Streszczenie rozprawy doktorskiej w języku angielskim

Long-term changes in stress responses in rats as a result of exposure to low-frequency electromagnetic fields (50 Hz)

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In recent decades, with the development of modern technologies and industrialisation, exposure to extremely low-frequency electromagnetic fields (50 Hz, ELF-EMF) has significantly increased. Continuous exposure to ELF-EMF affects the functioning of living organisms, including human health. Therefore, research is being conducted to identify the risks of exposure to ELF-EMF fields on organisms. However, the results are inconclusive, indicating the need for further analysis of the impact of this factor on organisms.

Extremely low-frequency electromagnetic field can be considered a stressor and may cause the development of stress-related disorders. Exposure to this type of environmental stress activates a wide range of interacting neuronal, molecular, and neurochemical systems that underlie physiological and behavioural stress responses. The main systems that regulate this response are the sympatho-adrenal-medullary (SAM) system and the hypothalamic-pituitary-adrenal (HPA) axis. Numerous studies have documented the impact of ELF-EMF on HPA axis activity, while the number of studies on the impact of ELF-EMF on the activity of the SAM system is significantly smaller. Considering the crucial role of the SAM system in the proper functioning of the brain, it is necessary to expand knowledge in this area.

The most important factors influencing the basic processes occurring in organisms are the frequency of the ELF-EMF, the value of magnetic induction, and the duration of exposure. In the planned experiments, it was decided to use ELF-EMF with a frequency of 50 Hz and two values of magnetic induction: 1 mT and 7 mT. The effects of longer exposure (simulation of occupational exposure - 8h/day for 7 days) were compared with the effects of shorter daily exposure (1h/day for 7 days). The key research question asked is whether the changes induced by ELF-EMF are permanent and persist after the stimulus ceases, or whether they are transient and diminish over time, suggesting the existence of compensatory or adaptive mechanisms to this stress factor. Previous studies on the impact of ELF-EMF on living organisms suggest that the interaction of the physical factor with biological matter is a bidirectional response (hormesis), in which a factor that is harmful in large doses acts stimulatively in small doses, causing an adaptive response. Therefore, the consequence of ELF-EMF-induced changes in the functioning of the SAM system, which regulates the organism's response to stress stimuli, can be the changes in the levels of neurotransmitters, hormones, and behavioural responses to other stress stimuli. The dynamics of this response, according to the assumptions of hormesis, will depend on the dose of the electromagnetic field and the daily exposure time. In the presented studies, I analyzed the direction and dynamics of changes in SAM system activity parameters resulting from exposure to ELF-EMF (50 Hz) with two magnetic induction values: 1mT and 7mT. I hypothesized that a hormetic dose-response relationship might occur after the initial disruption of homeostasis during exposure to ELF-EMF. Subsequently, the direction and dynamics of changes in SAM system activity in the months following exposure would be a consequence of the electromagnetic field dose and the number of hours of daily exposure. The effects of exposure may appear immediately after its termination but may also develop over a longer period and be visible even several weeks post-exposure, hence the observation period was planned up to 3 months post-exposure. Assuming that periodic exposure (once for 7 days) to ELF-EMF changes the "set-point" of SAM system activity, I predicted that it would alter the hormonal and behavioural response to subsequent stressors. The dynamics of this process and the direction of changes would depend on the strength of the field (magnetic induction) and the daily exposure time. Therefore, in the next stage of the research, I planned to verify the impact of exposure to ELF-EMF with two magnetic induction values (1mT and 7mT) and different daily exposure times (1h and 8h) on SAM system activity and animal behaviour induced by another stressor (open field test).

To verify the hypotheses, adult (3-month-old) male Wistar rats were exposed to ELF-EMF (50 Hz) with magnetic induction values of 1mT and 7mT. The exposure lasted 7 days, 1h or 8h daily. Control animals underwent the same experimental procedure, except for electromagnetic field exposure. Levels of noradrenaline, MHPG, utilization index (MHPG/NA), and adrenaline in the hypothalamus, locus coeruleus, adrenal glands, and plasma were measured immediately and 1-month post-exposure in the group exposed to ELF-EMF 1mT, and additionally 2 and 3 months post-exposure in the group exposed to ELF-EMF 7mT. Hormonal and behavioural changes in response to another stressor (open field test) were also verified.

The obtained results allowed us to conclude that exposure to electromagnetic fields has a dose- and daily exposure-dependent effect on the activity of the SAM system. The conducted studies did not show significant changes in the levels of the analyzed parameters in animals exposed to ELF-EMF with a magnetic induction value of 1 mT. The stress system's response to another stressor in animals from this group was weakened, suggesting adaptation to subsequent stress factors. The impact of exposure to ELF-EMF 7 mT on SAM system activity was significantly greater and visible in the levels of all parameters and all analyzed structures and plasma compared to the control group and, for most parameters, also compared to the group exposed to ELF-EMF 1 mT, suggesting the SAM system's sensitivity to this type of stressor. Greater changes were noted with longer daily exposure - stress hormone levels were higher, and the effect was visible for a longer period. SAM system activity disturbances persisted for several weeks, and this period may be a time of increased susceptibility to nervous system diseases. In the group exposed to the electromagnetic field with an intensity of 7 mT, a more intense SAM system response induced by exposure to another stressor was also observed. The obtained results suggest that high-intensity ELF-EMF (7 mT) can disrupt the functioning of the SAM system, resulting in an intensified response to subsequent stressful events. Additionally, higher levels of locomotor activity and more anxiety-related behaviours were observed in this group. Therefore, a strong electromagnetic field (7 mT) can disrupt the stress response and thus be considered harmful to the nervous system. In summary, changes in SAM system activity induced by electromagnetic field exposure determine the endocrine and behavioural response of the organism to subsequent stress factors.

The conducted studies are significant for determining the impact of electromagnetic fields on the stress response. They will help explain the basic mechanisms underlying the bidirectional action of ELF-EMF and will allow to broaden the knowledge regarding the therapeutic use of electromagnetic fields, as well as provide new data for the proper assessment of the risks associated with ELF-EMF exposure, which is crucial for public health.

Keywords: extremely low-frequency electromagnetic fields, stress, sympatho-adrenal-medullary system, behaviour, hormesis