

Effects of Radiofrequency Electromagnetic Field Exposure on Neurophysiology

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Abstract

The human body is a permissible medium, and radiofrequency electromagnetic field (RF-EMF) waves pass through this medium. The effects exerted by RF-EMF devices such as mobile phones on brain tissues are categorised into thermal and non-thermal effects. The aim of this review was to analyse the interactions and interface between RF-EMF exposure and the nervous system, to ascertain any negative impact on the nervous system at both cellular, molecular and systems level. Original studies that reported on the effects of RF-EMF exposure on the brain function and nervous system from inception to 20 August 2019 were searched online. The PubMed database was utilised. The MeSH system was used to excerpt relevant research studies from PubMed using the following keywords: electromagnetic field, radiofrequency, mobile phone, brain, central nervous system, radiation and neurophysiology. All selected articles were published in the English. Full articles were assessed, and relevant information was extracted. RF-EMF exposure significantly altered several neurophysiological mechanisms based on electroencephalogram studies and molecular and biochemical analysis. However, there was no substantial evidence linking RF-EMF exposure to the pathogenesis of brain tumour.

Keywords: Brain, central nervous system, electromagnetic field, mobile phone, radiation, radiofrequency

INTRODUCTION

The human body is a permissible medium, and radiofrequency electromagnetic field (RF-EMF) waves pass through this medium. The effects exerted by RF-EMF devices such as mobile phones on brain tissues are categorised into thermal and non-thermal effects. One possible biological mechanism by which RF-EMF causes deviations in neuronal activities is by upsetting regional cerebral blood flow.^[1] Residents living close to mobile phone base positions are at risk of developing neuropsychiatric complications and some vicissitudes in the performance of neurobehavioural functions both in facilitation and inhibition.^[2] The contact of adult rats with RF-EMF caused alterations in monoamine neurotransmitters and this might trigger several adverse effects such as stress and alterations in learning and memory.^[3] Sensorineural hearing loss was associated with mobile phone use.^[4] The use of mobile phones is a risk factor for health threats, and therefore, steady use of mobile phones should be minimised or avoided.^[5]

Chronic exposure to GSM 900 MHz microwaves (specific absorption rate = 6W/kg) induced insistent astroglia stimulation

in the rat brain which is a sign of possible gliosis.^[6,7] Mobile phone radiation causes oxidative stress in corneal and lens tissues, and Vitamin C as an antioxidant could aid in averting these effects.^[8] Few statistical indications showed that mobile phone exposure might cause headache and reduction of the reflex and clunking sound in the ears.^[9] Assessment of the unswerving recording of brain cortical and hippocampal activity throughout a high-frequency EMF exposure demonstrates the negative effects of RF-EMF on the central nervous system (CNS).^[10] The findings from a meta-analysis propose that RF-EMF might have a minor effect on human attention and functional memory.^[11] Neonates exposed to RF-EMF had a substantial reduction in their pyramidal cell quantity at the

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Submission: 01-09-2019 **Acceptance:** 30-09-2019
Published: 03-01-2020

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How to cite this article: Okechukwu CE. Effects of radiofrequency electromagnetic field exposure on neurophysiology. *Adv Hum Biol* 2020;10:6-10.

Access this article online

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DOI:
10.4103/AIHB.AIHB_96_19

cornu ammonis,^[12] and there was a significant rise in brain lipid and protein oxidation after RF-EMF exposure.^[13] The use of mobile and cordless phones amplified the risk for glioma, especially the ipsilateral use; the risk was maximum in the age group <20 years.^[14] Mobile phone use decreased pyramidal neuron numbers by 51.15% and improved ischemic neuron numbers by 73% at cortex region of the brain.^[15]

Mobile phone use changed resting electroencephalogram (EEG) patterns and values by reducing 1–4 Hz activity at the right hemisphere sites and increasing 8–12 Hz activity as a function of exposure period at the midline posterior positions. Cell phone exposure altered early phase-locked neural responses, decreasing the normal response over time in the 4–8 Hz band, reducing the response in the 1230 Hz band, and increasing midline frontal and lateral posterior responses in the 30–45 Hz band of resting EEG.^[16] Pulsated high-frequency EMF exposure could affect the normal brain physiology.^[17] Low specific absorption rate (SAR) microwave radiation exposure 2450 MHz at SAR 6.672×10^{-4} W/kg could induce DNA strand breaks in the brain tissue.^[18]

The amount of nitric oxide synthase (NOS)-positive neurons and the strength of positive staining in hippocampus decreased at 1.5 and 24 h after exposure to electromagnetic pulses. At 48 h, the quantity of NOS-positive neurons inverted to control level, but the intensity of positive staining was low, the mien of NOS in the cerebellum had no obvious changes.^[19] Perinatal and postnatal contact with mobile phones was linked to behavioural complications such as mood and hyperactivity problems within the age of school entrance.^[20]

Mobile phones discharge a pulsated high-frequency EMF which might infiltrate the scalp and the skull progressively, there is much curiosity in the communication between this pulsed microwave radiation with the human CNS.^[21] Mobile phone exposure might distress neuronal action, mostly in propinquity to the phone.^[22] Usage of analogue cellular phones augmented the risk for acoustic neuroma by 5% for every 100 h of use, the menace improved for astrocytoma Grade III–IV with latency period at uppermost estimations >10-year period from the onset use of these phone categories and the peril amplified each 1 year of use of analogue phones by 10%.^[23]

Same side or ipsilateral use of a cell phone augmented the risk of tumours in the temporal, temporo-parietal and occipital areas.^[24] The ipsilateral use of an analogue cell phone produced a significantly upgraded risk for malignant brain tumours.^[25] There was a propensity of a shorter tumour induction period for ipsilateral contact with microwaves than for contralateral, which specify a tumorigenesis effect.^[26] A significant association was found between vestibular Schwannoma and the use of analogue cell phones.^[27]

Long period of mobile phone use was linked to cancerous brain tumours.^[28,29] An enlarged risk was found for glioma, and on the use of mobile or cordless phone, the risk rises with latency time and collective use in hours and was uppermost in individuals with first use before the age of 20.^[30]

An analysis of 99 case studies of gliomas was carried out using logistic regression, the visible cases were those with the tumour midpoint within 4.6 cm from the mark between the mouth and the external meatus of the ear, which is the most likely position of the mobile phone investigation built on several indicators of mobile phone use as the consequence were conducted and most cases were consistent mobile phone users, a slightly higher percentage of gliomas exist among mobile phone users than non-users, this occurred around 4.6 cm from the supposed location of the mobile phone.^[31] With the aid of a light microscope, it was observed that emerging neurons of dorsal root ganglion exposed to RF-EMF were damaged and it was dose dependent and continued despite the exposure-free period between two exposures.^[32] The comparative dangers associated with a collective use of mobile phone for ≥ 100 h were 0.9 for glioma (95% confidence interval [CI]: 0.5–1.6), 0.7 for meningioma (95% CI: 0.3–1.7), 1.4 for acoustic neuroma (95% CI: 0.6–3.5) and 1.0 for all types of tumours combined (95% CI: 0.6–1.5).^[33]

A study was conducted to know if continuous wave (CW) RF fields induce neuron cell death *in vitro*, rat primary neuronal cultures stayed visible to a CW 900 MHz RF field with a SAR of 2 W/kg for 24 h, the outcomes showed that under the investigation settings used, exposure of primary rat neurons to CW RF fields might induce a caspase-independent pathway to apoptosis.^[34] The findings from an investigation of EEG reactions to mobile phone exposure, using an RF-EMF frequency of 902.4 MHz at an intensity of 0.06 mW/cm² showed a significant rise of comprehensive correlation dimension during the exposure and after exposure period, which was more distinct when the eyes was closed, this implies cortex activation during cellular phone RF-EMF exposure.^[35] Cell phone exposure effects on the human EEG have been described during waking and sleep states although with slight variations in the frequency affected, these variances might be partially due to individual variations in response and cellphone RF emissions might have huge but variance effects on human brain function.^[36] The widespread use of mobile phones increases the interface EMF and the CNS, high energetic radiofrequency exposure caused a reduction in cellular gamma-aminobutyric acid (GABA) level in the cerebellum.^[37]

A study conducted by using a head-only exposure device in rats, showed that rats exposed to 15-min of 900-MHz pulsed microwaves at a high brain-averaged power of 6 W/kg, had a strong glial reaction in their brain, this effect indicates neuronal damage, mostly in the striatum, also significant changes were observed in the equilibrium dissociation constant (K_d) and maximum number of receptors (B_{max}) values of N-methyl-D-aspartate (NMDA) and GABA_A receptors as well as on dopamine transporters at the postsynaptic membrane; generally, there was a swift cellular and molecular modifications in the rat brain after an acute exposure to high power Global System for Mobile communication 900-MHz microwaves.^[38] An examined time drifts in the age-adjusted occurrence frequency of adult neuronal cancers in the surveillance, epidemiology, and end Results program from 1973 to 2002, specify that mobile phone use is unconnected to the risk of neuronal cancers.^[39]

The aim of this review was to analyse the interactions and interface between RF-EMF exposure and the nervous system, to ascertain any negative impact on the nervous system at both cellular, molecular and systems level.

MATERIALS AND METHODS

Original studies that reported on the effects of RF-EMF exposure on brain function and nervous system from inception to 20th August 2019 were searched online. The PubMed database was utilised. The MeSH system was used to excerpt relevant research studies from PubMed using the following keywords: electromagnetic field, radiofrequency, mobile phone, brain, CNS, radiation and neurophysiology. All selected articles were published in the English. Full articles were assessed, and relevant information was extracted.

Effects of radiofrequency electromagnetic field exposure on the central nervous system

RF-EMF exposure was capable of eliciting changes in the CNS, by causing neuronal cell apoptosis, altering the physiology of nerve myelin and ion channels^[40] [Figure 1].

RF-EMF affects sleep pattern and quality.^[41] Interestingly, transgenic Alzheimer's mice exposed to RF-EMF for ≥ 8 months

had improvement in cognitive abilities.^[42] An increase in glucose metabolism was observed in the brains of rats exposed to RF-EMF over a long period of time.^[43] Exposure to a low-frequency RF-EMF is enough to modulate vesicle endocytosis by enhancing presynaptic calcium channel expression at a central synapse.^[44] However, the number of synaptic vesicles reduced significantly in the cerebral cortex of mice exposed to RF-EMF.^[45] Exposure of mice to 835 MHz RF-EMF over a long period of time induced hyperactivity, autophagy and demyelination in the cortical neurons.^[46] Male offspring of rats' exposed to RF-EMF had a rise in malondialdehyde and glutathione levels and atrophy of spinal cord; they also had hypertrophy of myelin in the cell body, which caused severe damage to the myelin sheaths.^[47] Long period of exposure to RF-EMF can lead to mood disorders, stress and poor quality of sleep.^[48] However, cytoarchitectural changes, single- and double-stranded DNA breaks were observed in rat brain cells after acute exposure to RF-EMF.^[49]

DISCUSSION

Many extensive animal-based experimental studies have been conducted in the past, to understand the effects of RF-EMF on the nervous system, most of the studies investigated on the interactions between brain cells and RF-EMF exposure.

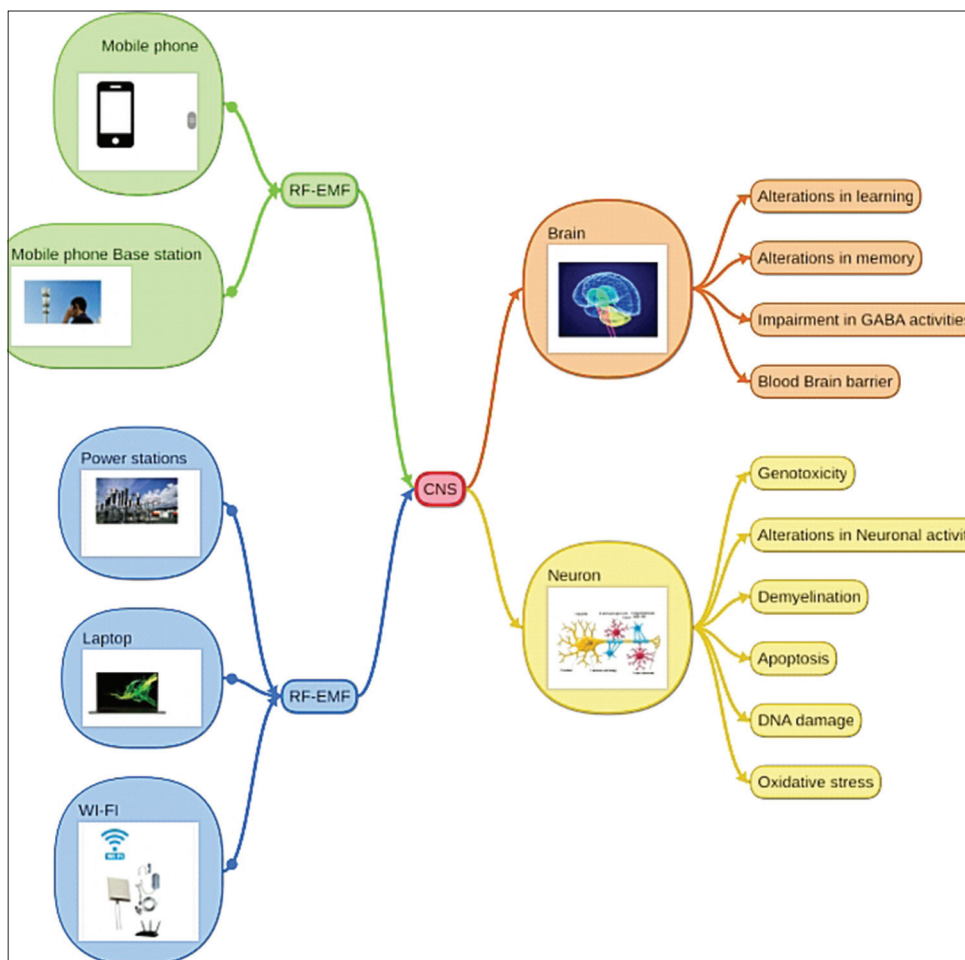


Figure 1: Possible biological effects of radiofrequency electromagnetic field on human nervous system.

With recent advances in technology and because RF-EMF are emitted by power lines, computers, mobile phones, mobile phone base stations, cordless phones, wireless networking technology (Wi-Fi) and bluetooth devices, more investigations are needed to understand the effects of these devices on neurophysiology.

Changes in the CNS function which manifested as instabilities in EEG pattern, sleep pattern and neuroendocrine function have been detected with increased mobile phone use, along with reduced melatonin secretion.^[50] Heat dissipation is mostly related to the absorption of high-frequency RF-EMF resulting from enhanced electrical conductivity of the nerve and brain tissues, heat effects might cause disruption of neuronal function and growth, increase in brain tissue temperature is associated with the disproportion between heat generation and heat dissipation, thermal generation depends on specific absorption rate and energy level, which is the power density of emitted RF-EMF radiations which must exceed 100 mW/cm² to have thermal effect on tissues of the CNS, thermal dissipation involves three mechanisms, which are heat conduction to the surrounding brain tissues, convection through blood perfusion and radiation to the surroundings.^[51]

Eser *et al.*^[52] found severe deteriorating changes, shrivelled cytoplasm and broadly dark pyknotic nuclei in brain cells of rats exposed to RF-EMF, laboratory analysis confirmed that the total antioxidative capacity level was significantly reduced in RF-EMF exposed rats and total oxidative capacity and oxidative stress index levels were significantly increased in the frontal cortex, brain stem and cerebellum. Interleukin-1 β level was significantly increased in the brain stem of rats exposed to RF-EMF, moreover, RF-EMF caused structural changes in the frontal cortex, brain stem and cerebellum and enhances the oxidative stress and inflammatory cytokine system in rats. There were fluctuations in human brain wave activity during exposure to RF emissions from mobile phones.^[53] **Exposure to RF emissions from cell phones alters the EEG pattern and this may have adverse effect on sleep quality and neuroendocrine system.**^[54] However, mobile phone use or exposure to RF emissions from cell phones is not a strong risk factor for mortality attributed to brain tumours.^[55]

Future directions

There is need for further studies to ascertain the effects of RF-EMF on mood, learning and memory. Mobile phone is the most common RF emitting device currently used today, there is need to investigate the thermal and non-thermal effects of smart phones RF emissions, on cell membrane structures, blood-brain barrier, endothelial function, immune system and on the nervous system excitability and inhibitory mechanisms.

CONCLUSION

RF-EMF exposure significantly altered several neurophysiological mechanisms based on EEG studies conducted on humans and molecular and biochemical findings in animal experimentations. However, there was no substantial

evidence linking RF-EMF exposure to the pathogenesis of brain tumour.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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