EFFECTS OF USE OF CELL PHONES ON EEG CHANGES IN CHILDREN WITH EPILEPSY

By

Amr Mohamed Mohamed Ismaeil*, Mohsen Taha Al-Keiy*,

Ayatallah Farouk Ahmed and Mahmoud Mohamed Saber***

*Pediatrics&**Clinical Neurophysiology Departments, Faculty of Medicine, Al-Azhar University, cairo

Corresponding Author: Amr Mohamed Mohamed Ismaeil,

Mobile No.: (+2) 01140893579, **E-mail:** amralmir6@gmail.com

ABSTRACT

Background: *Epilepsy has been identified by the World Health Organization (WHO) and its partners as a significant public health problem. Seizures caused by epilepsy are brought on by hyperexcitability and an imbalance between inhibition and excitation. Epilepsy is often misunderstood and difficult to diagnose due to its wide range of symptoms and causes.*

Aim of the Work: *To investigate the effect of use of cell phones on the electroencephalogram (EEG) finding and quantitative EEG analysis among children with epilepsy as well as healthy children.*

Patients and Methods: *This is A case control study that was conducted at Al-Azhar university, Al-Sayed Galal hospital from November 2022 to July 2023. A total of 60 children undergoing EEG evaluation before, during, and after exposure to cell phone radiation, were enrolled in our study.*

Results: *Visual EEG in Epileptic patients showed Ten out of twenty (50%) patients in group A and five out of twenty (25%) patients in group B, developed an abnormal EEG record. Quantitative EEG in Epileptic patients demonstrated significant higher power and faster frequency of theta band compared to healthy individuals before, during and after exposure ($P < 0.05$). There is a statistically significant inverse correlation between the number of epileptic events detected by visual EEG analysis during exposure to cell phone radiation and age of onset of epileptic fits. Also, there is a statistically significant direct correlation between the number of epileptic events detected by visual EEG analysis during exposure to cell phone radiation and the duration of the disease.*

Conclusion: *The current study showed that the exposure to mobile phone radiation resulted in significant increase in abnormal EEG discharges and epileptiform activity among children with epilepsy. Epileptic patients demonstrated significantly higher power and faster frequency of EEG compared to healthy individuals. In healthy children, the EEG under real MPR exposure showed no abnormal discharges.*

Keywords: *Cell Phones; EEG; Epilepsy.*

INTRODUCTION

Epilepsy has been identified by the World Health Organization (WHO) and its partners as a significant public health problem. Seizures caused by epilepsy are brought on by hyperexcitability and an imbalance between inhibition and excitation **(Anwar et al., 2020)**.

Epilepsy is often misunderstood and difficult to diagnose due to its wide range of symptoms and causes. Seizures may be triggered by certain activities or environmental factors, such as flashing lights or loud noises **(Oto, 2017)**.

In some cases, attacks may occur without warning signs or symptoms. People with epilepsy may also experience behavior, mood, and cognition changes before or after a seizure **(Johnson, 2019)**.

Cerebral trauma, cerebral immunological disorders, cerebral infections, cerebral tumors, cerebrovascular disorders, hippocampal sclerosis, and prenatal and infantile causes are among the causes of acquired epilepsy **(Balestrini et al., 2021)**.

Virus-induced meningitis, meningioma, cavernous hemangioma, open head surgery, and cerebral infarction are a few examples of epilepsy **(Fisher et al., 2017)**.

Positive family history, high fever, mental disability, delayed-release from NICU or premature birth, mother's alcohol misuse, and smoking during pregnancy are the main risk factors for seizures in children that doubles the chance of seizure incidence **(Minardi et al., 2019)**.

Also, the risk of repeated seizures is increased in 30% of children who have their first seizure in early infancy. Because epilepsies are more common in infants and children, it is vital to take their epidemiological characteristics into account **(Sartori et al., 2019)**.

Nowadays, cell phones or mobile are an essential component of modern communication in each person's life. Almost 50% of people worldwide use mobile phones, and the market for them is expanding quickly **(Wategaonkar et al., 2018)**.

Radiofrequency energy, a type of non-ionizing electromagnetic radiation that mobile phones emit, can be absorbed by tissues close to the phone **(Wategaonkar et al., 2018 and Azmy et al., 2020)**.

The brain is exposed to a higher specific absorption rate (SAR) of radio- frequency electromagnetic fields (RF-EMFs) from mobile phones than from other sources of this type of radiation. Mobile phone use has been associated with a variety of negative health effects, including modifications to sleep patterns, reaction times, and brain activity **(Kim et al., 2019)**.

Electromagnetic fields (EMFs) released by cellular phones may be the cause of the alterations in the brain's electrical activity, according to human experimental studies **(Kim et al., 2019)**.

AIM OF THE WORK

To investigate the effect of use of cell phones on the electroencephalogram (EEG) finding and quantitative EEG analysis among children with epilepsy as well as healthy Children.

Ethical consideration:

1. Ethical approval was obtained from the local ethical committee at Al-Azhar University.
2. Written informed consent from parents was obtained.
3. Privacy and confidentiality were a maintained throughout the study process using a unique code number.
4. The patient has the right to withdraw from the study at any time.
5. The author declared there is no conflict of interest regarding the study or publication.
6. No financial support regarding the study or publication.

Sample size equation:

The study utilized the Dawson and Trapp equation to determine the required sample size (n). Key factors influencing precision included the critical value ($Z\alpha/2$) set at 1.96 for a 95% confidence level and a reported prevalence of 4% **(Henz et al., 2018)**. With a specified margin of error (E) of 5%, the calculated sample size was determined to be 54 participants. To accommodate potential non-response rates, an additional 10% was added, resulting in a final sample size of 60 subjects (40 epileptic patients&20health control).

Inclusion Criteria: Patients with idiopathic generalized epilepsy are controlled on medication with a normal mentality and the age of the included children ranges from 5 to 15 years.

Exclusion Criteria: History of seizures attack in the last three days to avoid post ictal phase (During the postictal phase, an EEG will usually show slowed brain activity), cognitive impairment, drug-resistant epilepsy and psychiatric disorders,

Study Procedures:

This is a case control study that was performed on 60 childern recruited from pediatric department at Al-Sayed Galal hospital, Al-Azhar university. during the period from November 2022 to July 2023. they were selected by simple random method.

The total number of children were divided into three Groups:

Group (A): Twenty children with idiopathic generalized epilepsy (real exposure to mobile phone).

Group (B): Twenty children with idiopathic generalized epilepsy (Sham exposure to closed mobile phone).

Group (C): twenty normal children (real exposure to mobile phone).

Included patients underwent EEG recording as follow:

20 mins before use of cell phone followed by 30 min of use of cell phone and

a final post-exposure recording for extra 20 min.

The number of abnormal EEG activities were counted before. During, and after exposure for each group.

The included children with subject to the following:

1. Complete history taking including: age, gender, duration and type of seizures, last attak and medical treatment.

2. Thoroughly clinical assessment: This included careful general examination, systemic examination and complete neurological examination according to the standard Epilepsy sheet of the Neurology department, \ (Al-Sayed Galal hospital).

3. Neurophysiological procedure including: Digital EEG examination: Technique: EEG recording was carried out while the patient was lying in a dorsal recumbent position in a semi-luminated quiet room with his eyes gently closed at the clinical neurophysiology unit, alsayed galal University Hospitals, in a separate control room, the video EEG was continuously monitored by a technologist utilizing a video-electroencephalograph system with an NIHON KOHDEN MODEL JE-921A neurofax machine and the EEG scalp electrodes were applied according to the International 10-20 electrode placement system. A cap was used for each recording with an ear lobe electrode as a reference. each experiment lasted 70 minutes and included basal resting EEG activity of 20 minutes duration. Then the phone call switched on for the upcoming 30 minutes. The mobile used was Samsung Galaxy m10 and was placed 2cm away from the participant left ear to avoid heating effect of the machine. The last 20 minutes of the record the phone call was switched off. The patient was instructed not to move or respond to the phone call.

Analysis of EEG data: Interpretation of the Electroencephalograms: Each EEG was analyzed by visual inspection of concurrent split-screen video and EEG. In this regard, the presence in the EEG of the epileptic patients was visualized for paroxysmal inter-ictal spike discharges or sharp waves which is suggestive of generalized epileptic disturbance.

Quantitative EEG analysis was carried out for the epileptic and control groups:

(E0), before mobile phone exposure.

(E1) E1 after starting the phone call by 15 minutes and,

(E2) after starting the phone call by 30 minutes

(E3) at the end of record as follow.

4 artifacts free Epochs (E) were selected for quantitative EEG while awake and resting (each of 10 seconds duration), the data of 2 electrodes (O1, O2) were studied in the following frequency bands: theta (5-7 Hz), and alpha (8-12 Hz) in occipital region.

Statistical analysis: Normality of data distribution was evaluated using Shapiro–Wilk test. Description of means and standard deviation for quantitative variables and frequencies and percentage for qualitative variables were calculated using SPSS Version 22.0 (IBM Corp, Armonk, NY). In order to compare between groups, Chi-square test was used for categorical variables, while independent sample t-test or one wan AONVA was used for numerical variables. Repeated measures ANOVA was used to conduct comparisons of pre-exposure, exposure, and post-exposure data. Bonferroni test was used to perform post-hoc analysis and pairwise comparisons. P value less than.05 was considered to declare statistical significance Correlation analysis was done between the number of epileptic activities detected during the real exposure and the patients' clinical data.

RESULTS

Our study will be demonstrated in the following tables:

Table (1): Clinical data of the studied groups

Variables	Group A (n=20)	Group B (n=20)	Group C (n=20)	*P* value
Age, years	10.4 ± 3.6	9.2 ± 3.1	9.6 ± 3.8	0.526*
Gender	-	-	-	0.410**
Male	10 (50)	11 (55)	9 (45)	-
Female	10 (50)	9 (45)	11 (55)	-
Seizure Type:	-	-	-	0.879**
Atonic	9 (45)	8 (40)	-	-
GTC	9 (45)	9 (45)	-	-
Absence	2 (10)	3 (15)	-	-
Age of Onset, years	3.8 ± 2.5	3.6 ± 1.2	-	0.457***
Duration of Disease, years	1.2±0.7	1.5 ± 0.8	-	0.401***
Last Seizure (weeks)	9.3 ± 6.9	10.9 ± 6.3	-	0.423***
AEDs	-	-	-	0.736**
Monotherapy	14 (70)	13 (65)		
Polytherapy	6 (30)	7 (35)		

No statistically significant difference was found between the three groups regarding clinical data.

Table (2): Comparison of epileptiform activity between group A and B:

Variables	Group A (n=20)		Group B (n=20)		*P* value*
epileptiform activity	**10 (50%)**		**5 (25%)**		
No.of spikes:	**Mean ±**	**SD**	**Mean±**	**SD**	
Before Exposure	2.4	2.2	1.2	1.6	0.371
During Exposure	16.5	21.5	4.4	1.8	0.030
After Exposure	9	14.7	1.8	1.4	0.075
P* value*	0.001		0.016		
* Independent sample t test; ** Repeated measures ANOVA test.					

No statistically significant difference was found between groups(A&B) regarding No. of spikes before, during and after exposure.

While there is significant increase in spikes number during exposure than before &after exposure in both groups A&B.

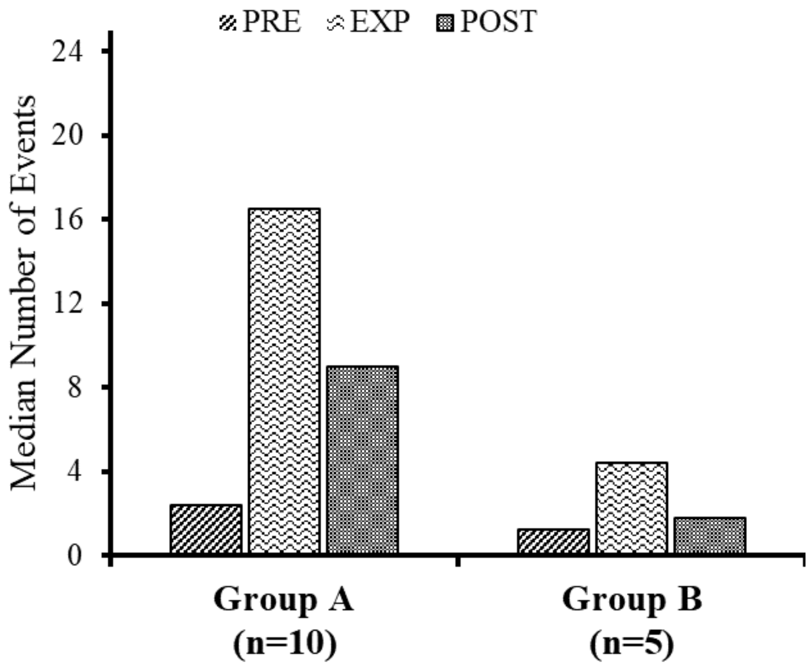

Figure (1): Epileptiform Activity (Comparison Between Groups A&B)

A statistically significant difference was observed in number of epileptiform events in group A during exposure to cell phone radiation However, no statistically significant difference in epileptiform activity was found between groups after exposure (Independent sample t test, P = 0.371).)

Table (3): Alpha Band Analysis comparison in the three studied groups regarding alpha band changes:

Variables	Group A (n=20)		Group B (n=20)		Group C (n=20)		*P* value*
	Mean	SD	Mean	SD	Mean	SD	
Power, µV							
E0	16.9	10.1	17.2	10.1	11.0	5.47	0.040
E1	14.4	8.0	16.8	7.4	9.8	5.49	0.019
E2	14.6	7.4	16.5	8.0	9.5	5.49	0.020
E3	16.5	9.9	17.0	9.9	10.8	5.48	0.038
P* value*	0.001		0.215		0.001		
Frequency, Hz							
PRE	7.7	1.5	8.3	1.2	9.6	1.4	0.001
POST	10.2	1.9	8.5	1.2	11.1	1.4	0.001
P* value*	0.001		0.051		0.001		

* Independent sample t test; ** Repeated measures ANOVA test.

Epileptic patients demonstrated significantly higher power and faster frequency compared to healthy individuals before, during and after exposure.

Table (4): Theta Band Analysis comparison in the three studied groups regarding theta band changes:

Variables	Group A (n=20)		Group B (n=20)		Group C (n=20)		*P* value*
	Mean	SD	Mean	SD	Mean	SD	
Power, µV							
E0	26.8	13.7	19.1	12.1	16.1	4.6	0.005
E1	23.5	11.7	18.9	8.9	14.5	4.9	0.006
E2	22.8	12.1	18.5	7.3	14.3	4.5	0.008
E3	26.5	17.0	19.2	11.0	15.7	4.7	0.017
P* value*	0.028		0.145		0.011		
Frequency, Hz							
PRE	3.9	1.4	3.8	1.4	4.9	1.5	0.046
POST	6.5	1.5	4.1	1.4	6.8	1.7	0.001
P* value*	0.001		0.052		0.001		

Epileptic patients demonstrated significantly higher power and faster frequency of theta band compared to healthy individuals before, during and after exposure.

Table (5): Relation between Demographics and Epileptiform Activity

	Correlation Coefficient	*P* value*
Age of Onset, years	-0.560	0.030
Duration of Disease, years	0.585	0.022
Last Seizure, weeks	-0.543	0.037
*Pearson test		

There is a statistically significant inverse correlation between the number of epileptic events detected by visual EEG analysis during exposure to cell phone radiation and age of onset. There is a statistically significant direct correlation between the number of epileptic events detected by visual EEG analysis during exposure to cell phone radiation and the duration of the disease. There is a statistically significant inverse correlation between the number of epileptic events detected by visual EEG analysis during exposure to cell phone radiation and the duration elapsed from the last seizure.

Table (6): Relation between Demographics and Quantitative EEG

	Age of Onset	Duration of Disease	Last Seizure
Alpha Band Power			
Correlation Coefficient	0.863	-0.854	0.857
P* value	0.001	0.001	0.001
Alpha Band Frequency			
Correlation Coefficient	-0.725	0.831	-0.829
P* value	0.001	0.001	0.001
Theta Band Power			
Correlation Coefficient	0.688	-0.688	0.705
P* value	0.001	0.001	0.001
Theta Band Frequency			
Correlation Coefficient	-0.613	0.798	-0.796
P* value	0.001	0.001	0.001
* Pearson test			

There is a statistically significant correlation between the Power and frequency of alpha and theta bands during exposure to cell phone radiation and age of onset, the duration of the disease, and the duration elapsed from the last seizure.

DISCUSSION

Epilepsy is a common chronic neurological disorder; the prevalence of epilepsy is about 7 per 1000 persons worldwide **(Fiest et al., 2017)**. It affects people at all ages, from birth to elderly. Most people with epilepsy (PWE) often enjoy a normal life, as others do. Optimal care of PWE includes addressing risks to their health, while they are enjoying a normal lifestyle (eg, driving, use of smartphone, and exercise). Identification of these risks and providing appropriate counsel about them may improve their seizure control and also the quality of life of PWE **(Noe, 2019)**.

There are more than 5 billion unique mobile users worldwide, and more than 3 billion of them use smartphones; more than 50% of the world's population are mobile Internet users **(Olson et al., 2022)**.

The Egypt Ministry of Communications and Information Technology (MCIT) **(Azmy et al., 2020)** estimated that the number of mobile phone subscriptions was 99.13 million in March 2018, and this number is increasing exponentially. The close proximity of mobile phones to the user's head makes the brain exposed to a high-specific absorption rate (SAR) of radio-frequency electromagnetic fields (RF-EMFs) than other sources of this kind of radiation **(Mohammed, 2022)**.

The electromagnetic fields of the Global System for Mobile Communications phone (GSM-EMFs) can produce effects on living organisms and brains due to thermal and non-thermal interactions. The detrimental thermal effects on the brain tissue have been extensively studied, and exposure limits were established, but non-thermal effects are still a matter of debate due to contrasting evidence **(Azmy et al., 2020)**.

The effects of EMF have been reported on various experimental models, in vitro and in vivo in animals and humans. These effects included alterations in intracellular signaling pathways such as ionic distribution and changes in calcium (Ca+2) ion permeability, the increase of cellular excitability, or the activation of cellular response to stress. On the other hand, there are pieces of evidence in the literature, reporting no measurable biological effects on brain functioning following exposure to the GSM-EMFs **(Parmar et al., 2019)**.

In humans, electromagnetic fields like the ones emitted by mobile phones have been suggested to influence the normal brain physiology through changes in cortical excitability modulating the activity of the neural networks towards electrical instability **(Vecchio et al., 2012)**.

Since people with epilepsy suffer from abnormal mechanisms of cortical neural synchronization, especially before and during the seizure with a tendency toward electrical instability of the neural networks, concerns about the effects of GSM-EMFs are strongly justified and should be investigated **(Asadi-Pooya et al., 2021)**.

The main aim of this study was to investigate the effect of use of cell phone on the electroencephalogram (EEG) finding and quantitative EEG analysis among children with epilepsy as well as healthy Children.

This case control study was conducted at Al-Azhar University hospitals. This study was conducted on 60 children undergoing EEG evaluation before, during, and after exposure to cell phone radiation, were enrolled in our study. Patients were divided into three groups: Group A included 20 children diagnosed with idiopathic epilepsy undergoing EEG evaluation for real exposure to cell phone radiation. Group B included 20 children diagnosed with idiopathic epilepsy undergoing EEG evaluation for sham exposure to cell phone radiation. Group C included 20 healthy children undergoing EEG evaluation for real exposure to cell phone radiation.

The main results of this study were as follows:

The current study showed that there were no statistically significant differences between the three groups regarding the age and gender. No statistically significant differences were found between groups A and B regarding type of seizures, age of onset, duration of epilepsy, time since last seizure, and number of antiepileptic drugs.

Regarding Visual EEG Interpretation, in control group it was revealed that before exposure to cell phone radiation, during exposure, and after exposure showed normal background activity, with no abnormal focal or paroxysmal discharges.

This comes in agreement with Azmy et al., who revealed that the EEG under real mobile phone radiation exposure showed no abnormal discharges in the healthy control group **(Azmy et al., 2020)**.

However, Parmar et al., revealed that experimental application of mobile phones may lead to some EEG changes and certain ill effects on the well-being. Hence, prolonged use of these gadgets warrants caution among 21 medical students **(Parmar et al., 2019)**.

Our base line record EEG show Ten (50%) patients in group A and five (25%) patients in group B devolped abnormal EEG record with no difference between group A and group B.

During exposure the current study showed that epileptiform activity was observed in 10 (50%) patients in group A and five (25%) patients in group B. Group A demonstrated a significantly higher rate of epileptiform activity compared to group B (Chi-square test, P = 0.001).

Before exposure to mobile phone radiation No statistically significant difference was found between groups regarding baseline EEG activity. During exposure to mobile phone the number of epileptiform events increased in group A and group B with significant increase in group A more than group B. after exposure to mobile phone the number of epileptiform events decreased in both groups with no significant difference between them.

The current study found a statistically significant difference in EEG activity of groups A and B at different exposure intervals (Repeated measures ANOVA test, P = 0.001, and 0.016, respectively). By running a post-hoc analysis for groups, A and B, a statistically significant increase in the mean number of epileptiform events was observed from pre-exposure to exposure intervals (PA = 0.001, PB = 0.022). When comparing pre-exposure or exposure to post-exposure values in groups A and B, no statistically significant differences were found.

The above results suggested that the exposure to mobile phone radiation resulted in significant increase in abnormal EEG discharges and epileptiform activity among children with idiopathic generalized epilepsy.

In concordance with the current study Azmy et al., assessed the effect of mobile phone radiation (MPR) on the electroencephalogram (EEG) of 30 adult persons with epilepsy and revealed that in patients with epilepsy, all of those with abnormal baseline records showed a significant increase in the rate of their interictal EEG discharges on exposure to MPR. In addition, one patient with normal basal record developed left focal temporal epileptiform discharges taking into consideration that the mobile phone was put on the left side. Such discharges decreased after the end of the call but did not reach the basal pattern in most patients till the end of the record **(Azmy et al., 2020)**.

Also, the current study was supported by López-Martín et al., who revealed that 900 MHz GSM radiation triggered a marked increase in neuronal excitability in seizure-prone rats, as manifested by behavioral indicators, EEG indicators, and neuronal c-Fos expression **(López-Martín et al., 2006)**.

As well, Cinarand et al., investigated the effects of exposure to different frequencies of EMWs in various durations in a mouse epilepsy model induced by pentylenetetrazole (PTZ), and they found that acute exposure to EMW may facilitate epileptic seizures by shortening initial seizure latency, which may be independent of EMW exposure time **(Cinar et al., 2013)**.

Similarly, Persinger and Belanger-Chellew, observed an increase in the incidence of seizures in rats when mean-field intensity was raised **(Persinger and Belanger-Chellew, 2019)**.

Regarding Quantitative EEG Interpretation, the current study demonstrated that real exposure to cell phone radiation in group A caused a statistically significant increase of alpha and theta band power and frequency during E1 and E2 as compared to E0 (Repeated measures ANOVA, $P < 0.05$). No statistically significant difference was found between E0 and E3. However, group B demonstrated insignificant increase in the alpha and theta band power and frequency during sham exposure (Repeated measures ANOVA, $P > 0.05$).

In group (C), real exposure to cell phone radiation caused a statistically significant increase of alpha and theta band power and frequency during E1 and E2 as compared to E0 (Repeated measures ANOVA, $P < 0.001$). No statistically significant difference was found between E0 and E3.

The above-mentioned results established that real exposure to cell phone radiation caused a statistically significant increase of EEG activity particularly cognitive and memory performance indicated by EEG oscillations in the alpha and theta band.

Also, several studies reported an increase in the alpha frequency band due to radiofrequency electromagnetic fields (RF-EMF) **(Regel et al., 2007, Valentini et al., 2007 and Croft et al., 2008)**.

In line with the current study Relova et al., reported an increase in alpha band power upon exposure to mobile phone radiation in epileptic patients **(Relova et al., 2010)**.

Our work showed an increase the alpha frequency band due to radiofrequency electromagnetic fields (RF-EMF) and increase in alpha band power upon exposure to mobile phone radiation in epileptic patients.

However, showed that Vecchio et al., also reported a reduction in alpha power after exposure to mobile phone radiation in epileptic patients **(Vecchio et al., 2012)**.

Also, ElSawy et al., found that there was a decrease in alpha band power in healthy resting adults and in epileptic patients on applying MPR. Moreover, the alpha band power continued to change in a non-linear manner after exposure in healthy subjects and even more profoundly in epileptic patients **(Elsawy et al., 2019)**.

Moreover, Roggeveen et al., reported significant radiation effects for the alpha, slow beta, fast beta, and gamma bands. The results support the notion that EEG alterations are associated with mobile phone usage and that the effect is dependent on site of placement **(Roggeveen et al., 2015)**.

Also, Wallace et al., revealed that theta brainwaves were significantly modulated during exposure to radiofrequency electromagnetic fields (RF-EMF) related to mobile phones **(Wallace et al., 2023)**.

A possible contributing factor to these varying results may be found in the diversity of designs and in the statistical analyses. Some examples are: type of exposure (network 2G/3G and a real mobile phone versus a radiating module), duration of exposure (ranging from minutes to several hours), and statistical tests (parametric versus non-parametric tests). Apart from these methodological aspects, it has been suggested that source of funding might influence the results **(Huss et al., 2007)**. It has been shown that 87% of brain activity studies are sponsored by the mobile phone industry **(Marino and Carrubba, 2009)**. Although this does not necessarily imply that the results of these articles are biased, the issue of conflict of interest cannot be neglected.

On comparing quantitative EEG between the studied groups, it was revealed that in alpha and theta bands, epileptic patients demonstrated significantly higher power and faster frequency compared to healthy individuals (One-way ANOVA, P < 0.05).

Also, Elkholy, concluded that patients with focal epilepsy had significant interictal functional connectivity disruption detected by coherence and phase lag degree of delta and theta waves and correlated with frequency of interictal epileptiform discharges **(Elkholy, 2023)**.

As well, Smith et al., stated that epileptic subjects exhibited significantly higher EEG power in all frequency bands and channels **(Smith et al., 2021)**.

Regarding the effect of demographics on epileptiform activity, the current study showed that there is a statistically significant correlation between the number of epileptic events detected by visual EEG analysis during exposure to cell phone radiation and age of onset (r = -0.560, P = 0.030), the duration of the disease (r = 0.585, P = 0.02), and the duration elapsed from the last seizure (r = − 0.543, P = 0.037).

In concordance with the current study Azmy et al., showed that there was a statistically significant positive correlation between the number of focal epileptic events detected by visual EEG analysis during the real exposure to MPR and the duration of the disease (R = 0.391, P = 0.038) while they correlated negatively with the duration elapsed from the last seizure (R = − 0.380, P = 0.046) **(Azmy et al., 2020)**.

Regarding the effect of demographics on quantitative EEG, it was revealed that there was a statistically significant correlation between the Power and frequency of alpha and theta bands during exposure to cell phone radiation and age of onset, the duration of the disease, and the duration elapsed from the last seizure.

In contrast, ElSawy et al., revealed that there were correlations between alpha band frequency and the time since last seizure, age of disease onset, or seizure semiology **(Elsawy et al., 2019)**.

CONCLUSION

- The current study showed that the exposure to mobile phone radiation resulted in significant increase in abnormal EEG discharges and epileptiform activity among children with epilepsy.
- Epileptic patients demonstrated significantly higher power and faster frequency of EEG compared to healthy individuals.

- In healthy children, the EEG under real MPR exposure showed no abnormal discharges.

RECOMMENDATION

- Restrict limitations of use of mobile phone among children with epilepsy.
- Mobile phone should be kept away from area near by children with epilepsy.
- Sports activity and physical games to compensate the use of mobile phone or mobile phone addiction among children with or without epilepsy.
- Further studies with larger sample size and longer follow-up are needed to confirm our results.

LIMITATIONS

- The number of the studied patients was not enough.
- Unwillingness to participate in the study due to fear of some adverse event.
- Arising out from application of mobile phones.
- The time period was limited.

REFERENCES

1. **Abela, E., Pawley, A. D., Tangwiriyasakul, C., Yaakub, S. N., Chowdhury, F. A., Elwes, R. D. C., et al. (2019):** Slower alpha rhythm associates with poorer seizure control in epilepsy. Ann Clin Transl Neurol, 6, 333-343.
2. **Anwar, H., Khan, Q. U., Nadeem, N., Pervaiz, I., Ali, M. & Cheema, F. F. (2020):** Epileptic seizures. Discoveries, 8.
3. **Asadi-Pooya, A. A., Mirzaei Damabi, N., Rostaminejad, M., Shahisavandi, M. & Asadi-Pooya, A. (2021):** Smart devices/mobile phone in patients with epilepsy? A systematic review. Acta Neurol Scand, 144, 355-365.
4. **Azmy, R., Shamloul, R., Elsawy, N. A. F., Elkholy, S. & Maher, E. (2020):** Effects of mobile phones electromagnetic radiation on patients with epilepsy: an EEG study. The Egyptian Journal of Neurology, Psychiatry and Neurosurgery, 56, 1-9.
5. **Balestrini, S., Arzimanoglou, A., Blümcke, I., Scheffer, I. E., Wiebe, S., Zelano, J., et al. (2021):** The aetiologies of epilepsy. Epileptic Disorders, 23, 1-16.
6. **Cinar, N., Sahin, S. & Erdinc, O. O. (2013):** What is the impact of electromagnetic waves on epileptic seizures? Med Sci Monit Basic Res, 19, 141-5.
7. **Croft, R. J., Hamblin, D. L., Spong, J., Wood, A. W., McKenzie, R. J. & Stough, C. (2008):** The effect of mobile phone electromagnetic fields on the alpha rhythm of human electroencephalogram. Bioelectromagnetics, 29, 1-10.
8. **Elkholy, M. M. (2023):** Disruption

of EEG resting state functional connectivity in patients with focal epilepsy. The Egyptian Journal of Neurology, Psychiatry and Neurosurgery, 59, 122.

9. **Elsawy, N., Elkholy, S., Azmy, R., Maher, E. A. & Shamloul, R. (2019):** Electrophysiological Assessment of the Impact of Mobile Phone Radiation on Cognition in Persons With Epilepsy. J Clin Neurophysiol, 36, 112-118.

10. **Fiest, K. M., Sauro, K. M., Wiebe, S., Patten, S. B., Kwon, C. S., Dykeman, J., et al. (2017):** Prevalence and incidence of epilepsy: A systematic review and meta-analysis of international studies. Neurology, 88, 296-303.

11. **Fisher, R. S., Cross, J. H., French, J. A., Higurashi, N., Hirsch, E., Jansen, F. E., et al. (2017):** Operational classification of seizure types by the International League Against Epilepsy: Position Paper of the ILAE Commission for Classification and Terminology. Epilepsia, 58, 522-530.

12. **Huss, A., Egger, M., Hug, K., Huwiler-Müntener, K. & Röösli, M. (2007):** Source of funding and results of studies of health effects of mobile phone use: systematic review of experimental studies. Environ Health Perspect, 115, 1-4.

13. **Johnson, E. L. (2019):** Seizures and epilepsy. Medical Clinics, 103, 309-324.

14. **Kim, J. H., Lee, J.-K., Kim, H.-G., Kim, K.-B. & Kim, H. R. (2019):** Possible effects of radiofrequency electromagnetic field exposure on central nerve system. Biomolecules & therapeutics, 27, 265.

15. **López-Martín, E., Relova-Quinteiro, J. L., Gallego-Gómez, R., Peleteiro-Fernández, M., Jorge-Barreiro, F. J. & Ares-Pena, F. J. (2006):** GSM radiation triggers seizures and increases cerebral c-Fos positivity in rats pretreated with subconvulsive doses of picrotoxin. Neurosci Lett, 398, 139-44.

16. **Marino, A. A. & Carrubba, S. (2009):** The effects of mobile-phone electromagnetic fields on brain electrical activity: a critical analysis of the literature. Electromagn Biol Med, 28, 250-74.

17. **Minardi, C., Minacapelli, R., Valastro, P., Vasile, F., Pitino, S., Pavone, P., et al. (2019):** Epilepsy in Children: From Diagnosis to Treatment with Focus on Emergency. Journal of Clinical Medicine, 8, 39.

18. **Mohammed, H. S. (2022):** Effects of Wireless Communication Electromagnetic Fields on Human and Animal Brain Activity. Electromagnetic Fields of Wireless Communications: Biological and Health Effects. CRC Press. 275-296.

19. **Noe, K. (2019):** Counseling and Management of the Risks of Living With Epilepsy. Continuum (Minneap Minn), 25, 477-491.

20. **Olson, J. A., Sandra, D. A., Colucci, É. S., Al Bikaii, A., Chmoulevitch, D., Nahas, J., et al. (2022):** Smartphone addiction is increasing across the world: A meta-analysis of 24 countries. Computers in Human Behavior, 129, 107138.

21. **Oto, M. M. (2017):** The misdiagnosis of epilepsy: appraising risks and managing uncertainty. Seizure, 44, 143-146.

22. **Parmar, K., Tandon, R., Kumar, N. & Garg, R. K. (2019):** Variations in electroencephalography with mobile phone usage in medical students. Neurol India, 67, 235-241.

23. **Persinger, M. A. & Belanger-Chellew, G. (1999):** Facilitation of seizures in limbic epileptic rats by complex 1 microTesla magnetic fields. Percept Mot Skills, 89, 486-92.

24. **Regel, S. J., Tinguely, G., Schuderer, J., Adam, M., Kuster, N., Landolt, H. P., et al. (2007):** Pulsed radio-frequency electromagnetic fields: dose-dependent effects on sleep, the sleep EEG and cognitive performance. J Sleep Res, 16, 253-8.

25. **Relova, J. L., Pérlega, S., Vilar, J. A., Lopez-Martin, E., Peleteiro, M. & Ares-Pena, F. (2010):** Effects of cell-phone radiation on the electroencephalographic spectra of epileptic patients [telecommunications health & safety]. IEEE Antennas and propagation Magazine, 52, 173-179.

26. **Roggeveen, S., van Os, J., Viechtbauer, W. & Lousberg, R. (2015):** EEG Changes Due to Experimentally Induced 3G Mobile Phone Radiation. PLoS One, 10, e0129496.

27. **Sartori, S., Nosadini, M., Tessarin, G., Boniver, C., Frigo, A. C., Toldo, I., et al. (2019):** First-ever convulsive seizures in children presenting to the emergency department: risk factors for seizure recurrence and diagnosis of epilepsy. Developmental Medicine & Child Neurology, 61, 82-90.

28. **Smith, R. J., Hu, D. K., Shrey, D. W., Rajaraman, R., Hussain, S. A. & Lopour, B. A. (2021):** Computational characteristics of interictal EEG as objective markers of epileptic spasms. Epilepsy Res, 176, 106704.

29. **Valentini, E., Curcio, G., Moroni, F., Ferrara, M., De Gennaro, L. & Bertini, M. (2007):** Neurophysiological effects of mobile phone electromagnetic fields on humans: a comprehensive review. Bioelectromagnetics, 28, 415-32.

30. **Vecchio, F., Tombini, M., Buffo, P., Assenza, G., Pellegrino, G., Benvenga, A., et al. (2012):** Mobile phone emission increases inter-hemispheric functional coupling of electroencephalographic α rhythms in epileptic patients. Int J Psychophysiol, 84, 164-71.

31. **Wallace, J., Shang, W., Gitton, C., Hugueville, L., Yahia-Cherif, L. & Selmaoui, B. (2023):** Theta band brainwaves in human resting EEG modulated by mobile phone radiofrequency. Int J Radiat Biol, 99: 1647-1639.

32. **Wategaonkar, V. S., Todake, S. & Throat, P. (2018):** Mobile Phone Radiation and Human Health. Asian Journal of Research in Pharmaceutical Science, 8, 30-34.

33. **Dawson B, Trapp RG (2004):** Basic and clinical biostatistics. 4th ed. USA:McGraw-Hill

34. **Henz, D., Schöllhorn, W. I., & Poeggeler, B. (2018):** Mobile Phone Chips Reduce Increases in EEG Brain Activity Induced by Mobile Phone-Emitted Electromagnetic Fields. Frontiers in neuroscience, 12,

190.
https://doi.org/10.3389/fnins.2018.0
0190.