Endocrine system (adrenal and thyroid) responses to exposure low frequency alternating magnetic fields

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Reaction of the endocrine system (adrenal gland and thyroid) to the influence of low frequency alternating magnetic fields

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SUMMARY

An overview of the results of experimental studies of the effect of alternating magnetic fields on the endocrine system for the period from 1972 to 2010 is presented. The functional activity of the adrenal glands and the thyroid gland has been analyzed, both in the general and in the local effect of magnetic fields on the projection area of the endocrine glands. The possibility of changes in the activity of the pituitary-adrenal system under the influence of low-frequency alternating magnetic fields was noted.

Key words: magnetic fields, low-frequency magnetic fields, pulsedmagnetic fields, endocrine system, adrenal glands, thyroid gland.

RESUME

The review of experimental researches of the influence of alternating magnetic fields on the endocrine system performed in 1972-2010 is presented. Functional activity of adrenal gland and thyroid under influence of general and localized over endocrine glands alternating magnetic field is analyzed. The possibility of changes in the activity of the pituitary-adrenal system under the influence of low frequency alternating magnetic fields is shown.

Keywords: low frequency magnetic fields, pulse magnetic fields, endocrine system, adrenal gland, thyroid.

Introduction

It has now been proven that the nervous, vascular, and endocrine systems of humans and animals are most sensitive to alternating magnetic fields (ACF) [1-3]. The shifts occurring in these systems as a result of the impact of AMF predetermine subsequent changes in the body, which can be multidirectional. Recently increased attention to the biomedical aspects of the action of PEM is associated with the alleged increase in the risk of oncological pathology in individuals exposed to fields both in industrial and domestic conditions [4]. As one of the hypothetical mechanisms of the onset of tumors, a violation of the secretion of the pineal gland hormone melatonin, which occurs under the influence of PMF, is considered [5, 6]. In this regard, one cannot but agree with the statement of fact, that the largest number of studies and, consequently, publications concerning the effect of AMF on the endocrine system, of all hormones, is devoted to melatonin [7]. However, despite the large number of large-scale epidemiological studies, this issue still cannot be considered fully studied and proven, since the reliability of the results obtained is largely influenced by methodological errors and different approaches to determining the risk of oncological pathology.

Analysis and generalization of features reactive changes v possessing sensitivity to PMF of functional systems will make it possible to determine the methodology for using this physical factor in the prevention and treatment of various diseases, to optimize the therapeutic effect, as well as to correct the functional human condition [8, 9]. In physiotherapy, since the mid-1980s, a direction has developed, consisting in the action of high-frequency electromagnetic fields on the structures of the brain and endocrine organs. The experience gained in the application of this method in a clinical setting in subsequent years allows us to consider such an effect on the body as corrective, accompanied by functional activation of the adrenal and thyroid glands [10]. Recently, this application has spread to low-frequency AMFs, which, when exposed to the adrenal and thyroid glands, can selectively influence the functional state of a person for the purpose of correction [11]. In this regard, in this review, the main attention is paid to the influence of the AMF of various parameters,

The majority of modern ideas about the effect of AMF on the body is based on the concept of field action as a direct stimulus for nerve and muscle cells, formulated by J. Bernhardt [12]. It is quite natural that the body responds to this irritation with an adaptive response, which consists of the stages of training, activation, or stress [13]. The formation of this or that reaction is determined by the set of biotropic parameters of the AMF and the individual characteristics of the organism's susceptibility to it. Among the various types of magnetic fields (constant, variable, pulsed), the largest number of such parameters is possessed by a pulsed field, which is characterized by the greatest biological activity.

The endocrine system contains the hypothalamic-pituitary-adrenocortical and hypothalamic-pituitary-thyroid components, which are directly involved in adaptation processes during changes in the internal or external environment, including in the body's responses to stress [14]. The concept of stress is based on the studies of G. Selye, who showed that during the implementation of the general adaptation syndrome, the activation of the hypothalamic-pituitary-adrenocortical component occurs, and with any effects on the body, as a rule, a rapid increase in the secretory activity of glucocorticoids by the adrenal cortex occurs, which is within certain limits directly proportional to the intensity of the impact.

In this regard, the purpose of this review was an analytical review of the main publications related to experimental studies of the effect of AMF on the functional activity of the adrenal and thyroid glands.

Materials and methods

The information was analyzed on the databases "Electromagnetic fields and human health" (Branch of the State Public Scientific Technical Library of the SB RAS), "Medline" (PubMed), obtained as a result of a search by keywords: "magnetic fields", "low-frequency magnetic fields", "pulsed magnetic fields" , "Endocrine system", "adrenal glands", "thyroid gland", "stress". In addition, the bibliography of relevant articles was analyzed and taken into account in order to search for additional publications. Editions in any language were taken into account.

Reactions of the adrenal glands to low frequency AMF exposureThe functional activity of the adrenal glands was studied mainly under the action of PEM at industrial frequency - 50/60 Hz, the results of which are reflected only in several reviews [15-19], while more detailed results of studying the glucocorticoid function of the adrenal glands under the action of the field are given in separate publications (Table 1) ...

The glucocorticoid function of the adrenal glands in rats was assessed after a single 24-hour exposure to AMF at a frequency of 50 Hz with a magnetic field strength of 200 Oe (15.9 kA / m) [20]. An activating effect was noted, consisting in an increase in an hour after the onset of exposure to the level of 11-hydroxycorticosteroids (11-OCS) in the blood plasma of experimental animals by 50% compared to the control groups. High plasma 11-OCS levels in rats persisted 4 and 12 hours after the end of a single exposure, but after 1; On days 2 and 7, the 11-OCS content returned to normal. Based on the data obtained on the stimulating effect on the function of the pituitary-adrenal system of a single 24-hour exposure to AMF with a frequency of 50 Hz at 200 Oe (15.9 kA / m), a conclusion was made about the stressful nature of the action of the field of these parameters on the body.

In the studies performed (16 subjects), it was found that as a result of daily exposure to AMF with a frequency of 50 Hz at 300-650 Oe (23.9-51.7 kA / m) for 5-30 minutes. over 1-1.5 months, the excretion of 17-oxycorticosteroids (17-OCS) increased at an initially low level (11 people) and, on the contrary, decreased at an increased initial level (5 people) [21].

Table 1

Influence of AMF on the functional activity of the adrenal glands

Характеристики ПеМП	Время и условия воздействия	Объект и исследуемая функция	Биологический эффект	Литературный источник
50 Гц, 200 Э (15,9 кА/м)	24 часовое общее однократное воздействие	крысы, уровень 11-ОКС в плазме крови	повышение уровня 11-ОКС в плазме крови на 50% по сравнению с контролем	[20]
50 Гц, 300–650 Э (23,9–51,7 кА/м)	5–30 мин./день, 1–1,5 мес., общее воздействие	люди, экскреция 17-ОКС	изменение уровня экскреции 17-ОКС в зависимости от исходного уровня	[21]
50 Гц, 200 Э (15,9 кА/м)	24 часа и 7 суток, общее однократное воздействие	крысы, уровень 11-ОКС в плазме крови и надпочечниках	повышение содержания 11-ОКС в плазме крови и надпочечниках	[22]
50 Гц, 200 Э (15,9 кА/м)	6,5 часов/сутки 5 дней, общее воздействие	крысы, уровень 11-ОКС в плазме крови	повышение уровень 11-ОКС в плазме крови 3-и сутки и снижение на 4–5	[23]
50 Гц, 200 Э (15,9 кА/м)	до 7 суток, общее воздействие	крысы, уровень 11-ОКС в плазме крови	повышение уровня 11-ОКС в плазме крови через 7–8 мин. после начала экспозиции и постоянство 15; 30 мин, 3; 7; 12; 24 часа и 7 суток	[24]
50 Гц, 200 Э (15,9 кА/м)	15 мин. и более, общее воздействие	крысы, уровень 11-ОКС в плазме крови	повышение уровня 11-ОКС в плазме крови через 15 мин.	[25]
3-5 Гц, 80 Э (6,37 кА/м)	30 мин., **общее воз**действие	крысы, уровень 11-ОКС в сыворотке крови	снижение через 5 мин. и повышение при 15 и 30 мин.	[26]
50 Гц, 10 мкТл	24 часа, экспозиция в режиме «включено» и «выключено» каждые 15 с, общее воздействие	добровольцы испытуемые, содержание кортизола в сыворотке крови	отсутствует	[27]
60 Гц, 5 Гс (500 мкТл)	1–175 дней, общее воздействие	мыши, кортикостерон в сыворотке крови	повышение уровня кроткостерона в сыворотке крови на 1; 49 и 175 дни экспозиции по сравнению с контролем	[28]
50 Гц, 2 Гс (200 мкТл)	1 и 2 недели, общее воздействие	крысы, кортикостерон в плазме крови	повышение уровня кроткостерона в плазме крови через 2 недели экспозиции по сравнению с контролем	[29]
5 Гц, 0,013 мкТл; 50 Гц, 0,207 мкТл	2 и 4 часа/день, 5 дней, общее воздействие	морские свинки, кортизол в плазме крови	снижение содержания кортизола в плазме крови после 2 и 4-х часовой экспозиции при 50 Гц (0,207 мкТл)	[30]

40 Гц, 2,9 мкТл (магнитотерапия); 200 Гц, 25–80 мкТл (магнитостимуляция)	12 мин/день, локальное воздействие на поясничную область 15 раз	пациенты с болевым поясничным синдромом	магнитотерапия снижает содержание кортизола в середине дня, магнитостимуляция повышает уровень кортизола в более ранние часы	[31]
1 Гц, 400 Э (31,8 кА/м)	15 мин., воздействие на голову	крысы, цитоморфология надпочечников	активация хромаффинной ткани и клубочкового слоя коры надпочечников	[32]
50 Гц, 200 Э (15,9 кА/м)	7 суток, общее воздействие	крысы, цитоморфология надпочечников	увеличение коры надпочечников на 2-е сутки экспозиции и отсутствие отличий на 5-е сутки по сравнению с контролем	[33]
0,01–20 Гц (режим плавающей частоты), 0,01–3,4 Э (0,8–270 А/м)	12; 36 и 64 часа, общее воздействие	крысы, цитоморфология надпочечников	увеличение площади клеток пучковой зоны коры надпочечников через 12; 36 и 64 часа экспозиции	[34]

The data obtained allowed us to make an assumption about the possibility of correcting the corresponding parameters of the 17-ACS excretion level with the help of AMF, which can occur both in the positive and in the negative direction. It is especially emphasized that in order to achieve the desired effect, it is necessary to take into account the applied dose of the current PMP.

In other experiments carried out with 24-hour and 7-day exposures of rats to an AMF with a frequency of 50 Hz at a field strength of 200 Oe (15.9 kA / m), it was found that the exposure also led to a significant activation of the glucocorticoid function of the adrenal glands of the animals. An increase in the content of 11-OCS was observed not only in the blood plasma, but also in the tissue of the adrenal glands of rats and was noted both on the 1st and 7th day of the experiment [22]. At the same time, it was found that under the influence of PMF, the total content of 11-OCS increased due to an increase in free forms of all plasma steroids, which indicated a significant activation of the secretory function of the adrenal glands and the development of an adaptive response.

A somewhat different character was observed in studies with intermittent exposure to PEM with the same parameters, when the state of the pituitary-adrenal system changed depending on the exposure conditions. Thus, chronic exposure to PEM with a frequency of 50 Hz at an intensity of 200 Oe (15.9 kA / m) for 6.5 hours a day led to an increase in the level of 11-OCS in the blood plasma of animals on the 3rd day after the start of the experiment, and by 4 5th and 5th, there was a decrease in the level of functioning of all links of the pituitary-adrenal system [23].

Investigations of the peculiarities of the adaptive response of the pituitary-adrenal system to single and repeated exposure to AMF with a frequency of 50 Hz were carried out at a field strength of 200 Oe (15.9 kA / m) [24]. It was found that the simultaneous activation and deactivation of PMP did not have a significant effect on the 11-OCS content in the blood plasma of rats. The release of 11-OCS into the blood increased only in the course of further exposure - after 7–8 min; after it started. In the next 15; 30 minutes, 3; 7; 12; For 24 hours and 7 days, the level of steroids remained steadily elevated, mainly due to the free forms of the hormone. At the same time, an increase in the content of adrenocorticotropic hormone (ACTH) in the pituitary gland and an increase in steroidogenesis in the adrenal glands were found, which made it possible to assume that in animals, when adapting to continuous exposure to PMF with the same magnetic field strength, a stable level of higher activity of the pituitary-adrenal system is established. The absence of changes in the content of 11-OCS in the blood plasma of animals in response to the switching on and off immediately of the AMF with a frequency of 50 Hz at a magnetic field strength of 200 Oe (15.9 kA / m) is due to the presence of a latent period of the action of the field, which is necessary for the synthesis of hormones [25]. This is evidenced by the results of experiments, when after 15 minutes. after the onset of exposure to AMF of the same parameters, the 11-OCS level in the blood plasma of animals increased almost 2 times, while further continuation of exposure did not lead to The absence of changes in the content of 11-OCS in the blood plasma of animals in response to the switching on and off immediately of the AMF with a frequency of 50 Hz at a magnetic field strength of 200 Oe (15.9 kA / m) is due to the presence of a latent period of the action of the field, which is necessary for the synthesis of hormones [25]. This is evidenced by the results of experiments, when after 15 minutes. after the onset of exposure to AMF of the same parameters, the 11-OCS level in the blood plasma of animals increased almost 2 times, while further continuation of exposure did not lead to The absence of changes in the content of 11-OCS in the blood plasma of animals in response to the switching on and off immediately of the AMF with a frequency of 50 Hz at a magnetic field strength of 200 Oe (15.9 kA / m) is due to the presence of a latent period of the action of the field, which is necessary for the synthesis of hormones [25]. This is evidenced by the results of experiments, when after 15 minutes. after the onset of exposure to AMF of the same parameters, the 11-OCS level in the blood plasma of animals increased almost 2 times, while further continuation of exposure did not lead to

an increase in the concentration of the hormone, which remained at the same level.

The influence of AMF with a frequency of 3–5 Hz at a tension of 80 Oe (6.37 kA / m) on the 11-OCS content in the blood serum of rats revealed a decrease in the hormone concentration after 5 min. from the beginning of the exposure and an increase after 15 and 30 minutes, which continued with a further increase in the exposure time [26]. As a result of the fact that rats with different typological levels were used in the experiments, the changes were more pronounced in animals of the middle type, in rats of the weak type they were not observed at all, and in the strong type they were statistically insignificant.

In studies carried out with the involvement of male volunteers (32 people aged 20–30 years), the circadian rhythm of the blood cortisol content was studied against the background of exposure to AMF for 24 hours with a frequency of 50 Hz at 10 μT, and the exposure was carried out in the field mode "on ”And“ off ”every 15 s [27]. There were no significant changes in serum cortisol levels in the PMF-exposed volunteers (16 people) compared to the sham-exposed group (16 people).

The study of the effect of a 60 Hz PMF at a magnetic induction of 5 Gs (500 μT) on the glucocorticoid function of the adrenal glands of rats was carried out with chronic exposure for 175 days in 7 independent experiments [28]. A statistically significant increase in the level of corticosterone in the blood serum of experimental animals in comparison with the control group was found in the 1st; 49th and 175th days of exposure. The nonlinear nature of the reaction of the adrenal glands of rats in response to the action of an AMF with a frequency of 60 Hz with a magnetic induction of 5 Gs (500 μT) is noted.

In similar experiments with chronic exposure to PMF with a frequency of 50 Hz with a magnetic induction of 2 Gs (200 μT), an increase in the level of corticosterone in the blood plasma was observed in rats 2 weeks after the start of blood exposure compared with the control group of animals [29]. The increased content of corticosterone in the blood plasma persisted 4 weeks after the end of the exposure.

The dynamics of the cortisol content in the blood plasma of guinea pigs was compared with exposure for 2 and 4 hours a day for 5 days in an AMF with a frequency of 5 Hz (0.013 μT) and 50 Hz (0.207 μT) [30]. A statistically significant decrease in cortisol content was observed in guinea pigs after 2- and 4-hour exposure to an AMF at a frequency of 50 Hz with a magnetic induction of 0.207 μT compared to the control and a group of experimental animals exposed to a field with a frequency of 5 Hz (0.013 μT).

The effect of AMF in pulsed modes, which are used in magnetotherapy and magnetostimulation, on the serum cortisol content was studied in patients with pain in the lumbar region [31]. The magnetotherapy mode (frequency 40 Hz, 2.9 μT) was used in a group of 16 patients, magnetostimulation (frequency 200 Hz, 25–80 μT) - in 10 patients. In both cases, the impact of AMF was carried out on the lumbar region for 12 minutes. and was repeated 15 times. It has been found that magnetotherapy alters the circadian rhythms of secretion by decreasing the secretion of cortisol in the middle of the day, while magnetostimulation increases the production of the hormone in the earlier hours.

Morphofunctional changes in the adrenal cortex under the action of AMF make it possible to assess the state of the endocrine gland cortex (bundle and reticular zones). Exposure to an AMF with a frequency of 1 Hz with a magnetic induction of 400 Oe (31.8 kA / m) on the head of rats for 15 minutes. led to the activation of chromaffin tissue and the glomerular layer of the adrenal cortex, an increase in the size of the nuclei of cells of the glomerular, fascicular, reticular and medullary layers [32]. One month after the end of the exposure, all morphological parameters of the adrenal glands of the experimental animals returned to their initial values. The results obtained are considered as evidence of the central mechanism of changes in endocrine functions under the action of AMF of the indicated intensity and frequency.

Changes in the state of the adrenal glands in rats, observed after 7 days of exposure of animals to an AMF with a frequency of 50 Hz at a magnetic flux density of 200 Oe (15.9 kA / m) for 7 days, consisted of two stages [33]. The first stage, which fell on the 2nd day of exposure, consisted in an increase in the adrenal cortex due to its most active zones (bundle and reticular), the appearance of foci of cytolysis in all zones of the cortex, depletion of the bundle zone in lipids. The second stage (5th day of exposure) was characterized by the absence of significant differences in the functional state of the adrenal glands in experimental and control animals.

Studies were carried out to study the state of the adaptive reserve in rats under the influence of AMF in dia

the frequency range 0.01–20 Hz (floating frequency mode) at a magnetic flux density of 0.01–3.4 Oe (0.8–270 A / m) for 12; 36 and 64 hours [34]. The severity of morphological changes consisted in a significant increase in the area of cells of the fascicular zone of the adrenal cortex, which depended both on the individual sensitivity of animals and on the parameters of the AMF in the frequency and intensity range used.

Thyroid responses to low frequency AMF exposureThe functional activity of the thyroid gland of rats (Table 2) with a single 15-minute, 6.5-hour and chronic 6.5 hours a day for 5 days exposure to an AMF with a frequency of 50 Hz at an intensity of 200 Oe (15.9 kA / m) was estimated by the accumulation of 131I in it, which was administered at a dose of 0.5 microcurie [35]. The measurement of the accumulation of the radionuclide in the thyroid gland was carried out 2, 4, 6, 8, 10, 12, 24 and 48 hours after the end of the exposure. It was found that after 15-minute and 6.5-hour exposure to PMF, the accumulation of 131I in the thyroid gland decreased, while in the case of chronic exposure, the incorporation of the radionuclide increased sharply, especially 12 hours after the end of the exposure to the field. In the light of the experimental results obtained, one-time exposures are considered as activating the function of the thyroid gland, and chronic - as stressful. In other studies devoted to the effect of exposure to PMF with a frequency of 50 Hz at a magnetic induction of 14 μT for 24 hours, the accumulation of 5-iodine-deoxyuridine 125I in the thyroid gland of mice, results were obtained indicating the absence of significant changes in the experimental group of animals compared with the control [36].

The study of the circadian dynamics of the content of thyroid hormones (free and bound triiodothyronine (T3) and thyroxine (T4), thyrotropin) in volunteer subjects (32 men, 20-30 years old) was carried out under the conditions of a 24-hour single exposure to PEM with a frequency of 50 Hz at 10 μT, and the "on" and "off" modes of the field were used, which occurred every 15 s [27]. The research results showed no statistically significant changes between the groups exposed to PEM (16 people) and the control group (16 people).

table 2

Influence of AMF on the functional activity of the thyroid gland

Характеристики ПеМП	Время и условия воздействия	Объект и исследуемая функция	Биологический эффект	Литера-турный источник
50 Гц, 200 Э (15,9 кА/м)	15 мин., 6,5 часов, 6,5 часов/день, 5 суток	крысы, накопление 131I в щитовидной железе	повышение накопления 131I в щитовидной железе	[35]
50 Гц, 14 мкТл	54 часа	мыши, накопление 5-йод-дезоксиуридин 125I в щитовидной железе	отсутствует	[36]
50 Гц, 10 мкТл	24 часа, экспозиция в режиме «включено» и «выключено» каждые 15 с, общее воздей-ствие	добровольцы испы-туемые, содержание гормонов щитовидной железы в сыворотке крови	отсутствует	[27]
200 Гц, 25–80 мкТл (магнитостимуляция), 40 Гц, 2,9 мкТл (магнитотерапия)	магнитостимуляция (12 мин./день 15 раз), магнитотерапия (20 мин./день 15 раз), локальное воздействие на поясничную область	пациенты с болевым поясничным синдро-мом,	магнитостимуляция снижает уровень тиреотропина, а магнитотерапия повышает содержание Т3 и Т4 в сыво-ротке крови	[37]
50 Гц, 50–500 мкТл	7 час/день, 5 дней в неделю, 3 месяца	крысы, цитоморфоло-гия щитовидной же-лезы, Т3 и Т4 плазмы крови	снижение активности щито-видной железы (уменьшение объемной плотности фолли-кулярного эпителия, сниже-ние содержания Т3 и Т4 в плазме крови)	[38]
5–10 Гц, 10 мТл	1 час/день, 7 дней в неделю, 4 месяца	крысы, цитоморфо-логия щитовидной железы	повышение функциональной активности клеточных ядер тиреоцитов	[39]
40 Гц, 10 мТл	1 час/день, 7 дней в неделю, 4 месяца	крысы, цитоморфо-логия щитовидной железы	стимуляция метаболизма тиреоцитов	[40]

The results of the effect on patients with pain in the lumbar region of pulsed PEM with parameters used for magnetostimulation (frequency 200 Hz, 25–80 μT) and magnetotherapy (frequency 40 Hz, 2.9 μT) were assessed by the level of secretion of thyroid hormones [37]. The impact was carried out locally on the lumbar region. Thyrotropin was determined in the blood serum of patients after magnetostimulation (10 people, 12 minutes 15 sessions), and those who had undergone magnetotherapy (16 people, 20 minutes 15 sessions) - free T3 and T4. It has been shown that magnetostimulation decreases the thyrotropin level, and magnetotherapy increases the content of T3 and T4 in the blood serum of patients.

Morphofunctional changes in the thyroid gland under the influence of AMF were studied in combination with the dynamics of thyroid hormones. Exposure of rats to PEM at a frequency of 50 Hz with induction from 50 to 500 μT for 7 hours a day, 5 days a week for 3 months led to a significant decrease in the thyroid activity index, which was expressed in a decrease in the volumetric density of the follicular epithelium against the background of an increase in the density of the colloid and a decrease in the level of T3 and T4 in the blood plasma of animals [38].

The morphology of the epithelium of thyrocytes in rats was studied after a 4-month exposure for 1 hour a day for 7 days with an AMF with a frequency of 5–10 Hz, with an induction of 10 mT [39]. The results of the experiments showed that in the experimental animals, in comparison with the control ones, after the exposure, the functional activity of the thyrocyte cell nuclei increased, associated with an increase in DNA synthesis. In other experiments, similar in direction, when rats were exposed to 1 hour per day for 7 days with PMP with a frequency of 40 Hz, with an induction of 10 mT, information was also obtained that allows us to state that exposure causes changes in the epithelium of thyrocytes, indicating the stimulation of metabolism as a result of exposure to fields with the specified parameters.

Conclusion

Analysis of the results of experimental studies allows us to consider the response of the endocrine system to the action of AMF from the standpoint of the concept of the body's resistance as a function of the adaptive response (training, calm and increased adaptation and stress) [13]. In this case, certain shifts in the endocrine system can be caused by short-term exposure to low-intensity PMF, varying, for example, only the frequency of the field. It follows that, depending on the parameters and exposure time, the effect of AMF can cause an activation reaction, accompanied by an increase in the functional activity of the adrenal glands and thyroid gland.

At the same time, PEM with greater intensity and duration of exposure acts as a stressor factor and can cause such changes in the functional activity of the endocrine system, which entail shifts in metabolism, a decrease in the level of energy processes, etc.

At the same time, depending on the AMF parameters used, it seems possible to change the level of activity of the pituitary-adrenal system, since it is characterized by high sensitivity to the action of this physical factor.

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