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Current State Of Knowledge Regarding The Effects Of Electric, Magnetic, And Electromagnetic Fields On The Circadian System

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Abstract

One of the unintended consequences of each electrical device's operation is the electromagnetic field generated near the device's location. Every creature, including humans, is daily exposed to the influence of several forms of this field, each defined by a unique set of physical attributes. As a result, it is critical to precisely define how an electromagnetic field affects physiological and pathological processes occurring in cells, tissues, and organs. Numerous epidemiological and experimental studies indicate that the extremely low frequency magnetic fields produced by electrical transmission lines and electrically powered devices, as well as the high frequency electromagnetic radiation emitted by electronic devices, may have a detrimental effect on the circadian system. On the other hand, numerous investigations have discovered that these fields have little effect on chronobiological markers. Several previously offered hypotheses, including one about the critical role of melatonin secretion disruption in the pathophysiology of electromagnetic field-induced disorders, should be reconsidered in light of current understanding. The purpose of this article is to summarise the research on the effect of electric, magnetic, and electromagnetic fields on melatonin and cortisol rhythms two main markers of the circadian system—as well as on sleep. Additionally, it contains fundamental information about these fields' nature, classification, characteristics, and sources.

Keywords: Electrical Devices, electric, magnetic, and electromagnetic fields, electromagnetic field

INTRODUCTION

One of the unintended consequences of each electrical device's operation is the electromagnetic field generated near the device's location. All creatures, including humans, are constantly subjected to the effect of several varieties of this field, each with its own set of physical parameters. As a result, it is critical to precisely quantify the electromagnetic field's influence on organisms. All electrically powered devices and transmission lines generate a low frequency (often 50 or 60 Hz) field that is quasistationary in nature and consists of two distinct components: the electric and magnetic fields. Although the mechanism of this field's biological action is unknown, it is believed to have a possibly harmful effect on organisms. Electronic equipment, on the other hand, such as cell phones, television sets, and radio transmitters, emit electromagnetic radiation at high frequencies (between 300 MHz and 300 GHz). This form of high-energy radiation has a thermal effect, which can raise the temperature of tissues and organs and also cause serious cell damage. The International Agency for Research on Cancer (IARC) classed electrical gadgets' extremely low frequency magnetic fields as probably harmful to humans in 2002 [1]. IARC and WHO classified radiofrequency electromagnetic fields as possibly raising the risk of developing malignant brain tumours in 2011 [2].

The visible portion of electromagnetic radiation, with a relatively small frequency band between 389 and 789 THz, plays a critical role in the regulation of diurnal rhythms by influencing the activity of the suprachiasmatic nucleus via melanopsin-positive retinal ganglion cells [3]. Several research, however, have established that electric and magnetic fields also have an effect on the circadian rhythm. A deficit in melatonin secretion has been hypothesised to be accountable for the electromagnetic field's carcinogenic effect [4].

The purpose of this article was to summarise the evidence about the effects of electric, magnetic, and electromagnetic fields on melatonin and cortisol rhythms, two main markers of the circadian clock, as well as sleep. Additionally, we included information about the nature, physical characteristics, classification, and sources of fields, which may be of help to biologists and medical doctors.

ELECTROMAGNETIC FIELDS IN LIVING ORGANISMS' HABITATS

Since the origin of life on Earth, electromagnetic radiation and fields have accompanied living creatures. However, their current intensity and ubiquity should be credited first and foremost to human activity—technological advancements in modern engineering connected to the invention and practical use of electrical power transmission systems, electrical equipment, and telecommunications.

Electromagnetic radiation and fields originate from both natural and non-natural sources. Celestial bodies such as stars and magnetars, the Earth, and biological processes involving the passage of electrical impulses in living things are all natural sources (Figure 1). The microwave background radiation that reaches the Earth's surface from space is a result of the big bang and the universe's evolution in the first seconds of its existence. This form of radiation is classified as the most perfect black body in nature due to its thermal energy distribution. It has a nearly ideal Planck spectrum at temperatures around 2.7 K and a maximum of its surface power density at a wavelength of 272 GHz [6]. Solar radiation that reaches the Earth's surface has a relatively low surface power density of roughly 3 W/m [6] and is composed of discrete frequency bands, referred to as atmospheric windows, that are not absorbed by the Earth's atmosphere. They may be classified as

- The radio window is comprised of electromagnetic wavelengths ranging from 15 MHz to 300 GHz.
- optical window – electromagnetic wavelengths ranging from 150 THz to 1000 THz,
- The microwave window is defined by electromagnetic wavelengths ranging from 23.1 to 37.5 GHz.

Earth's magnetic field is another natural field that originates in the planet's core and extends to a wide area encircling the globe, dubbed the magnetosphere. Atmospheric discharges, also known as lightning, are a significant source of powerful electromagnetic fields. Rapid radiation discharges associated with these natural events have a high power density and a high frequency. Electromagnetic fields originate in living beings as a result of signal transmission through the nervous system and from structures that generate electrical impulses on their own (like the heart).

The history of man-made sources of electromagnetic radiation and fields is brief, spanning barely the last century. Two categories of non-natural sources of electromagnetic radiation or fields exist. The first category contains ionising radiation, which has a relatively high energy and is capable of ionising matter particles.

This type of radiation is present for purely natural reasons (the median yearly exposure dose is approximately 2.4 mSv). However, non-natural sources of ionising radiation, such as technical gadgets that utilise a variety of radioactive isotopes, are currently regarded as the most serious threats to public health protection. The second category includes nonionising radiation with an energy level that is insufficient to ionise matter particles.

Table 1 The following is a list of the numerous sources of electromagnetic fields/radiation that have an effect on living organisms [7].

Level	Frequency range	Radiation source
Static	0Hz	Earth, vide screens, magnetic resonance imaging, and other diagnostic/scientific equipment, electrolysis, welding
Extremely low frequency field	0-300 Hz	Power transmission lines, home wiring, car electric engines, electric trains and trams, welding devices
Intermediate frequency	300 Hz - 100 kHz	Video screens, antitheft devices used in cars, homes, shops, card readers, metal detectors, magnetic resonance imaging, welding devices
Radio frequency	100 kHz-300 GHz	Radio, television, mobile phones, microwave ovens, radar and ratio transmitters, magnetic resonance imaging.

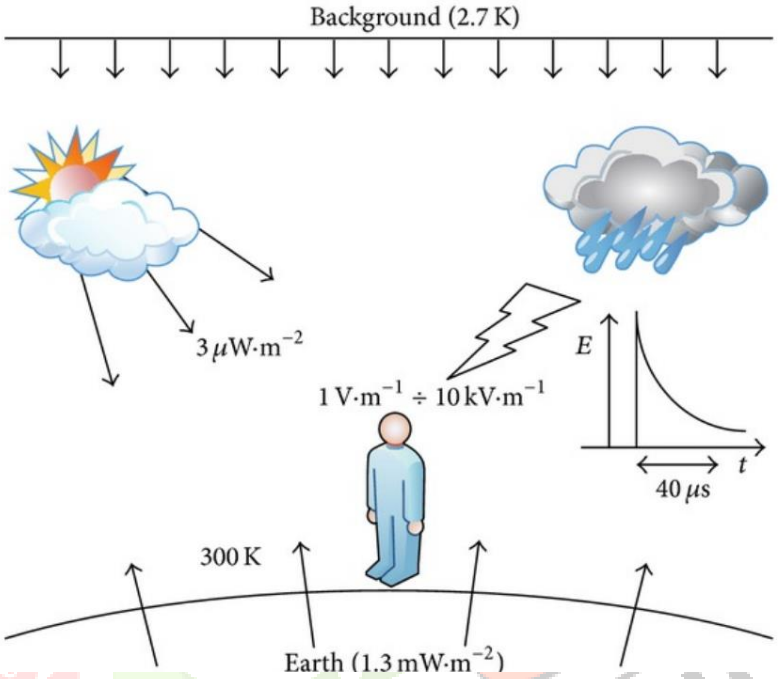

Figure 1 : On Earth, there is natural sources of radiation (based on [6])

EFFECTS OF ELECTRIC, MAGNETIC, AND ELECTROMAGNETIC FIELDS ON MELATONIN SECRETION'S DIURNAL RHYTHM

Melatonin is the primary hormone that regulates the circadian rhythm in all animals, including humans [8]. The suprachiasmatic nucleus the key endogenous oscillator directly related to the retina drives the diurnal rhythm of its production in the mammalian pineal gland [8–10]. Under physiological conditions, regulatory systems guarantee that this rhythm is correctly synchronised with the light-dark cycle, and so the increased night-time melatonin release can act as a clock and calendar for all cells in the body [8, 11, 12]. Melatonin is critical for the regulation of numerous physiological processes associated with daily or seasonal rhythms, including as sleep, metabolism, and reproduction [13]. Additionally, melatonin regulates the immunological system [14], the cardiovascular system [15], and the development of cancer [13, 16, 17]. Additionally, it is a highly effective free radical scavenger [18].

The effect of exposure to an electromagnetic field with a frequency of 1800 MHz on melaton secretion from the pineal gland of the Dzungarian hamster was examined [19-24] using the same experimental setup as for the ELF-MF [25,26] studies. This study indicated that both continuous and pulse signals at an adsorption intensity of 800 mWkg1 for seven hours boosted isoproterenol-stimulated melatonin production [27, 28].

EFFECTS OF ELECTRIC, MAGNETIC, AND ELECTROMAGNETIC FIELDS ON CORTISOL SECRETION'S DIURNAL RHYTHM:

Cortisol is a critical steroid hormone that the adrenal gland produces. As with melatonin, it demonstrates a stable and predictable diurnal cycle when physiological parameters are met [29–34]. Debono et al. [35] found that cortisol concentrations reached their lowest levels at midnight in a study of 33 healthy people using 20-minute-interval cortisol profiling across 24 hours. It subsequently began to increase about 02:00 03:00 and peaked at approximately 08:30. Following that, the cortisol level gradually fell to its nadir. The maximum cortisol concentration in human blood was around 399 nmol/L, whereas the nadir cortisol concentration was approximately 50 nmol/L. Cortisol secretion, like many other physiological processes in the body, is regulated by the suprachiasmatic nucleus in the hypothalamus.

Cortisol affects hunger and appetite, stress, inflammatory reaction, and many other functions [36–42]. The relevance of cortisol is most clear when it becomes inadequate in a situation known as adrenal insufficiency [43, 44]. It has been postulated that cortisol functions as a secondary messenger between central and peripheral clocks and may be an important element in the synchronisation of body circadian rhythms [45]. Alterations in the rhythmic generation and level of the cortisol lead to considerable detrimental effects [46-51]. Children with autism usually demonstrate a wide variation in day-time patterns of cortisol and considerable elevations in salivary cortisol in response to a nonsocial stressor [52, 53].

CONCLUSION

The results of investigations on the effects of electric, magnetic, and electromagnetic fields on the release of melatonin and cortisol, as well as on sleep, are mostly conflicting. The negative data on the effect of these physical variables on the production of both "circadian" hormones were obtained in all types of investigations, including epidemiological studies, volunteer studies, and animal experiments. Additionally, in vitro studies on rodent pineals have produced contradictory results [54-58]. The causes of the discrepancies are unknown; however, factors such as inaccurate exposure level estimation, interferences with other factors such as light and medication, differences in the phase of the circadian rhythm during exposure, and interindividual variability in sensitivity to electromagnetic fields appear to be particularly noteworthy [59-62]. The notion that some persons are more sensitive to electromagnetic fields than others, possibly related to their genetic makeup or present health situation, looks quite intriguing and should be investigated further. It is worth noting that conflicting results have also been reported in research examining the various impacts of electrical, magnetic, and electromagnetic fields on organisms, such as their tumor-promoting influence [63–67].

Regardless of the reported results, ELF-MF and radio frequency electromagnetic fields must be considered as possible factors influencing the circadian system's function, as a large number of studies have demonstrated changes in melatonin and cortisol secretion, as well as sleep, following exposure to these fields. Due to the ubiquitous exposure of humans and animals to ELF-MF and radio frequency electromagnetic fields, it is necessary to continue studying their biological impacts [68-70]. A significant and unresolved topic is the link between the physical features of fields and their biological consequences, as well as the processes by which fields affect on the circadian clock.

In view of the available research, the concept that electrical, magnetic, or electromagnetic fields cause cancer is not supported by epidemiological or experimental data. As a result, it should be regarded as unconfirmed at the moment.

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