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Research Article

EFFECT OF ELECTROMAGNETIC RADIATION EMITTED BY CELLULAR (MOBILE) PHONE ON BRAIN ELECTRICAL ACTIVITY MEASURED BY QUALITATIVE ELECTROENCEPHALOGRAM

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A B S T R A C T

Introduction: Brain tissue has higher exposure to radiofrequency fields as cellular phones are used in close vicinity to it. Their use is associated with symptoms like tinnitus, headache, dizziness, fatigue, sensations of warmth, dysesthesia of the scalp, visual disturbances, memory loss and sleep disturbances. Hence determining whether they affect human physiological parameters was important and therefore a study to measure the electrical activity of the brain, when exposed to cell phone radiation was undertaken.
Method: It was a single blind, cross over, unicentric study on 50 healthy male adults between ages of 18 to 24 years. Real and sham exposure of cellular EMF was given. EEG was analyzed for qualitative parameters of focal abnormality, unusual pattern for given age, rhythm abnormality including fast activity and slow activity.
Result: Unusual pattern for given age, rhythm abnormality and focal abnormality was observed.
Conclusion: In normal use, cellular phone EMR can alter brain electrical activity.

INTRODUCTION

There is presently intense concern regarding the possible deleterious effects of electromagnetic fields on human health. This is due to humans being increasingly exposed to these fields of varying frequencies as a result of exponential advance of technology and its application involving the use of EMF. Familiar sources of exposure along with their frequency range are given below (Table 1) which also indicates the ubiquitous nature of this exposure.

Table 1 Typical sources of electromagnetic fields[14]

Frequency Range	Frequencies	Some examples of sources of Exposure
Static	0 Hz	video displays (VDU), MRI and other diagnostic scientific instruments, industrial electrolysis, wielding devices
Extremely Low Frequency (ELF)	0-300 Hz	power-lines, domestic distribution lines, domestic appliances, electric engines in cars, trains and tramways, wielding devices
Intermediate Frequency (IF)	300 Hz – 100 kHz	video displays (VDU), anti-theft devices in shops, hands-free access control systems, card readers, metal detectors, MRI, wielding devices
Radio Frequency (RF)	100 kHz- 300 GHz	mobile telephony, broadcasting and TV, microwave oven, radar, portable and stationary radio transceivers, personal mobile radio, MRI

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Various studies have been conducted to examine the effects of EMF exposure within specific frequency ranges. Information on the effects on health due to static fields is currently insufficient while that due to ELF has not shown any adverse effect in adults or children though epidemiological studies have strengthened its association with childhood leukemia. EMF is unlikely to damage DNA directly as the photon energy of radiation from even mobile phones which use the radio frequency range is much lower than the energy necessary to break chemical bonds[14].Its effects like genotoxicity are likely mediated indirectly via alteration of cellular constituents like, free radicals[11,13]. So studies have been undertaken to examine its effect at the level of cellular membrane, gene expression, signal transduction pathways, cellular proliferation, regulation of cell cycle, cell differentiation, apoptosis, metabolism, levels of heat-shock proteins[14], production of melatonin[11], to name a few. There is increasing evidence that EMF exposure has a major impact on the oxidative and nitrosative regulation capacity in affected individuals and the susceptibility to EMF is probably dependent on the duration of exposure and efficiency of individual's homeostatic abilities[1]. Chronic exposure has shown to be detrimental while short term exposure may have beneficial effects.

Currently, of particular interest is the use of mobile or cellular phones as they operate in the radiofrequency range, are held close to the human body and the use of which is greatly increasing Though IARC designates cellular phone as

"possible [class 2B] carcinogen", its effects on human health have been inconclusive. Nevertheless, symptoms like tinnitus, visual disturbances, headache, dizziness, memory loss, sleep disturbances, fatigue, sensations of warmth and dysesthesia of the scalp have been associated with their use. Thus, it is important to determine whether they affect human physiological parameters. As the mobile phone is used in close proximity to the head, the head is the targeted recipient of the electro-magnetic energy. Therefore, this study measuring electrical activity of the brain (EEG), during exposure to cell phone radiation (EMF) was undertaken.

METHOD

After approval of the institutional ethics committee, the study was carried out at tertiary care medical institute of a corporation of a metropolitan city after obtaining informed and signed consent from 50 young healthy male adult voluntary participants, in the age group of 18 to 24 years fulfilling the following inclusion and exclusion criteria.

Inclusion Criteria

Normal healthy young adults male
In the age group of 18 to 24 years
Right handed
Normal sleep wake cycle
Normal hearing and native speaker

Exclusion Criteria

- History of caffeine consumption 8 hours prior to study
- Alcoholic and smokers
- Participants taking any medication
- Participants having any known cardiovascular, neuro-developmental and neurobehavioral disorders
- Participants having any middle ear disorder
- History of sleep disorder

Equipment's used: A modified helmet with 2 similar cellular phones fixed on either side (Model no.1616 Nokia GSM, maximum SAR corresponding to 2 W/kg, Emission frequency of 900-1800 MHZ and maximum power output of 1-2 watt), Neuromax 32 (Medicaid Chandigarh) - portable EEG machine, 10-20 conducting gel.

Subjects were seated in a relaxed position, with the head resting on a comfortable chair, in a quiet, dimly lit room with their eyes closed and no significant movements. Room temperature and relative humidity were maintained. All other electrical devices were unplugged to minimise the background field levels.

Two cellular phones, one 'ON' and the other 'OFF' were held by a modified helmet, oriented in the normal position for use over the ear with the microphone towards the corner of the mouth and antenna near the head in parieto-temporal area. On one side, the exposure was real with a Test Mobile Phone switched 'ON', while on the other side it was sham with similar mobile phone switched 'OFF', to balance the weight and prevent localisation of side of stimulation, and therefore attention and hence avoiding confounding effects from the expectation of a signal from the side of the brain where the cell phone was located. Thus the patient was unaware of the side of the test and sham exposure. There is no exposure from a mobile phone in a switched 'Off' position[14]. In each test condition the cellular phone was in talk mode but the sound was muted and the display screen was covered by a tape to exclude the thermal effect. The total duration of the procedure was approximately 30 minutes.

3 EEG Recordings, each of 100 Seconds Associated with the 3 test Conditions were Made

1. EEG without exposure with both the cell phones turned 'OFF' (Baseline)
2. EEG recorded with 'Test Mobile Phone' on Right side
3. EEG recorded 'Test Mobile Phone' on Left side

A 100 sec 'resting' period was allotted after each EEG recording. Data were sampled at a rate of 256 s in a bandwidth of 1-100 Hz. Subsequently, all EEG traces were scanned, and artefacts of occasional muscle twitches and mechanical interferences were removed. Analysis and interpretation of EEG reports for qualitative parameters were done by a senior professor in the department of psychiatry.

EEG was analyzed for qualitative parameters of focal abnormality, unusual pattern for given age, rhythm abnormality including fast activity and slow activity.Statistical analysis of qualitative parameters was done by chi-square test. P value less than 0.05 was taken as significant. Outcome variables of test conditions 2 and 3 were compared with test condition 1 (baseline EEG).

Spectral power density ($GRMS^2$) for each physiologically significant frequency band was calculated by FFT (Fast Fourier Transform). After selecting the artefact free data, 10 seconds of EEG segment was taken in to consideration for calculation of spectral power density in GRMS2(sensitivity 10μV/sec, HFF(high frequency filter) -70HZ and LFF(low frequency filter)-1HZ, Notch-50 HZ, sweep-30mm/sec .

As normative database was not available for Indian population, the spectral power of each physiologically significant frequency band was compared with baseline. These frequency bands were selected and their spectral power density was calculated for all channels. The spectral power densities of the subjects were averaged and comparisons were made between different test conditions using paired sample student t-test with two-tailed significance. Results are represented as mean ± standard deviation.

RESULT

Out of 50 participants, data of three participants was excluded because EEG reports of these participants showed excessive muscle artefacts.

Table 2 Unusual pattern

Outcome	Exposure Condition		
	Baseline	Rt exp	Lt exp
Y	0	14	15
N	47	33	32
X^2	NA	14.19	15.55
P	NA	0.0002*	0.0001*

X^2= Yates' chi-square value Rt - Right, Lt - Left, Exp – Exposure

Most common statistically significant abnormality observed in the test conditions was an unusual pattern for given age in the form of sharp wave discharges on comparison with baseline EEG. This finding supports the various studies [58,19]

Table 3 Rhythm Abnormality (Slow Activity)

Outcome	Exposure Condition		
	Baseline	Rt exp	Lt exp
Y	0	10	12
N	47	37	35
X^2	NA	9.06	11.56
P	NA	0.0026*	0.0007*

X^2= Yates' chi-square value Rt - Right, Lt - Left, Exp – Exposure

Slow activity, a second commonly observed rhythm abnormality signifying presence of excessive delta waves was a statistically significant observation in the test conditions.

Table 4 Focal Abnormality

Outcome	Exposure Condition		
	Baseline	Rt exp	Lt exp
Y	0	7	5
N	47	40	42
X^2	NA	5.6	3.38
P	NA	0.01*	0.06

X^2= Yates' chi-square value Rt - Right, Lt - Left, Exp – Exposure

Third outcome observed was focal abnormality which includes any waveform abnormality in single or multiple channel of right or left hemisphere which was statistical significant only when right side of the head exposed to electromagnetic radiation while effects in other test conditions are not statistically significant.

Table 5 Rhythm Abnormality (Fast Activity)

Outcome	Exposure Condition		
	Baseline	Rt exp	Lt exp
Y	0	1	3
N	47	46	44
X^2	NA	0	1.38
P	NA	0.31	0.24

X^2= Yates' chi-square value Rt - Right, Lt - Left, Exp – Exposure

Next rhythm abnormality observed was fast activity though it was not found to be statistically significant which suggests that EMF emitted from cellular phone does not result in fast activity.

Table 6 Comparison of Baseline vs. Different Exposure types

Wave Type	Exposure Comparison	BASELINE (Mean ± SD)	Exposure Type (Mean ± SD)	P value
Delta	Baseline Vs. Rt exp	25.91 ± 19.68	26.43 ± 18.46	0.81
	Baseline Vs. Lt exp	25.91 ± 19.68	33.60 ± 30.26	0.14
Theta	Baseline Vs. Rt exp	6.10 ± 4.39	6.55 ± 4.23	0.57
	Baseline Vs. Lt exp	6.10 ± 4.39	7.22 ± 5.92	0.21
Alpha	Baseline Vs Rt exp	3.98 ± 3.68	4.37 ± 3.78	0.47
	Baseline Vs Lt exp	3.98 ± 3.68	4.30 ± 4.51	0.33
Beta	Baseline Vs Rtexp	0.34 ± 0.21	0.43 ± 0.39	0.12
	Baseline Vs Lt exp	0.34 ± 0.21	0.40 ± 0.25	0.08

Spectral power of physiologically significant bands of delta, theta, alpha, beta, when compared with baseline, do not show any statistically significant findings.

DISCUSSION

Exposure of the general public to low level RF field is now essentially universal. Furthermore exposure to RF field from cellular phone is highest in brain region because of its proximity to human head. In our study exposure to electromagnetic radiation has led to significant impact on brain electrical activity as per analysis of qualitative data.

Although low, oscillatory frequencies of RF-EMF energy from cellular phone correspond to some of those recorded in neural tissue and could interfere with neuronal activity causing the unusual pattern ofsharp wave discharges[2,10].D'Costa*et al*.,(2003) and Marino *et al*., (2003) concluded that, in normal use, the fields from a standard cellular telephone can alter brain function. Their results also showed an initial increase in excitability of the brain after mobile use (GMS exposure) followed by inhibition (cortical synchronization and slow wave).

Slow activity rhythm abnormality in the test conditions suggests existence of association between cellular phone RF and change in brain electrical activity. These waves could be caused by altered brain glucose metabolism as it is more proximal marker of neuronal activity as stated by Nora D Volkow, Dardo Tomas in 2011[12]. Additionally, the slow-wave activity repeated periodically at the same leads every 15–20s. This finding supports studies by Kramarenko *et al*., [2003], who has reported abnormal EEG slow waves in awake subjects exposed to cell phone radiation [8]and Hietanen *et al*., [2000] who found no abnormal EEG effect, except at the delta band, in subjects exposed to 900 and 1800 MHz fields under awake, closed-eye condition [3]

The observation of focal abnormality in one of the test condition was supported by the study conducted by Fathy El-Komey in 2005[2], in which, focal EEG abnormality was found in 31 out of 50 awake male participants during exposure to radiation emissions from a mobile phone.

Fast rhythm abnormality though observed was not found to be statistically significant suggesting that EMF emitted from cellular phone does not result in fast activity. This finding supports the study conducted by Wagner *et al*., which reported that cell phone radiation had no significant effect on EEG.[15]
In our study, spectral power of physiologically significant bands of delta, theta, alpha, beta, when compared with baseline, did not show any statistically significant findings. There are a few studies that have reported an increase in the alpha waves in response to cell phone EMF exposure[5,9]. For instance, Huber *et al*., reported an increase in the power of alpha activity[7]; however it was observed in simulated conditions using pulse modulated waves [40].

The difference between the reported results can be attributed to the considerable difference in the protocols and the settings of these studies, different periods of exposure to EMF and study of changes in EEG on different time scales. We considered the immediate changes in the EEG signals during 100 seconds EMF exposures, whereas some studies examined EEG signals up to 30 minute after exposure.

CONCLUSION

The present data of this study provides evidence for an immediate effect of short term radiofrequency-electromagnetic field exposure on human electroencephalogram. Results from this study suggest that in normal use cellular phone exposure may affect neural activity as a consequence of absorption of RF energy by the brain tissue, though potential mechanisms for these changes as stated earlier could not be elucidated.

Limitations of the study

1. Microwave dosimeter for measuring actual tissue exposure was not used.
2. Effect of other RF-EMF sources in the surrounding on EEG findings could not be excluded in this study.
3. The clinical significance of these small changes in brain activity is difficult to determine.

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