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## **INFLUENCE OF LOW-FREQUENCY ELECTROMAGNETIC RADIATION ON THE COMPLEMENT SYSTEM (EXPERIMENTAL STUDY)**

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*Abstract. The article presents the data of an experimental study on determining the state of the complement system under the conditions of exposure to low-frequency electromagnetic radiation (EMR) on the body of rats under the conditions of a subacute experiment. The relevance of the research is dictated by the fact that low-frequency EMR can change the membrane potential and disrupt nerve cell conduction. This can primarily affect the functioning of the hypothalamic-pituitary-adrenal system, which also influences the effectiveness of the immune system functioning.*

*In the conditions of the natural experiment, male rats were exposed to radiation of 600 V/m with a frequency of 70 kHz for 4 hours every day for 30 days. The studies of immunological indices were carried out in the dynamics of the experiment on the 5th, 15th and 30th days.*

*The study showed that under conditions of 30-day exposure to low-frequency EMR, the humoral link of immunity was characterized by suppression of the C4 component in the first half of the study, followed by a compensatory increase in the C4, C5 components. It has been proven that the general effector reactions of activation of the complement system are able to influence the functions of lymphocytes and macrophages. Thus, under the conditions of an anthropogenic factor, a flexible adaptation process takes place in the body of rats, which involves the redistribution of protein functions for the purpose of "economic" functioning of the body under the conditions of stressor action.*

**Key words:** *electromagnetic radiation, compliment system, immune response, adaptation, rats*

**Introduction.** Officially introduced in 1995 by the World Health Organization, the term "global electromagnetic pollution of the environment" continues to gain relevance today due to the rapid technogenic development of humanity. Electromagnetic radiation (EMR) belongs to an exogenous factor with high biological activity and the modern high saturation of the environment with EMR turns it into a dangerous environmental factor.

In almost all ranges, EMR can have a negative impact on biological systems. The human immune system is the vanguard of the body's reactions to the influence of any factor, and the destructive processes that occur as a result of EMR action lead to changes in the immune response and the development of autoimmune reactions. Low-frequency EMR can change the membrane potential and disrupt nerve cell conduction, which, first of all, can affect the functioning of the

hypothalamic-pituitary-adrenal system, and as a result, the effectiveness of the immune response [1, 2]. Changes in the immune system are also an important link in the implementation of systemic adaptive reactions under the influence of EMR [3, 4, 5].

The scientific interest of the authors of the study in the effect of low frequency EMR (10-100 kHz) on the human immune status is caused by its predominant use in industrial conditions. In addition, electrical radiation in this range is characteristic of most household electrical appliances, video monitors, radio waves with amplitude modulation signals (AM waves), etc. On the other hand, the impact of low frequency EMR on the health of the human population is still not sufficiently studied. The above determined the relevance of conducting this study of the state of the immune system under the conditions of exposure to EMR with a frequency of 70 kHz, the intensity of the electrical component of 600 V/m.

**The aim of the study.** To determine the state of the complement system under the conditions of the influence of low-frequency electromagnetic radiation on the body of rats in the conditions of a subacute experiment.

**Research materials and methods.** Taking into account the fact that in natural conditions the effect of EMR is long-lasting, an experiment was conducted to study the effect of low-frequency electromagnetic radiation lasting 30 days. Rats were exposed to radiation of 600 V/m with a frequency of 70 kHz, irradiation was carried out for 4 hours a day, in parallel with the experimental group there was a control group that was in comfortable conditions. The experimental study was performed on male rats of the WAG line in compliance with the recognized standards of humane treatment of animals in accordance with the provisions of the European Convention for the Protection of Vertebrate Animals (Strasbourg, 18.03.1986) [6], the directive of the Council of the European Parliament (Directive 2010/63/EU ) [7], the Law of Ukraine "On the Protection of Animals from Cruelty" (2006) [8].

The study of immunological parameters was carried out in the dynamics of the experiment on the 5th, 15th and 30th day, after the end of the exposure, 6 rats were taken out and, with help of sparing decapitation, the collection of biological material (blood serum) was carried out.

Immunological reactions were determined using commercial kits for enzyme-linked immunosorbent assay ELISA Kit from Elabscience (China), based on the content of the concentrations of components of the complement system in blood serum (Rat: C3, C4, C5).

Statistical analysis of the data was carried out using the "Statistica 10" program using the non-parametric method of the Mann-Whitney U-test; the mechanisms of biological effects of the complement system were determined using correlation analysis.

**Results and their discussion.** General effector reactions of activation of the complement system are able to influence the functions of lymphocytes and macrophages, which are of

significant importance in the development of the immune response. C3, C4 and C5 components of complement are substances that increase vascular permeability [9].

In the conditions of the isolated effect of EMR, the key component C3 of the complement system did not undergo statistically significant changes, but its concentration was lower than the control values during the entire experimental period (table 1).

Table 1

Concentration of the components of the complement system in blood serum of rats when exposed to electromagnetic radiation (70 kHz, 600 V/m) in dynamics

Immunological value	Control group n=6		EMR group n=6	
	$\frac{min}{max}$	$\frac{Me}{(25\% - 75\%)}$	$\frac{min}{max}$	$\frac{Me}{(25\% - 75\%)}$
The 5th day of experiment				
C3, ng / ml	399.00 615.30	591.00 (541.40 – 613.70)	258.20 611.10	567.55 (552.60 – 598.20)
C4, ng / ml	18.39 29.11	23.07 (20.33 – 25.81)	10.96 24.88	11.48* (11.01 – 13.00)
C5, ng / ml	0.10 1.87	0.87 (0.58 – 1.81)	0.27 1.63	0,38 (0.31 – 1.32)
The 15th day of experiment				
C3, ng / ml	487.00 601.50	555.20 (513.30 – 599.90)	208.90 584.40	526.70 (507.40 – 572.70)
C4, ng / ml	17.03 21.83	21.39 (20.44 – 21.77)	10.99 13.77	11.58* (11.25 – 13.68)
C5, ng / ml	0.66 2.20	0.76 (0.74 – 0.79)	0.40 2.93	1.15 (0.41 – 1.48)
The 30th day of experiment				
C3, ng / ml	147.80 617.90	560.65 (279.90 – 609.50)	3112.50 643.90	535.20 (473.20 – 558.70)
C4, ng / ml	11.11 29.68	24.45 (20.64 – 27.13)	20.47 72.80	48.19* (29.70 – 66.45)
C5, ng / ml	0.48 1.76	1.07 (0.72 – 1.68)	1.16 7.72	3.13* (1.27 – 6.34)

Note. \* – p<0.05 statistically significant difference compared to the control group.

The C4 component underwent more significant changes. Under the influence of EMR, the concentration of the C4 component of complement on the 5th day of observation was reduced by 41% ( $p < 0.05$ ) relative to control values and continued to decrease until the middle of the experiment (15 days) with the same difference between groups (table 1). However, on the 30th day, there was a sharp rise in the C4 content by 108% ( $p < 0.05$ ) (Fig. 1). A direct correlation between C 3 and C4 ( $r = 0.60$ ) was established on the 30th day.

The concentration of the component of the C5 system of complement, which has chemotoxic activity, underwent changes only on the 30th day, having increased by 145% ( $p < 0.05$ ) in the blood serum of rats in the EMR experimental group, compared to the control group (Fig. 1) ( table 1).

On the 5th day of the experiment, a direct correlation between the C4 and C5 indices ( $r = 0.60$ ) was established in the group with isolated effect of EMR, on the 15th day - a strong correlation between C3 and C5 ( $r = -0.94$ ;  $p < 0, 05$ ).

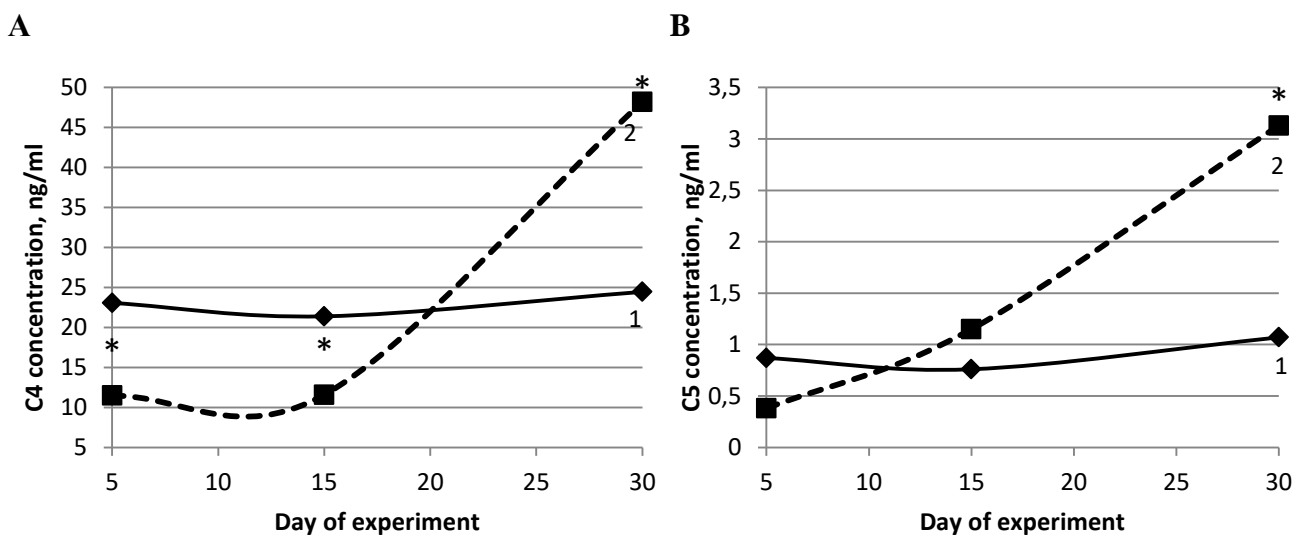


Fig. 1. **A** – the concentration of C4 component of the complement system in the blood serum of rats kept under standard conditions of  $20 \pm 2^\circ\text{C}$  (1) and rats kept for 4 hours under the influence of EMR with parameters of 70 kHz, 600 V/m in dynamics; **B** – the concentration of C5 component of the complement system in the blood serum of rats kept under standard conditions of  $20 \pm 2^\circ\text{C}$  (1) and rats kept for 4 hours under the influence of EMR with parameters of 70 kHz, 600 V/m in dynamics. The value of the median of six samples is given; \* – a statistically significant difference of  $p < 0.05$  was noted in the experimental group compared to the control group.

The absence of a statistically significant difference in the C3 concentration of all experimental groups can be explained by the fact that the C3 content is about 70% of the total number of all components of the complement system [10]. Considering this fact, we can assume that such a concentration of C3 was sufficient to activate the cascade of the complement system in response to the influence of a stress factor.

Revealing an imbalance of the immune response of the complement system in the form of an initial deficiency of the C4 component was the difference in the biological effects on the impact of EMR. The cause of C4 deficiency may be its intensive consumption, which is possibly related to the activation of the complement system according to the classical way and the adsorption of the component on immune complexes [11], which is indicated by the further strengthening of the activation of the complement system in the form of aggregation of the later component C5, which participates in the formation of the membrane attacking complex. An increase in the concentration of the C5 component indicates a more likely activation of the system [12]. The established correlations between the components of the complement system confirm the activation mechanism of the complement system.

**Conclusions.** Therefore, the humoral link of immunity was characterized by suppression of the C4 component in the first half of the study, which was compensated by its growth on the 30th day with a subsequent increase in the synthesis of the C5 component of complement system.

Thus, the evaluation of immunological indices under the influence of low frequency EMR in the experiment proved that, under the conditions of the action of a stress factor, a flexible adaptation process takes place in the body of rats, which involves the redistribution of the functions of effector proteins for the purpose of "economic" functioning of the body under the conditions of the action of the stressor.

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## **ВПЛИВ НИЗЬКОЧАСТОТНОГО ЕЛЕКТРОМАГНІТНОГО ВИПРОМІНЮВАННЯ НА СИСТЕМУ КОМПЛЕМЕНТУ (ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ)**

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*Анотація.* У статті наведені дані експериментального дослідження щодо визначення стану системи комплементу за умов впливу електромагнітного випромінювання низької частоти на організм щурів в умовах підгострого експерименту. Актуальність проведення дослідження продиктовано тим, що низькочастотне електромагнітне випромінювання здатне змінювати мембранний потенціал і порушувати нервовоклітинну провідність. Це у першу чергу може відбиватися на функціонуванні гіпоталамо-гіпофізо-наднирникової системи, котра також впливає на інтенсивність функціонування імунної системи.

В умовах натурального експерименту щури-самці протягом 30 діб зазнавали впливу випромінювання 600 В/м з частотою 70 кГц, 4 години щодня. Дослідження імунологічних показників проводили в динаміці експерименту на 5, 15 та 30 добу.

Дослідження показало, що в умовах 30-денного впливу низькочастотного електромагнітного випромінювання гуморальна ланка імунітету характеризувалася пригніченням компонента С4 у першій половині дослідження з подальшим компенсаторним

зростанням компонентів С4, С5. Доведено, що загальні ефекторні реакції активації системи комплементу здатні впливати на функції лімфоцитів і макрофагів. Таким чином, за умов дії антропогенного чинника в організмі щурів відбувається гнучкий адаптаційний процес, що передбачає перерозподіл функцій білків з метою «економічного» функціонування організму в умовах дії стресора.

**Ключові слова:** електромагнітне випромінювання, система компліменту, імунна відповідь, адаптація, щури

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