ELF MAGNETIC FIELD EXPOSURE AND NEUROENDOCRINE RESPONSE

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ABSTRACT

Melatonin has been most extensively investigated, among many other hormones ,for estimating possible effects following magnetic field exposure. Kato, Shigemitsu[1,2,3] have completed 21 exposure experiments in which melatonin was assayed following magnetic field exposure for 6 weeks. Circularly polarized fields exceeding 1.4μTrms produced suppression, elliptical field with the ratio of major vs minor axes at 2:1 was effective, while elliptical field at 4:1 as well as horizontal and vertical fields were not effective to produce suppression. These results indicate that intensity of the field as well as degree of polarization appear to be important variables.

INTRODUCTION

Endocrine system is one of the three systems controlling physiological body functions, along with the nervous system and the immune system. These three systems work interacting with each others. For these reasons endocrine system has been a target of interest of the Bioelectromagnetics.
Effects of electric field exposure on a variety of hormones have been investigated since mid-1970s, when possible biological effects of electric fields drew attention of researchers. Although most of the early research did not yield any positive results, Wilson,Anderson et al[4] reported that nighttime melatonin secretion was inhibited following chronic exposure to 60 Hz electric fields. Since Wertheimer, Leeper[5] reported possible association between magnetic field and childhood leukemia, public concern and research interests have shifted to possible biological and/or health effects of magnetic field.
Melatonin has been most extensively investigated among many other hormones for estimating possible effects following magnetic field exposure. Melatonin is synthesized and secreted from the pineal gland, although insignificant amount is produced in other tissues, as well. Pineal gland is regarded as a neuroendocrine transducer that converts a neural signal, initiated by light, into an endocrine output, melatonin. In mammals, information about the light-dark environment is detected at the retina and transferred, via optic nerve, to the suprachiasmatic nuclei, where the circadian rhythm is generated. The timing signal is conveyed from the nuclei to the pineal gland via thoracic spinal cord, superior cervical ganglia and post-sympathetic fibers.Synthesis of melatonin takes place only during night. Melatonin has several important physiological functions such as 1) inhibitory effects on sex hormones, 2) oncostatic action, 3) regulatory actions on immune system, etc.
Rodents, farm animals, non-human primates and humans have been studied for estimating possible effects of magnetic field exposure on melatonin.

METHODS

Kato, Shigemitsu[1,2,3] have completed 21 experiments in which melatonin was assayed using albino Wistar-King rats in 19 exposure experiments and pigmented Long-Evans rats for the remaining 2 experiments. Age of the rats was about

9 weeks old when the exposure started. Exposure duration was set for 6 weeks, strength of the field were varied from 1.0μT to 350μTrms. Circularly polarized, elliptically polarized and linearly polarized magnetic fields were exposed. Among the 18 exposure experiments, we performed 5 experiments using a circularly polarized field and with the experimental group at 1.4μTrms. The rotating plane was perpendicular to the horizontal component of the geomagnetic field. In each of these experiments, the sham-exposed control group was exposed to 0.02μTrms. The intent here was to establish across time the continuing efficacy of the critical positive control experiment. To test the effects of different exposure parameters, elliptical magnetic fields were exposed in 4 experiments; in two experiments elliptical field of which the ratio of major vs minor axes was 2:1 and another two exposure experiment it was 4:1 and the intensities were 1.4μT and 7.0μTrms each. Also to test the effects of polarization of the magnetic field, a vertical field of 1.0μT and horizontal field of 1.0μT and 5.0μT were exposed. A 12:12 h light:dark cycle was used; lights were turned on at 06:00 h and turned off at 18:00 h. Melatonin was assayed from both plasma and pineal gland. In the initial two experiments, samples were collected every 4 hours meaning the sample size per time points were six or seven. In the later 19 experiments the sample size was about 24 per group per time point in order to increase statistical power; only daytime at 12:00 h and nighttime at 24:00 h samples were collected.

RESULTS

When circularly polarized magnetic field was exposed, any magnetic field intensity exceeding 1.4μTrms produced a suppression of melatonin in both plasma and pineal gland. Furthermore, the degree of melatonin suppression was the same for magnetic field intensities between 1.4μT and 350μTrms. These results suggest a sharp, step-function relationship rather than a more gradual dose-response relationship between magnetic field intensity and melatonin suppression. Nocturnal melatonin concentration, decreased significantly at the end of 6 weeks exposure period, recovered to normal level at both 1 and 4 weeks after cessation of exposure, indicating the magnetic field induced suppression effect is both short-lived and fully recoverable. For the elliptical magnetic field exposure, when the ratio of major vs minor axes was 2:1 there was a significant reduction of melatonin at the 1.4μT as well as at 7.0μTrms. However, there was no effect on pineal function when the ratio was 4:1 at 1.4μT and 7.0μTrms. When the magnetic field was linearly polarized, horizontal field at 1.0μT and 5.0μT have not induced melatonin suppression, and the vertical field at 1.0μT did not produce any significant difference.

DISCUSSION

These results indicate that intensity of the field is clearly a factor to be taken into account when we think about the effects of magnetic field exposure on living creatures. Degree of polarization also appear to be an important variable. Cumulative or interactive effects of duration and intensity also should be considered.

Selmaoui,Touitou[6] studied the effects of 50-Hz, horizontal magnetic field at 100μT for one week to either aged Wistar rats of 23 month old or young rats of 9 weeks old. Serum melatonin concentration decreased by 28% ($P<0.05$) and pineal NAT activity decreased by 52%($P<0.05$) in the young rats, while no effect was observed in the aged rats, suggesting that old rats are insensitive to the magnetic field.

When discussing possible biological and/or health effects of electric-, magnetic fields exposure, we usually are most concerned about if the exposure exerts any effects on humans. Concerning the studies whether magnetic field exposure affects melatonin production of human subjects, there are two categories; experimental and observational. Each of the studies have their own advantages and limits. In the experimental study the researchers can determine the experimental conditions such as strength, wave form, frequency, duration etc and recruit experimental subjects according to the concern and interest of the researcher. Another important advantage is that the experimenter can obtain data directly from humans which is the most valuable for discussion of the effects of magnetic field on humans, thereby we can avoid time-consuming efforts to extrapolate animal data to humans. The limits of the experimental studies using human subjects are that one can only perform acute exposure only for a few days, mainly from ethical point of view. Any experiments cannot be planned if adverse effects are predictable, again from ethical viewpoint. The observational studies have the advantage to assess potential effects of chronic, long-term exposure in the real world. The limits are that exposure is not determined by the researchers and characteristics of the exposure, e.g. waveform, strength etc may not be fully analyzed. Hence the responsible parameters of the field might be left unsolved.

Graham and colleague of USA, Selmaoui and colleague in France and Wood and colleague of Australia have studied patterns of melatonin production of healthy human subjects exposed to magnetic fields in specifically built laboratories. The former two groups found no effect of exposure on melatonin. Wood found magnetic field exposure delayed phase of melatonin rise during night. Burch et al(2000) carried out measurement of environmental magnetic fields in relation to urinary 6-hydroxymelatonin sulfate(6-OHMS) excretion over 3 consecutive workdays of electric utility workers. 6-OHMS is a metabolite of melatonin and there is highly linear relationship between urinary 6-OHMS and circulating melatonin. There was a magnetic field dependent reduction in 6-OHMS levels among men working in substation and 3-phase environments where circularly or elliptically polarized magnetic fields were measured.

More than 8 laboratories worldwide have reported inhibitory effect of magnetic field exposure on melatonin production in rodents, and more than 3 positive effects were reported in human occupational investigation, although negative results have been reported as well.

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