000), resulting in the deficiency of micronutrients having a detrimental effect on the health of both pregnant women and the growing foetus (Priyali et al., 2004), the aim of this paper is to show the effects of EMF of 60 Hz, 3 µT, in the regulation of the hormonal and metabolic concentrations in pregnant rats, which were fed RBD during their pregnancy as compared with pregnant rats fed a standard diet.

2. Materials and Methods

2.1. Animals

Twenty female Wistar rats were used in this experiment; they were 90 days old at the onset of exposure, which started after pregnancy was detected. Fertilization was detected by the presence of sperm in the vaginal washing of the mated females. They were kept under conditions of constant temperature (23 ± 2 °C), light/dark cycle (12/12 hours) with a background magnetic field of less than 0.3 µT. The animals had food and water ad libittum. Animal use was approved by the Federal University of Pernambuco Committee on Animal Research.

2.2. Diets

The ingredients (g.100 g^{-1}) of the multi-deficient diet used in this experiment were beans (*Phaseolus vulgaris*), manioc flour (*Manihot esculenta*), dried and salted meat, and sweet potato (*Ipomaea batatas*) (Teodósio et al., 1981). The diet was prepared in our laboratory as follows: all ingredients (except the manioc flour) were cooked, dehydrated for 24-60 hours (according the type of ingredient) at 60 °C and pulverized. Each component was mixed with manioc flour by humidifying. Meat fat was then added, and the mixture was shaped into balls which were dehydrated for 24 hours at 60 °C. The centesimal composition of the RBD, which was determined by the Department of Nutrition of the Federal University of Pernambuco, is given in Table 1. The caloric adequacy of the RBD was calculated to be about 316 Kcal per 100 g. The control diet provided 18% of protein (commercial casein) and it was balanced according to recommendations for pregnant rats (AIN – 93), as shown in Table 2. The diet during the mating period was maintenance pellet chow (Purina do Brasil Ltd., São Paulo, SP, Brazil).

2.3. Feeding protocol

During the mating period, all female and male rats were fed with a standard balanced diet provided by Purina. Throughout this period, the detection of sperm in the vagina was taken to indicate that fertilization had occurred. Fertilized females were then immediately transferred to cages, two per cage, of 60 cm length, 50 cm width and 22 cm height, put on supports made from polystyrene of 35 cm width, 50 cm length and 35 cm height (Lucena et al., 2002). Two Groups were fed RBD and two Groups were fed casein.

2.4. Exposure to EMF

The rats were divided into four Groups: Group A (n = 6), composed of rats that consumed casein without exposure to EMF; Group B (n = 4), composed of rats that consumed casein and were exposed to EMF; Group C (n = 6), composed of rats that consumed RBD and were not exposed to EMF; and Group D (n = 4), composed of rats that consumed RBD and were exposed to EMF. The Groups B and D were exposed to EMF of 60 Hz, senoidal, of 3 μT, measured by a gauss meter, on the scale of 0-100 mG, for two hours per day for twenty-one consecutive days, one hour in the morning from 8:00 to 9:00 AM and one hour in the afternoon from 2:00 to 3:00 PM. They were exposed when pregnancy was detected and removed from exposure when they gave birth. As the radiation source, transformers of 220/110 V of 500 VA, working with opened secondary, and controlled by an electronic timer were used, and placed under the polystyrene supports. Control animals were achieved by simply not placing the transformers under the polystyrene supports. The transformers were previously examined and tested to confirm their working parameters at the Biomedical Engineering Department of the Biophysics and Radiobiology Department of the Federal University of Pernambuco. The EMF was measured inside the cage and it remained constant independent of the position. It should be noted that, except for the weekly cage cleaning, and the weekly measuring of their weight, the rats were not moved or handled during this experiment. Exposed animals should be compared with those of the control group that have been derived from the same source and simultaneously handled and assayed in the same way, except for the presence of the fields.

On the last day of the experiment, the twenty-first day, when the rats had given birth, all animals were anaesthetized with ethylic ether. After that, blood was taken by a cardiac puncture (3 mL) to obtain the serum, always at the same time in the afternoon, from 12:30 to 2:00 PM. Serum samples obtained after centrifugation were stored at –5 °C for assay of cortisol, triiodothyronine (T_3), thyroxine (T_4), and insulin and glucose concentrations.

2.5. Metabolic and hormone assessment

Serum concentration of cortisol, insulin, T_3 and T_4 was measured by the radioimmunoassay technique (RIE) using the cortisol coat-A-count kit, DPC (USA) and the analysis was made in a gamma meter of scintillation, auto-gamma, CobraII (Packard a Camberra Company), at the Department of Biophysics of the Federal University of Pernambuco. Serum glucose levels were measured by the glucose oxidase method using the PAPglucose kit –

Table 1. Centesimal composition of the Regional Basic Diet (RBD).

Ingredients	g% (g)	Proteins (%)	Carbohydrates (%)	Fats (%)	Fibres (%)	Kcal (%)
Beans	18.34	3.99	10.66	0.24	1.09	60.76
Manioc flour	64.81	0.84	48.59	0.12	5.64	198.80
Poor fat dried and salted meat fat	3.74	2.74	-	0.21	-	12.85
Dried and salted meat fat	0.35	-	-	0.35	-	3.15
Sweet potato	12.76	0.30	9.99	0.03	0.48	41.43
Total	100.00	7.87	69.24	0.95	7.21	316.99

Table 2. Centesimal composition of the Control Diet (Casein).

Ingredients	g (%)	Proteins	Carbohydrates	Fats	Calories
Comercial casein*	19.6	18.00	-	-	72.00
Vegetable fat	7.00	-	-	7.00	63.00
Biscomil	63.35	0.18	53.37	-	214.20
Salt Mixture	3.50	-	-	-	-
Vitamin mixture	1.00	-	-	-	-
Fibres	5.00	-	-	-	-
L-Cystine	0.30	-	-	-	-
Choline bitartrate	0.25	-	-	-	-
Total	100.00	18.18	53.37	7.00	349.20

*92% of protein.

Labtest Diagnóstica – Brazil. Every measure was duplicated or triplicated.

2.6. Statistical analysis

The results were analysed using variable average. The significance of the results were assessed through the ANOVA and Tukey for the comparison among Groups, considering the level of significance $p < 0.05$.

3. Results

3.1. Effects of the undernutrition and EMF in the glucose serum concentration

The average of glucose serum concentration for Group A was 111.8 ± 16.8 mg.dL^{-1}, for Group B was 81 ± 15.9 mg.dL^{-1}, for Group C was 63.4 ± 12.2 mg.dL^{-1}, and for Group D was 135.1 ± 55.1 mg.dL^{-1}, Figure 1. They only showed a significant difference ($p = 0.012$) between Groups C and D, where Group D was 113.09% greater than Group C.

3.2. Effects of undernutrition and EMF in the insulin serum concentration

The average of the insulin serum concentration for Group A was 1.22 ± 0.55 μIU.mL^{-1}, for Group B was 0.97 ± 0.45 μIU.mL^{-1}, for Group C was 0.28 ± 0.08 μIU.mL^{-1}, and for Group D was 0.83 ± 0.15 μIU.mL^{-1}, Figure 2. They only showed a significant difference ($p = 0.03$) between Groups A and C, where Group C was 77.5% lower than Group A.

3.3. Effects of undernutrition and EMF in the cortisol serum concentration

The average of the cortisol serum concentration for Group A was 0.75 ± 0.25 μg.dL^{-1}, for Group B was 0.64 ± 0.33 μg.dL^{-1}, for the Group C 0.34 ± 0.12 μg.dL^{-1} and for Group D was 0.44 ± 0.13 μg.dL^{-1}, Figure 3. They only showed a significant difference ($p = 0.045$) between Groups A and C, where Group C was 54.67% lower than Group A.

3.4. Effects of undernutrition and EMF in the T_3 serum concentration

The results show that the T_3 serum concentration of the rats was significantly different among Groups ($p = 0.01$). The average for Group A was 1.47 ± 0.05 nmol.L^{-1}, for Group B was 0.42 ± 0.09 nmol.L^{-1}, for Group C was 0.13 ± 0.03 nmol.L^{-1}, and for Group D was 0.04 ± 0.01 nmol.L^{-1}, Figure 4. In addition, the greater difference was between Groups A and D, where Group D was 97.28% lower than Group A, whereas the smallest difference was between Groups B and C, where Group C was 69.05% lower than Group B. Therefore, the figure of Group B was 71.43% lower than the figure of Group A, the figure of Group C was 91.16% lower than the figure of Group A. Finally, the figure of Group D was lower than the figures of Groups B and C with a difference of 90.48% and 69.23% respectively.

3.5. Effects of the undernutrition and EMF in the T_4 serum concentration

The results show that the T_4 serum average concentration of the rats for Group A was 14.89 ± 2.17 nmol.L^{-1}, for Group B was 9.25 ± 1.92 nmol.L^{-1}, for Group C

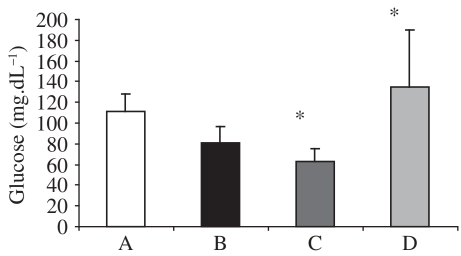

Figure 1. Determination of glucose serum concentration in mg.dL^{-1} of the four Groups: Group A, rats that consumed casein; Group B, rats subjected to casein and EMF; Group C, rats that consumed the RBD; and Group D, rats subjected to RBD and EMF. Figures are mean(s) ± standard deviation (*p = 0.012).

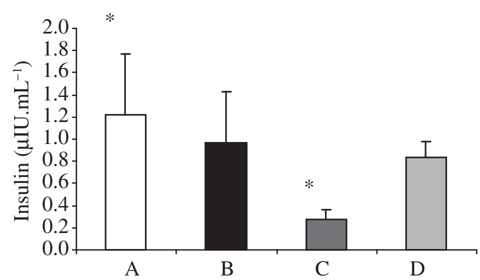

Figure 2. Determination of insulin serum concentration in μIU.mL^{-1} of the four Groups: Group A, rats that consumed casein; Group B, rats subjected to casein and EMF; Group C, rats that consumed the RBD; and Group D, rats subjected to RBD and EMF. Figures are mean(s) ± standard deviation (*p = 0.03).

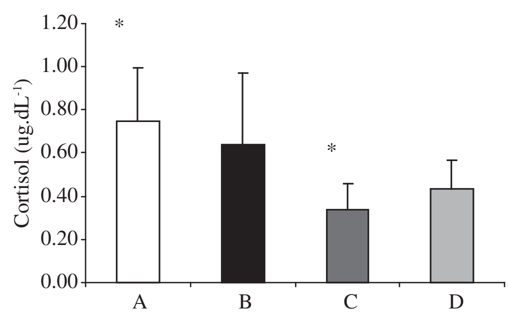

Figure 3. Determination of cortisol serum concentration in μg.dL^{-1} of the four Groups: Group A, rats that consumed casein; Group B, rats subjected to casein and EMF; Group C, rats that consumed the RBD; and Group D, rats subjected to RBD and EMF. Figures are mean(s) ± standard deviation (*p = 0.045).

was 3.87 ± 1.10 nmo.L^{-1}, and for Group D was 7.24 ± 3.47 nmol.L^{-1}, Figure 5. Some Groups showed a significant difference ($p < 0.001$). The figure of Group A showed a significant difference from Groups B, C and D, where the figures of Groups B, C and D were 37.88%, 74%, and 51.38% lower than Group A, respectively. Therefore the figure of Group B was significantly different from Group C, where Group C showed a figure 58.16% lower than the figure of Group B.

3.6. Effects of undernutrition and EMF in the relationship T4:T3

The relationship between the serum concentrations of T_4:T_3 in this study is given in Table 3. A huge difference, almost eighteen-fold, can be seen between Group A, the control group, and Group D, the group fed on RBD and exposed to EMF.

4. Discussion

The experimental diet used here is not only deficient in protein, but also in lipids, vitamins, sodium and other minerals (Monteiro et al., 2001). The choice of intensity of 3 µT was due to the necessity of using a higher intensity of EMF than that found in residences and most work places. In those places, the average 50/60 Hz magnetic fields are between 0.01 and 0.3 µT (National Academy of Science, 1996). In this study, a value ten times higher than the maximum value expected was used. Depending on the distance between the conductors and ground, and magnetic flux densities can average 22 µT in function of the current load in the line (Simon, 1992) and this value could also depend on the geographic location and the nature of the magnetic material near the subject area (Repacholi; Greenebaum, 1999).

Despite the numeric difference of the concentrations of glucose, insulin, cortisol, T_3 and T_4 among Groups, they do not show a statistically significant difference in all cases. However, a trend can be seen in their figures. For instance Group A, composed of rats that consumed casein without exposure to EMF, always have the biggest concentration when compared to the other Groups except for glucose, where the largest concentration was Group D, formed of rats that consumed RBD and were exposed to EMF. The concentration of glucose in Group D was significantly different from Group C, composed of rats that consumed RBD and were not exposed to EMF. This result was unexpected, since both Groups C and D were feeding on RBD, which is deficient. It could be explained because Group D was exposed to EMF. And in accordance to Martí, Armario (1997), repeated stress is associated with the sensitivity of glucose, inducing hyperglycaemia. In accordance with Harakawa et al. (2004), EMF of 50 Hz increases ACTH, glucose, lactate, and pyruvate levels in stressed rats, demonstrating that the 50 Hz EMF alters both stress responses and energy metabolism in stressed rats.

The trend of the concentration of insulin among groups was similar to that of glucose. However, in this case Group A, composed of rats that consumed casein without exposure to EMF, and Group C, composed of rats that consumed RBD and were not exposed to EMF, there was a significant difference, which was expected because Group A was fed casein and Group C was fed RBD. Although Group C, composed of rats that consumed RBD and were not exposed to EMF, and Group D, formed by rats that consumed RBD and were exposed to

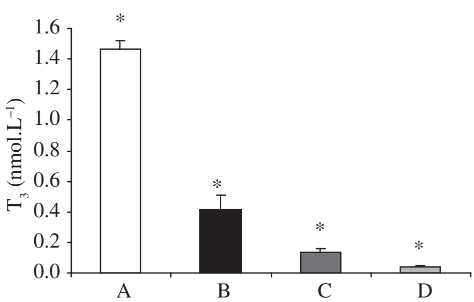

Figure 4. Determination of T^3 serum concentration in nmol.L^{-1} of the four Groups: Group A, rats that consumed casein; Group B, rats subjected to casein and EMF; Group C, rats that consumed the RBD; and Group D, rats subjected to RBD and EMF. Figures are mean(s) ± standard deviation (*$p = 0.001$).

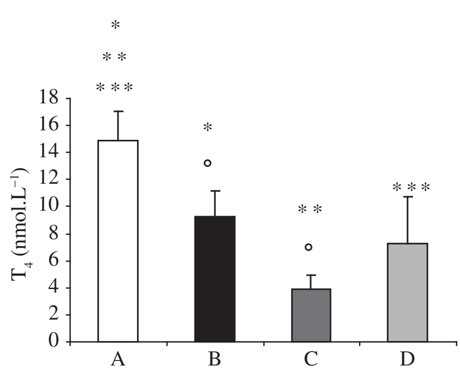

Figure 5. Determination of T^4 serum concentration in nmol.L^{-1} of the four Groups: Group A, rats that consumed casein; Group B, rats subjected to casein and EMF; Group C, rats that consumed the RBD; and Group D, rats subjected to RBD and EMF. Figures are mean(s) ± standard deviation ($p < 0.001$).

Table 3. relationship serum concentration T_4:T_3. The serum concentrations of T_4 and T_3 were shown in mean ± Standard deviation.

	T_4 (nmol.L^{-1})	T_4 (nmol.L^{-1})	T_4:T_3
Group A	14.89 ± 2.17^{abc}	1.47 ± 0.05^{e}	10:1
Group B	9.25 ± 1.92^{ad}	0.42 ± 0.09^{e}	22:1
Group C	3.87 ± 1.10^{bd}	0.13 ± 0.03^{e}	30:1
Group D	7.24 ± 3.47^{c}	0.04 ± 0.01^{e}	181:1

Letters indicate significant differences between the groups ($p < 0.05$).

EMF, do not show significant difference between them, they had the same pattern of glucose, where Group D, that had the same diet as Group C, suffered an increase in its figures. This can be explained by the same mechanism which increased the glucose levels, since when glucose levels rise, the level of insulin has to increase as well. According to Champe and Harvey (2002), the level of blood glucose controls the level of blood insulin. Theses results show that EMF changes the body's metabolism, because it was expected that Group B (composed of rats that consumed casein and were exposed to EMF) and, Group C, control group, (composed of rats that consumed RBD) had presented a statistically significant difference between their figures to agree with what happened between Group A, composed of rats that consumed casein without having been exposed to the EMF, and Group C (composed of rats that consumed RBD) and were not exposed to the EMF.

The same occurred with the cortisol dosages as occurred with the insulin dosages in this study. These results show once more that EMF exposure affects the body's metabolism. In according with Stevens' hypothesis (Steven, Davis, 1996) the field exposure has effects not only on melatonin, but also on the reproductive hormones and the immune system. The reason for measuring the cortisol serum concentration in this experiment was because cortisol is well known as a stress indicator (Clow and Hucklebridge, 2001).

Our results regarding glucose and cortisol dosages do not agree with the results obtained by Lucena et al. (2002). They exposed adult male rats, fed on labina, over thirty days to EMF with the same parameters as we did. However, the rats that were exposed to EMF suffered an increase in their cortisol and glucose dosage levels when compared with the control.

The serum concentrations T_4 and T_3 presented a greater number of Groups that differ statistically. We can see in this study that the Groups subject to EMF and/or RBD present a lower serum concentration for T_4 and T_3 when compared with the control Group (A), the control Group. This data is in agreement with data reported by Zagorskaya and Rodina (1990) Apud Rajkovic et al. (2003). These authors found lowered concentration of thyroid hormones during two months after a single exposure of rats to 20 mT ELF-EMF. And our data is in agreement in part with Rajkovic et al. (2003), who exposed rats to 50 Hz, 50-500 μT ELF-EMF for three months when a part of them (Group I) were sacrificed, while the rest of the animals were subjected to recovery evaluation of the gland and sacrificed after one (Group II), two (Group III) and three (Group IV) weeks. They found that serum T_3 and T_4 concentrations were significantly lower in all exposed animals, except in Group I. However, our data do not agree with data obtained by Lafreniere and Persinger (1979) or Selmaoui et al. (1997). Lafreniere and Persinger (1979) had shown that no alterations in serum T_3 and T_4 concentrations were found in rats exposed to 0.5 Hz EMF perinatally or/and as adults. The study of Selmaoui et al. (1997), reported insignificant differences in serum T_3 and T_4 levels between sham-exposed men and men exposed to continuous and intermittent 50 Hz magnetic field of 10 μT for one night. On the contrary, Udintsev et al. (1978) Apud Rajkovic et al. (2003) found increased levels of circulating T_4 and TSH in rats exposed to 50 Hz EMF of 20 mT for 18 hours. However, differences in exposure facilities and experimental protocols among these experiments, including our study, complicate the adequate comparison of obtained results.

The serum concentration of T_3 in all Groups in our study was much lower than the serum concentration of T_4. This can be explained by Pazos-Moura, Ortiga-Carvalho, Moura (2003) and Moura, Pazos-Moura (2004). They say that the thyroid releases T_4 predominantly and small quantities of T_3. In human beings, this rate is 14:1, while in adult rats this rate is 5:1. In this study, the difference between T_4 and T_3 was greater than expected in all Groups. The difference in Group A, the control group, was the smallest, while the difference in Group D, subjected to EMF exposition and RBD, was the greatest. According to Moura, Pazos-Moura (2004), individuals subject to acute stress can experience a significant decrease of the serum TSH, despite the simultaneous reduction of the serum concentrations of free T_3 and normal levels of T_4.

The T_4:T_3 relations could have been exaggerated in this study due to the pregnant conditions of the rats. In humans pregnancy increases the mother's needs of T_4, increasing production of that substance 25-50% (Burrow; Fisher; Larsen, 1994). However, in this experiment, these dosages were performed at the end of the rat pregnancy. In this period, the dosages are normally lower (Calvo et al., 1990). The data reveals that T_4 and T_3 decreased in all extra thyroidal tissues studied, namely plasma, liver, kidney, lung, heart, and skeletal muscle in normal pregnant rats between 17-22 days of gestation. In this study, we had a huge difference in this relation, almost eighteen-fold, between Group A, the Group control, and Group D, feeding by RBD and exposed to EMF. This can be explained by a decrease in the amount of deiodases or its inactivity due to the two factors acting together, i.e. EMF and undernutrition. According to Bianco et al. (2002) and Bianco (2004), the active thyroidian hormone is T_3. T_3 is produced by two different and relatively independent processes, namely by direct thyroid secretion or during extra thyroidal 5'deiodination of T_4. The deiodination occurs by the action of three isoenzymes, classified by the biochemical and functional criteria, and the tissue distribution: deiodinase type I (5'D-I), deiodinase type II (5'D-II) and deiodinase type III (5'D-III). According to Bianco et al. (2002) in both experimental animals and humans the coordinated changes in the expression and activity of these enzymes ensure thyroid hormone homeostasis and the constancy of T_3 production, constituting a major mechanism for adaptation to changes in the ingestion of iodine, starvation and changes in environmental temperature.

The thyroidian functions may be affected by many factors during different phases of the individual's lifetime and in function of age, nutrition, gender, and pregnancy. Undernutrition affects the thyroidian function (Passos et al., 2002a; 2002b). Possible alterations in enzyme actions involved in cytotic processes in thyroicytes and hormone release should be taken into consideration. Results of experimental investigations that demonstrated the EMF effect on enzymes (Ding et al., 2001) and alterations in the structure and function of cellular membranes (Lisi et al., 2000; Bordiushkov et al., 2000) which are appointed as primary targets of EMF action on biological systems (Tenforde; Kaune, 1987; Goodman; Greenebaum, Marron, 1995), implicate the possible aspect of a direct EMF influence on the thyroid gland (MATAVULJ et al, 1998) Apud Rajkovic et al. (2003). Furthermore Tonini et al., (2001) in their study demonstrated that a 50/60-Hz magnetic field interacts with cell differentiation through two opposing mechanisms. ELF-EMF is able to prevent the shift in surface charges potential promoted by differentiating agents. Simultaneously, it stimulates the increase in intracellular calcium in a dose-dependent manner.

5. Conclusions

The group subjected to the association of EMF and undernutrition suffered a decrease in its serum concentration of T_4 and T_3, when compared to the well-nourished group and the relationship T_4:T_3 in the former group was almost eighteen-fold the later one. These changes imply that the association of EMF and undernutrition leads to changes in the basal metabolism of the pregnant rats.

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