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Functional Connectivity Analysis: A Promising Approach to Understanding Idiopathic Childhood Epilepsy

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Abstract

Background: Epilepsy, a common neurological disorder affecting around 50 million people globally, involves recurrent seizures and complex brain alterations. This study focuses on childhood epilepsy, where the immature brain is especially prone to seizures due to unique developmental factors. Current diagnostic tools, like EEG and MRI, have limitations in thoroughly assessing brain connectivity. While some studies have shown altered brain synchrony in epilepsy, they are often inconsistent due to heterogenous methodologies.

Aim of Study: To comparethe brain connectivity in untreated children with idiopathic epilepsy to healthy controls, using EEG coherence and phase lag as parameters for a clearer understanding.

Patients and Methods: This case-control study, conducted at Beni Suef University Hospital, followed the STROBE guidelines and involved 60 participants aged 6-14. Group I included 30 newly diagnosed idiopathic childhood epilepsy cases (15 generalized and 15 focal), and Group II consisted of 30 healthy controls. Subjects, recruited retrospectively, underwent demographic, clinical assessments, EEG monitoring, and functional connectivity analysis. EEG data were quantified using FFT, with coherence and phase lag measurements across frequency bands. Statistical analyses were performed using SPSS, with significance set at $p<0.05$. Ethical approval and informed consent were obtained, ensuring participant confidentiality and rights.

Results: The study compares EEG coherence and phase lag in three groups generalized, focal, and control across various frequency bands. Demographic data showed no significant differences in age or sex. In the left hemisphere, the generalized group exhibited significantly lower coherence in the beta band (F3-F7) and higher coherence in the delta (F3-F7) and theta bands (P3-T5) compared to other groups. In the right hemisphere, the generalized group showed notably higher theta band coherence at F4-F8. Interhemispheric coherence results revealed significantly higher coherence in the generalized group across alpha, beta, and delta bands (F3-F4, P3-P4, T5-T6). Phase lag findings showed lower alpha and beta phase lags in the generalized group, especially in left hemisphere pairs (P3-T5) compared to focal and control groups, indicating distinct brain activity patterns across the epileptic spectrum.

Conclusion: Our study identified significant connectivity differences in newly diagnosed, untreated pediatric epilepsy. Generalized epilepsy showed reduced coherence, especially in beta and delta bands, compared to focal epilepsy and controls. Findings regarding the phase lag analysis highlighted that generalized epilepsy disruptedbrain connectivity more, with abnormal interhemispheric variations observed in alpha and delta bands, emphasizing the need forfiltered frequency analyses.

Key Words: *Epilepsy – Functional connectivity – Generalized Epilepsy – Focal Epilepsy – Coherence – Phase Lag – Idiopathic Childhood Epilepsy – EEG – Phase – Based Connectivity.*

Introduction

THE human brain is essentially enigmatic. When impacted by disease, the complexity of the human brain is further intensified by the underlying pathological processes. Epilepsy is a chronic neurological disorder which causes recurrent seizures, associated with chronic alterations of brain functions, with a multifactorial etiopathogenesis **[1-4]**. Seizures may vary from focal aware seizures to generalized convulsive seizures with loss of consciousness **[2,5-8]**. It

List of Abbreviations:

EEG	: Electroencephalography.
MRI	: Magnetic Resonance Imaging.
FFT	: Fast Fourier Transformation.
SPSS	: Statistical Package for the Social Sciences.
STROBE	: Strengthening the Reporting of Observational Studies in Epidemiology.
AEDs	: Anti-Epileptic Drugs.
SL	: Synchronization Likelihood.
MEG	: Magnetoencephalography.
SEEG	: Stereotactic Electroencephalography.
EZ	: Epileptogenic Zone.
PZ	: Propagation Zones.
NIZ	: Non-Involved Zones.
PLV	: Phase Locking Value.
IMCOH	: Imaginary Coherence.
NICE	: National Institute for Health and Care Excellence.
ILAE	: International League Against Epilepsy.
ANOVA	: Analysis of Variance.
t-test	: Paired Sample *t*-test.
F3, F4, F7, etc.	: EEG Electrode Positions.

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is one of the most common brain disorders, with recent estimates showing that around 50 million people worldwide are affected by some type of epilepsy [1]. The incidence rate of epilepsy is approximately 50-60/100,000 persons per year [9,10]. The most recent reports from Africa showed that the prevalence of epilepsy in African children is estimated at nearly 1 in 50 children [11].

The pattern of epilepsy also varies with age, as the immature brain of neonates and young infants differs from that of the adult brain in terms of input resistance, delayed development of ion channels, developing synapses, and delayed formation of functional inhibitory synapses, among other factors that promote epileptogenesis with unprovoked seizure activity in children. Therefore, this difference in pathogenesis, clinical manifestations, and EEG patterns of childhood epilepsy makes it an intriguing area of research [12].

Seizures are characterized by excessive or synchronous neuronal discharges of the cerebral cortex, which can be unprovoked, i.e. in absence of a potential medical condition or related to preexisting brain lesions [13]. Every child presenting with a new-onset unprovoked seizure which cannot be explained by medical causes, should be evaluated at minimum with a brain MRI and EEG [14,15], aiming at detecting any structural brain abnormalities and dysplastic lesions, as well as temporal lobe pathology, which is a common site for seizure activity [16]. Moreover, an EEG will aid in the classification of seizures as well as detect interictal epileptiform discharges, which is the most specific finding for childhood epilepsy. However, a normal EEG does not rule out epilepsy, and often specialized techniques are needed to determine the diagnosis in patients with repeatedly normal EEGs with no interictal epileptiform discharges [15].

Weighing the benefits of EEG, as a cost-effective and low-burden assessment tool, against the limitations of the current diagnostic methods as well as the interpretation of isolated wave abnormalities [15], in the context of the complexity of the human brain, heralded the growing popularity of assessing brain functional connectivity, in order to analyze the interaction between two or more EEG parameters, which allows a more holistic approach to neurological disorders, including epilepsy [17,18]. Studies conducted on epileptic subjects showed altered brain synchrony during epileptic seizures, especially during interictal and resting states. While the methods of detecting this connectivity alteration varied between MRI, EEG, or magnetoencephalography (MEG), the consensus remained in favor of observed structural or functional connectivity alterations [19,20]. Even in focal epilepsy, a variant which was previously thought to be due to pathological discharges localized to a part of the brain recent research has deemed it a more widespread network disorder with spatial organization of epileptic discharges on a wider scale [21,22].

The current available literature on functional connectivity remains limited, with comparability of produced data being cumbersome and impractical due to the heterogeneity of methods used to analyze functional activity, with most of the available literature on connectivity focusing on MRI as a method of analyzing connectivity [19,23]. Even studies which utilize EEG to analyze connectivity are difficult to generalize and compare due to dissimilar techniques [22,24]. Some studies were limited by the lack of comprehensive bandpass filtration leading to distorted outcomes [25], while others were attenuated by their inclusion of patients with structural brain disorders which are known to distorted structural and subsequently functional connectivity [26], or the inclusion of patients who are being treated with anti-epileptic drugs (AEDs) or other centrally-active medications that may influence EEG connectivity results [18,26]. Additionally, some studied measured power-based connectivity, which is limited by computational issues with inconsistent outcomes that are unreliable [27].

In this case-control study we aimed to fill the gap in the literature by investigating the effects of epileptiform discharges on brain functional connectivity in children with newly diagnosed idiopathic epilepsy who are not yet receiving any antiepileptic medications comparing the cases with age- and sex-matched healthy controls, using coherence and phase lag degree as quantitative EEG parameters.

Patients and Methods

During the reporting process of this manuscript, we adhered to the checklist of items of the STROBE statement (28). This case-control study was conducted at the Department of Clinical Neurophysiology, Beni-Suef University Hospital following the approval of the Ethical Committee at Faculty of Medicine in Beni-Suef University (Ethical approval number: FMBSUREC/06112022/Ali) from December 2022 to June 2023. It included 60 subjects; Group I consisted of 30 cases with newly diagnosed idiopathic childhood epilepsy which were further subdivided into 15 cases with generalized type and 15 cases with focal type. Group II consisted of 30 age- and sex-matched healthy controls.

Subjects were retrospectively recruited from the pediatric outpatient clinic between November 2022

and July 2023. We included subjects who were 6 to 14 years old, newly diagnosed with idiopathic focal epilepsy according to the 2017 classification criteria, and who were untreated oronmonotherapy for less than 3 months. We excluded those who were below 6 or above 14 years of age, with MRI proven structural brain pathology, as well as those who were on combined antiepileptic therapy or monotherapy for a duration of more than 3 months, and those who suffered from chronic diseases such as chronic renal disease or chronic liver disease.

All patients were subjected to demographic and clinical data collection with full history taking, including patients' comorbidities, duration of illness, drug history, form of seizures and duration of attacks. A neurological examination was done to assess the physical and mental state. Patients underwent routine EEG using Nihon Khoden software with subsequent raw data quantification by NeuroGuide software.

EEG recording was conducted according to the international 10/20 system of electrode placement with reference and ground electrodes placed at the forehead. Impedances of the electrodes were always below 5kOhms. The EEG recording session lasted for 20 minutes, during which subjects laid supine in a state of relaxed wakefulness, with eyes closed, in a silent environment with a technician monitoring signal quality and ensuring wakefulness to minimize eye and muscle artifacts.

Functional connectivity analysis was performed using Fast Fourier Transformation (FFT) for different frequency bands and frequency spectra, which were averaged across the selected Epochs to obtain coherence and phase lag values.

The frequency bands were Delta (1-4 Hz), Theta (4-8 Hz), Alpha (8-13Hz) and Beta (13-30 Hz). Selected electrodes were frontal for (F3 and F4), parietal for (P3 and P4) and temporal for (T5 and T6). Interhemispheric coherence and phase lag were measured between frontal (F3-F4), parietal (P3-P4) and temporal (T5-T6) electrodes between the right and left hemispheres.

Intrahemispheric coherence and phase lag were measured between frontal (F4-F8), parietal, and temporal (P4-T6) electrodes in right hemisphere and between frontal (F3-F7), parietal, and temporal (P3-T5) electrodes in the left hemisphere.

Statistical analysis:

Statistical analysis was conducted using the Statistical Package of Social Science (SPSS) software version 22 in windows 7 (SPSS Inc., Chicago, IL, USA). Quantitative variables were presented as mean and standard deviation, while qualitative variables were described as frequencies and percentages. Data collected and coded to facilitate data manipulation were double entered into Microsoft Access. Quantitative data included in the study were first tested for normality by One-Sample Kolmogorov-Smirnov test in each study group then inferential statistic tests selected. Comparisons of quantitative measures among more than two independent groups of quantitative data were made using the One-way ANOVA test followed by the Benferroni post-Hoc to test the significance between each two groups. The paired *t*-test was used to compare two dependent quantitative parametric data. Moreover, the Kruskal-Wallis test was used to compare more than two independent groups for quantitative non-parametric data, and the Wilcoxon tests were used to compare two dependent quantitative non-parametric data. The *p*-value was calculated, with values greater than or equal to 0.05 considered not significant and those less than 0.05 deemed significant.

The following study was approved by the ethical committee of the Faculty of Medicine, Beni Suef University. Informed written consent was obtained from all participants before commencing the study and after explaining the objectives of the work to the subjects and/or their guardians. Confidentiality was guaranteed when handling the database and all individuals were informed about the related procedures and their rights to refuse participation or withdraw from the study at any given moment.

Further details regarding the methodology are mentioned in the supplementary materials Appendix I.

Results

Comparison of demographic data in different study groups:

Comparisons between the subjects studied according to age, sex, and comorbidities are detailed in Table S1 and Table S2. No significant differences were noted regarding patients' age and sex (p=0.9, p=0.8; Table S1). More details regarding the demographics are mentioned in Appendix II of the supplementary materials.

Left:

In the alpha band, among the three groups, neither F3-F7 (43.9 vs. 56.7 vs. 54.1; p=0.06; Table 1) nor P3-T5 (57.8 vs. 54.2 vs. 43.1; p=0.23; Table 1) electrode pairs showed any statistically considerable differences, this applies to comparisons drawn be-

tween generalized group and the focal group, as well as the generalized group and the controls, and the focal group with the controls. In the beta band, among the three groups, there was significantly lower coherence in the generalized group compared to the focal group at the F3-F7 pair (35.8 vs. 58.2; p=0.001; Table 1). Additionally, coherence in the beta band at the F3-F7 pair was shown to be significantly lower in the generalized group when compared with the controls (35.8 vs. 49.2; p=0.01; Table 1).

In the delta waves, the notable differences in coherence were observed at the F3-F7 pair when comparing the generalized and the focal group, with the generalized group showing significantly higher coherence (52.05 vs. 41.1; p=0.04; Table 1). Moreover, there was a significantly lower coherence of the focal group as opposed to the controls (47.7 vs. 53.2; p<0.001; Table 1). Lastly, the only substantial difference in the theta band was at the parietotemporal pair, P3-T5, exhibiting significantly higher coherence in the generalized group compared to the controls (56.1 vs. 43.01; p=0.04; Table 1).

Right:

The only considerable finding was observed in the theta band with significantly higher coherence at the F4-F8, in the generalized group as opposed to the controls (63.2 vs. 45.7; p=0.001; Table 1), as well as a significantly higher coherence at the P4-T6 pair in the generalized group as opposed to the controls (59.1 vs. 46.7; p=0.01; Table 1).

Table (1): FFT coherence of the left and right hemispheres in different study groups.

Coherence LT	Generalized (N=15) Mean ± SD	Focal (N=15) Mean ± SD	Control (N=30) Mean ± SD	*p*-value	Sig.
Alpha:					
F3-F7	43.9±19.8	56.7±20.1	54.1±9.7	0.06 a,b,c	NS
P3-T5	57.8±20.3	54.2±14.6	43.1±21.01	0.23 a,b,c	NS
Beta:					
				0.001a*	HS
F3-F7	35.8±24.2	58.2±8.7	49.2±7.5	0.01b*	S
				0.13c	NS
P3-T5	48.2±21.1	49.5±21.2	38.6±6.3	0.08 a,b,c	NS
Delta:					
F3-F7	52.05±19.2	41.1±11.3	56.7±6.8	0.04a*	S
				0.7b	NS
				<0.001c*	HS
P3-T5	57.3±25.4	47.7±16.4	53.2±8.3	0.27 a,b,c	NS
Theta:					
F3-F7	48.7±19.7	55.1±9.4	53.7±11.5	0.4 a,b,c	NS
P3-T5	56.1±25.7	45.7±17.2	43.01±7.9	0.25a	NS
				0.04b*	S
				0.9c	NS

Coherence RT	Generalized (N=15) Mean ± SD	Focal (N=15) Mean ± SD	Control (N=30) Mean ± SD	*p*-value	Sig.
Alpha:					
F4-F8	55.03±16.5	51.9±23.2	54.6±10.1	0.8 a,b,c	NS
P4-T6	61.9±18.6	51.3±22.1	52.4±8.9	0.11 a,b,c	NS
Beta:					
F4-F8	60.4±18.01	50.03±14.7	51.1±7.8	0.2 a,b,c	NS
P4-T6	60.6±18.3	49.1±20.7	53.5±10.1	0.1 a,b,c	NS
Delta:					
F4-F8	59.2±11.9	51.4±19.1	50.2±10.4	0.1 a,b,c	NS
P4-T6	56.3±13.3	48.8±15.7	44.9±15.02	0.06 a,b,c	NS
Theta:					
F4-F8	63.2±15.9	55.6±10.8	45.7±11.6	0.3a	NS
				0.001b*	HS
				0.06c	NS
P4-T6	59.1±12.03	54.8±19.4	46.7±10.8	0.09a	NS
				0.01b*	S
				0.2c	NS

*a: Significance difference between generalized & focal groups.
*b: Significance difference between generalized & control groups.
*c: Significance difference between focal & control groups.

Among the statistically significant findings, regarding the interhemispheric coherence, was the alpha band at the F3-F4 pair, which showed significantly higher coherence in the generalized group as opposed to both the focal group (64.3 vs. 41.9; p=0.01; Table 2) and the controls (64.3 vs. 43.5; p=0.007; Table 2). At the P3-P4 pair, the alpha band coherence was significantly higher in the generalized group compared to the focal group (46.1 vs. 15.5; p=0.007; Table 2), while it was shown to be significantly lower in the focal group as opposed to the controls (15.5 vs. 24.2; p=0.002; Table 2).

Furthermore, in the beta frequency band, coherence at the F3-F4 in the generalized group was significantly higher than both the focal group and the controls (50.1 vs. 29.1 vs. 30.1; p<0.001; Table 2), as well as the P3-P4 (38.2 vs. 17.5 vs. 20.1; p=0.002; Table 2), and the T5-T6 pair (19.1 vs. 3.3 vs. 6.9; p=0.004, p=0.01, respectively; Table 2).

In the delta band, we found that the interhemispheric coherence was significantly higher in the generalized group when compared with both the focal and the controls at the F3-F4 pair (75.2 vs. 40.2 vs. 28.8; p<0.001; Table 2), as well as the P3-P4 (62.2 vs. 26.1 vs. 34.9; p<0.001; Table 2), and the T5-T6 pair (59.3 vs. 14.5 vs. 12.7; p<0.001; Table 2). When comparing the focal group to the controls, significantly higher coherence was observed in the focal group as opposed to the controls at the F3-F4 pair (40.2 vs. 28.8; p=0.02; Table 2).

Lastly, the theta band coherence was shown to be significantly higher in the generalized groups as opposed to both the focal group and the controls, at the F3-F4 (66.1 vs. 36.7 vs. 35.6; p<0.001; Table 2), the P3-P4 (42.2 vs. 24.1 vs. 27.4; p=0.005, p=0.009, respectively; Table 2), and the T5-T6 pair (26.7 vs. 9.7 vs. 5.3; p=0.009, p=0.001, respectively; Table 2).

Table (2): Inter-hemispheric coherence in different study groups.

Coherence Inter-hemispheric	Generalized (N=15) Mean ± SD	Focal (N=15) Mean ± SD	Control (N=30) Mean ± SD	*p*-value	Sig.
Alpha:					
				0.01[a*]	S
F3-F4	64.3±16.9	41.9±10.1	43.5±25.5	0.007[b*]	HS
				0.9[c]	NS
				0.007[a*]	HS
P3-P4	46.1±21.9	15.5±13.5	24.2±20.6	0.9[b]	NS
				0.002[c*]	S
T5-T6	20.6±22.1	11.1±4.2	14.7±18.2	0.22	NS
Beta:					
F3-F4	50.1±14.4	29.1±9.5	30.1±14.4	<0.001 [a,b*]	HS
				0.9[c]	NS
P3-P4	38.2±25.4	17.5±10.2	20.1±11.4	0.002 [a,b*]	HS
				0.9[c]	NS
T5-T6	19.1±23.03	3.3±2.1	6.9±7.5	0.004[a*]	HS
				0.01[b*]	S
				0.9[c]	NS
Delta:					
F3-F4	75.2±17.5	40.2±9.6	28.8±11.2	<0.001[a,b*]	HS
				0.02[c*]	S
P3-P4	62.2±22.2	26.1±11.9	34.9±13.2	<0.001 [a,b*]	HS
				0.2[c]	NS
T5-T6	59.3±15.8	14.5±10.2	12.7±10.8	<0.001 [a,b*]	HS
				0.9[c]	NS
Theta:					
F3-F4	66.1±18.5	36.7±13.1	35.6±10.1	<0.001 [a,b*]	HS
				0.9[c]	NS
P3-P4	42.2±20.6	24.1±18.6	27.4±8.7	0.005[a*]	HS
				0.009[b*]	HS
				0.9[c]	NS
T5-T6	26.7±24.05	9.7±15.2	5.3±7.2	0.009[a*]	HS
				0.001[b*]	HS
				0.9[c]	NS

*a: Significance difference between generalized & focal groups.
*b: Significance difference between generalized & control groups.
*c: Significance difference between focal & control groups.

Left:

A significantly lower phase lag in the generalized group was noted in the alpha band at P3-T5 when compared to the controls (-6 vs. -0.65; p=0.03; Table 3). Regarding the beta band, there was a significantly lower phase lag in the generalized group as opposed to the focal group as well as the controls (-4 vs. 2.5 vs. 0.90; p=0.007, p<0.001, respectively; Table 3).

Right:

A significantly higher phase lag in the generalized group was noted in the alpha band, at the F4-F6 when compared to the focal group (4.5 vs. -0.8; p=0.007; Table 3). Regarding the beta band, there was a significantly lower phase lag at the P4-T6 in the focal group as opposed to the control group (-0.2 vs. 5.6; p=0.04, p<0.001; Table 3).

Table (3): Comparisons of phase lag in the leftand right hemisphere among different study groups.

Phase lag LT	Generalized (N=15) Median/range	Focal (N=15) Median/range	Control (N=30) Median/range	*p*-value	Sig.
Alpha:					
F3-F7	2.7 (-13/14)	2 (-8.4/47.5)	3.7 (-10/19.8)	0.5 a,b,c	NS
P3-T5	-6 (-137/15)	0.23 (-8.4/45)	-0.65 (-20/19.8)	0.4 a,c	NS
				0.03b*	S
Beta:					
F3-F7	-4 (-120/15)	-1.4 (-16/65)	0 (-11/8)	0.5a,b,c	NS
P3-T5	-4 (-11/1.4)	2.5 (-16/99)	0.90 (-11/11.5)	0.007a*	HS
				<0.001b*	HS
				0.4c	NS
Delta:					
F3-F7	1.5 (-12/15)	9 (-120/99)	-0.55 (-6.9/11.5)	0.7 a,b,c	NS
P3-T5	2.1 (-21/8.1)	1.4 (-39/63)	-0.75 (-11/8)	0.7 a,b,c	NS
Theta:					
F3-F7	2.4 (-14/12)	2.7 (-56/63)	2.5 (-10/19.8)	0.8 a,b,c	NS
P3-T5	2.3 (-11/15)	2.2 (-9.6/63)	-0.60 (-20.19.8/)	0.9a,b,c	NS

Phase lag RT	Generalized (N=15) Median/range	Focal (N=15) Median/range	Control (N=30) Median/range	*p*-value	Sig.
Alpha:					
F4-F8	4.5 (-1.1/26)	-0.8 (-154/18)	4.2 (-18/23)	0.007 a*	HS
				0.1 b,c	NS
P4-T6	0.6 (-12/11)	-2.5 (-27/18)	0.25 (-18/24)	0.7 a,b	NS
				0.02 c*	S
Beta:					
F4-F6	0.4 (-8/22.5)	-0.8 (-145/18)	2 (-39/23.2)	0.21 a,b,c	NS
P4-T6	0.2 (-20/160)	-0.2 (-24/10.6)	5.6 (-39.5/23.9)	0.9 a,b	NS
				0.04 c*	S
Delta:					
F4-F6	3.2 (-13/150)	2.6 (-145/18)	0.9 (-11/48)	0.3 a,b,c	NS
P4-T6	-0.6 (-11/5)	-1.4 (-18/13)	0.9 (-11/23)	0.9 a,b,c	NS
Theta:					
F4-F6	1.6 (-23/42)	-1.3 (-144/10)	2.6 (-13/10.5)	0.2 a,b,c	NS
P4-T6	2.4 (-5/6)	-2.3 (-111/19)	-0.15 (-18/23)	0.2 a,b,c	NS

*a: Significance difference between generalized & focal groups.

*b: Significance difference between generalized & control groups.

*c: Significance difference between focal & control groups.

Interhemispheric phase lag in the alpha band at the T5-T6 showed significantly higher phase lag in the generalized group when compared to the controls (-0.3 vs. -26.5; p=0.04; Table 4). Additionally, there was a significantly higher phase lag at the T5-T6 in the focal group as opposed to the controls (-1.8 vs. -26.5; p=0.01; Table 4). At the T5-T6 pair, in the delta band, there was a substantially lower phase lag in the generalized group as opposed to the controls (-5.4 vs. 2.6; p=0.03; Table 4), and again at the P3-P4 pair in the theta band, we noted a significantly lower phase lag in the generalized group as opposed to the controls (-5 vs. -0.44; p=0.04; Table 4).

Further details regarding study results can be found in Appendix II of the supplementary materials.

Table (4): Inter-hemispheric Phase lag in different study groups.

Phase lag Inter- hemispheric	Generalized (N=15) Mean ± SD	Focal (N=15) Mean ± SD	Control (N=30) Mean ± SD	p-value	Sig.
Alpha:					
F3-F4	-0.6 (-31/9.2)	-3.3 (-31.2/9.4)	-0.8 (-3.4/63)	0.3 a,b,c	NS
P3-P4	1.3 (-163/12.7)	1 (-167/180)	-0.71 (-27.9/6.7)	0.8 a,b,c	NS
				0.7 a	NS
T5-T6	-0.3 (-179/132.9)	-1.8 (-173/165.7)	-26.5 (-175.4/91.9)	0.04 b*	SS
				0.01 c*	
Beta:					
F3-F4	-1.1 (-59.7/12.9)	0.70 (-11.5/24.4)	1.5 (-1.3/3.3)	0.2 a,b,c	NS
P3-P4	0.4 (-159/19)	0.6 (-163/180)	1.5 (-17.3/14.2)	0.9 a,b,c	NS
T5-T6	-0.3 (-160/177)	-3.6 (-169/176)	-25.2 (-176.2/171.1)	0.8 a,b,c	NS
Delta:					
F3-F4	-0.01 (-32/3.2)	0.5 (-20.4/19.7)	-0.98 (-3.9/5.4)	0.1 a,b,c	NS
P3-P4	-0.6 (-71.2/4.1)	2.8 (-18.5/180)	1.1 (-2.5/3.2)	0.02 a	NS
				0.6 b,c	NS
T5-T6	-5.4 (-133/80.3)	2.5 (-39/162)	2.6 (-11.8/27.2)	0.3	S
				0.03 b*	
Theta:					
F3-F4	-3.3 (-170/3.9)	-3.1 (-19.7/3.3)	-0.38 (-10.2/5.8)	0.7 a,b,c	NS
P3-P4	-5 (-38/5.6)	-3.6 (-137/180)	-0.44 (-13.7/4.06)	0.8 a,c	NS
				0.04 b*	S
T5-T6	0.6 (-161/172)	-9.6 (-168/172)	-0.9 (-174.9/168.2)	0.3 a,b,c	NS

*a: Significance difference between generalized & focal groups.

*b: Significance difference between generalized & control groups.

*c: Significance difference between focal & control groups.

Discussion

Brain connectivity can be assessed through EEG by identifying synchronous signals obtained from two or more EEG electrodes [29]. Connectivity can either be estimated as effective connectivity or functional connectivity. Functional connectivity, unlike the effective estimate, is bi-directional, depicting inter-regional activity [30].

In this case-control study, we aimed to investigate the effects of epileptiform discharges on brain functional connectivity in children with newly diagnosed untreated idiopathic epilepsy, quantifying functional connectivity using coherence and phase lag degree as EEG parameters.

We analyzed the intrahemispheric coherence between different selected electrodes over the left hemisphere (L) and we found significant differences between the generalized group and the focal group, as well as between the generalized group and the controls, regarding the mean coherence between F3-F7 in the beta frequency band, with values being the lowest in the generalized epilepsy group (35.8; p=0.001, p=0.01, respectively). Wijayanto et al. reported, based on a pediatric dataset with known epileptic seizures, that there was a significant reduction in the left intrahemispheric coherence value under ictal conditionscompared to preictal data, with the lowest coherence value at the F3-F7 electrode pair in the full band (p<0.0008) [27]. Douw et al. contrasted our findings showed that regarding the functional connectivity between epileptic and non-epileptic patients, the beta frequency band did not show any statistically considerable variations [26]. Elkholy disputed these findings and noted that the intrahemispeheric coherence of the alpha band was comparable between epileptic patients and the con-

trols; however, it is worth noting that their sample included medicated patients, a criterion which we explicitly excluded [18].

Furthermore, we noted that there was a significant difference in coherence (L) estimates at F3-F7, in the delta band, between the generalized group and the focal group (52.05 vs. 41.1; p=0.04), with a significant reduction seen in the focal group when compared to the controls (41.1 vs. 56.7; p<0.001). Ravish et al., reported that in patients with seizure activity, there were significantly greater coherence values within the delta band, than in non-seizure activity at the left intrahemispheric frontotemporal level (p<0.05) [25]. Wijayanto et al., reported that under ictal conditions, between the F3-F7 electrode pairs, left coherence values in the delta band were significantly lower as opposed to preictal conditions (p<0.05) [27]. Douw et al., described disparate findings, inferring no significant differences regarding functional connectivity between epileptic, whether generalized or partial, and controls; however, the measure of functional connectivity they used was synchronization likelihood, which might explain the inconsistent outcomes. Moreover, they included patients on AEDs and patients with radiological evidence of brain pathology, both of whom we excluded from our study [26]. Elkholy also contradicted these results with no significant differences noted between either group regarding the left fronto-parietal coherence. This discrepancy could be explained by several differences in their protocol, especially the fact that only the frontoparietal coherence was studied, while our data detected significant differences of intrahemispheric frontal coherence between our study groups [18].

We found no significant differences concerning the F3-F7 electrode pair at the theta frequency band (p=0.4). However, we noted a statistically significant variance of estimated coherence (L) between the generalized group and the controls, at the P3-T5 connection (56.1 vs. 43.01; p=0.04). Douw et al. reported in accordance with our findings that there were substantial differences regarding the functional connectivity between epileptic and non-epileptic controls in the theta frequency band, where the epileptic patients demonstrated a notably higher synchronization likelihood (SL), a measure of functional connectivity, than those without epilepsy (0.033 vs. 0.028, U=0.005, p<0.001). Moreover, they noted that these differences were not observed when comparing patients with generalized epilepsy and those with partial/focal seizures, which firmly aligns with our findings [26]. Elkholy relayed data under a common protocol, highlighting a significantly lower coherence of theta frequency (p=0.017) in epileptic patients; however, these findings were noted at the frontal-parietal level, while ours were noted at the parietal-temporal level [18]. Wijayanto et al., disputed our findings, showing that there was a significant reduction at the F3-F7 electrode pairs in the theta band under ictal conditions unlike preictal ones (p<0.05) [27].

Touching upon the right hemisphere (R), in terms of intrahemispheric coherence estimates, we found no considerable differences between the three groups except across the theta frequency band, where we observed an appreciable difference between the generalized group and the controls at the F4-F8 connection (63.2 vs. 45.7; p=0.001). Again, at the theta frequency, we highlighted that the difference of estimated coherence between the generalized and the controls, at P4-T6, was statistically substantial (59.1 vs. 46.7; p=0.01). Douw et al. validated our observations by testing the diagnostic potential of functional connectivity, although under a divergent protocol with a disparate measure, and relaying that theta band SL yielded a significant sensitivity upgrade to the conventional EEG model, elevating the sensitivity from 35% to 58%, and the accuracy from 67% to 75%; however, the specificity of the model went down to 91% from 100% after adding the theta band SL (p<0.001) [26]. Opposing our results, Wijayanto et al., indicated that there were generally lower right-sided coherence values under ictal conditions compared to the preictal condition, identifying 10 electrode pairs in the theta band which demonstrated significant reductions in coherence values, with the most notable reduction being in the F4-F8 electrode pair (p<0.05). Furthermore, they disputed our findings regarding the bands which were abnormal, as they reported that the highest reduction of the mean coherence was observed in the delta band (p=0.0004) [27]. Lagarde et al., reported that there were significant spatial differences regarding epileptic discharges—obtained mostly from patients with right hemispheric epileptogenic zones, and the functional connectivity value, with structures within the epileptogenic zone (EZ) having significantly higher functional connectivity within themselves than with propagation zones (PZ; p<0.001). Moreover, they found that EZ had significantly stronger functional connectivity with the PZ as opposed to the non-involved zones (NIZ; p<0.001) [22].

We evaluated the three groups for interhemispheric coherence at various frequency bands and observed a significantly higher alpha band interhemispheric coherence at F3-F4, and these differences were shown to be significant between the generalized and focal group, as well as the generalized

and controls (p=0.01, p=0.007). Additionally, the P3-P4 alpha band interhemispheric coherence was significantly higher in the generalized group as opposed to the focal group (p=0.007), and considerably lower in the focal group when compared to the controls (p=0.002). Wijayanto et al., reported that under ictal conditions, the alpha band showed significantly lower interhemispheric coherence values, at the F3-F4 and the P3-P4 pairs, compared to the preictal condition (p<0.05), highlighting significant network disruption in epileptic patients within the frontal and parietal regions *[27]*.

The interhemispheric coherence of the beta band showed significant findings across the board, with a significantly higher coherence at F3-F4 in the generalized group as opposed to both the focal group and the controls (p<0.001), and again at the P3-P4 (p=0.002), and finally at the T5-T6 (p=0.004, p=0.01). Wijayanto et al., inferred that the interhemispheric coherence, at the F3-F4 and the P3-P4 pairs, was significantly lower in the ictal period compared with the preictal period, in the alpha band (p<0.05) *[27]*. Ravish et al., inferred that in patients with seizure activity, there were slightly lower coherence values within the beta band than in those with no seizure activity at the frontotemporal level in both the right and left hemispheres; however, these findings did not prove to be of statistical significance *[25]*.

When comparing the generalized vs. the focal group, and the generalized vs. the controls, we underlined significant differences at the delta band, showing that at F3-F4, P3-P4, and T5-T6, the interhemispheric coherence was significantly higher in the generalized group as opposed to the focal group, as well as the controls (p<0.001, p<0.001, p<0.001). Elkholy et al., demonstrated a significantly lower coherence in the delta band in patients with focal epilepsy compared to the controls (p=0.045) at the frontal level *[18]*. Wijayanto et al., expounded on the interhemispheric coherence in the delta band, showing that there was a significantly lower value in the delta band when comparing ictal periods to the preictal condition (p<0.05), these were noted at the F3-F4 and the P3-P4 pairs, with the highest reduction in the F3-F4 pair (p=0.0049) *[27]*.

Our study addressed the phase lag as a measure of functional connectivity, and we found significant differences at the intrahemispheric as well as the interhemispheric level. Our data showed that the left parieto-temporal phase lag at the alpha band as well as the beta band (P3-T5), was significantly lower in the generalized group as opposed to the controls (p=0.03, p<0.001). Moreover, the beta band showed significantly lower parieto-temporal phase lag in the generalized group as opposed to the focal group (p=0.007). Adebimpe et al., inferred that epileptics displayed significantly lower phase locking value (PLV) in the delta and beta bands when compared to the controls and those without spike conditions (p<0.05), which partially aligns with our findings since we noted no significant findings regarding the phase lag in the delta band *[31]*. Endorsing the use of phase synchrony and coherence as measures of functional connectivity that can be used to diagnose and classify epileptic seizures, Matos et al., reported on their development of a model that yielded significantly accurate results that utilized IMCOH (a measure of EEG coherence) as well as PLV (a measure of phase synchronization) to determine the classification of epileptic seizures, and compared to the conventional EEG analyses, the model demonstrated a sensitivity of 74.5%, a specificity of 57.1%, and an accuracy of 67.1% (AUC=0.649), emphasizing a significant predictive value of functional connectivity in the diagnosis of epilepsy *[32]*.

Regarding the right intrahemispheric phase lag, we reported that there was a significantly higher frontal phase lag at the alpha band in the generalized group compared to the focal group (p=0.007), and a significantly lower parietotemporal phase lag of the alpha band in the focal group compared to the controls (p=0.02). Moreover, we found that the intrahemispheric parietotemporal phase lag at the beta frequency band was significantly lower in the focal group as opposed to the controls (p=0.04). Adebimpe et al., compared patients with childhood epilepsy regarding phase synchronization and found that those with spike conditions had significantly lower PLV in the alpha band compared to controls and those with no spike conditions (K (PLV degree) =12.12) *[31]*.

We found that the temporal (T5-T6) interhemispheric phase lag showed significant differences between the three groups at the alpha and delta bands only, being significantly higher in the generalized group vs. the controls (p=0.04), as well as the focal group vs. the controls (p=0.01) in the alpha band; however, it was significantly lower at the delta band compared to the focal group (p=0.03). Lastly, the theta band showed a significantly lower parietal phase lag in the generalized group as opposed to the controls (p=0.04). Adebimpe et al., reported on abnormalities detect on functional connectivity analysis of epileptic patients regarding the PLV of those with spike conditions as they have shown that epileptic patients with wave spiked showed significantly higher PLV in the alpha and delta bands over the right centrotemporal region [K (PLV degree)

=12.45]. Moreover, they showed that theta bands displayed significantly higher PLV values in epileptic patients with spike conditions compared to the control, which contrasted our finding ***[31]***. According to the work of Ravish et al., phase synchrony was shown to be higher for seizure cases than those without seizures, which contrasts our findings. However, these results were not statistically significant. Moreover, they did not analyze the PLV of different frequency bands, and their results regarding phase synchrony were based on unfiltered frequency data, which were reported to distort connectivity analysis ***[25,33,34]***.

Limitations:

Conclusion:

In conclusion, our study illuminated notable variations in functional connectivity among children with newly diagnosed, untreated idiopathic epilepsy. Through EEG connectivity measures, namely coherence and phase lag analyses, across different frequency bands, we observed significant inter- and intrahemispheric connectivity differences between generalized, focal, and control groups. Notably, generalized epilepsy cases exhibited reduced coherence, particularly within beta and delta bands, as compared to both focal epilepsy and controls. This finding was partially in accordance with previous studies as we observed discrepancies, most probably owed to divergent methodologies, evidently concerning selection criteria and analytical techniques. Our data provide in sights into the functional connectivity patterns in epilepsy, suggesting that generalized epileptiform activity may lead to greater disruption in network coherence than focal activity, while also reflecting on the widespread functional connectivity disruptions in focal epilepsy. Moreover, phase lag analysis elucidated distinctive interhemispheric differences in the alpha and delta bands, emphasizing the need for bandpass filtered analyses to augment our understanding of epileptiform network synchronization.

Declarations:

- Ethical approval and consent to participate: The study protocol by the research ethics committee of faculty of medicine of Beni-Suef University.
- Consent for publication: All patients gave consent for publication.
- Availability of data and materials: the data will be available on demand.
- Competing interests: Authors declare that there is no competing of interest.
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References

1- FISHER R.S., ACEVEDO C., ARZIMANOGLOU A., BOGACZ A., CROSS J.H., ELGER C.E., et al.: ILAE Official Report: A Practical Clinical Definition of Epilepsy, 55 (4): 475-82, 2014.

2- FISHER R.S., CROSS J.H., D'SOUZA C., FRENCH J.A., HAUT S.R., HIGURASHI N., et al.: Instruction Manual for the <scp>ILAE</Scp> 2017 Operational Classification of Seizure Types., 58 (4): 531-42, 2017.

3- SCHEFFER I.E., BERKOVIC S., CAPOVILLA G., CONNOLLY M.B., FRENCH J., GUILHOTO L., et al.: <scp>ILAE</Scp> Classification of the Epilepsies: Position Paper of the <scp>ILAE</Scp> Commission for Classification and Terminology, 58 (4): 512-21, 2017.

4- PACK A.M.: Epilepsy Overview and Revised Classification of Seizures and Epilepsies, 25 (2): 306-21, 2019.

5- BERG A.T., BERKOVIC S.F., BRODIE M.J., BUCHHALTER J., CROSS J.H., VAN EMDE BOAS W., et al.: Revised Terminology and Concepts for Organization of Seizures and Epilepsies: Report of the ILAE Commission on Classification and Terminology, 2005–2009, 51 (4): 676-85, 2010.

6- FISHER R.S., CROSS J.H., FRENCH J.A., HIGURASHI N., HIRSCH E., JANSEN F.E., et al.: Operational Classification of Seizure Types by the International League Against Epilepsy: Position Paper of the ILAE Commission for Classification and Terminology, 58 (4): 522-30, 2017.

7- Proposal for Revised Clinical and Electroencephalographic Classification of Epileptic Seizures, 22 (4): 489-501, 1981.

8- Proposal for Revised Classification of Epilepsies and Epileptic Syndromes, 30 (4): 389-99, 1989.

9- FIEST K.M., SAURO K.M., WIEBE S., PATTEN S.B., KWON C-S., DYKEMAN J., et al.: Prevalence and Incidence of Epilepsy, 88 (3): 296-303, 2017.

10- SANDER J.W.: The Epidemiology of Epilepsy Revisited, 16 (2): 165-70, 2003.

11- BISET G., ABEBAW N., GEBEYEHU N.A., ESTIFANOS N., BIRRIE E. and TEGEGNE K.D.: Prevalence, Incidence, and Trends of Epilepsy Among Children and Adolescents in Africa: A Systematic Review and Meta-Analysis, 24 (1), 2024.

12- STAFSTROM C.E. and RHO J.M.: Neurophysiology of Seizures and Epilepsy, 506-12, 2017.

13- BEGHI E., CARPIO A., FORSGREN L., HESDORFFER D.C., MALMGREN K., SANDER J.W., et al.: Recommendation for a Definition of Acute Symptomatic Seizure, 51 (4): 671-5, 2010.

14- WILMSHURST J.M., GAILLARD W.D., VINAYAN K.P., TSUCHIDA T.N., PLOUIN P., VAN BOGAERT P., et al.: Summary of Recommendations for the Management of Infantile Seizures: Task<scp>F</Scp>orce<scp>R</

Scp>eport for The<scp>ILAE C</Scp>ommission Of<scp>P</Scp>ediatrics., 56 (8): 1185-97, 2015.

15- Epilepsies: Diagnosis and management. London: National Institute for Health and Care Excellence (NICE), 2021.

16- HSIEH D.T., CHANG T., TSUCHIDA T.N., VEZINA L.G., VANDERVER A., SIEDEL J., et al.: New-Onset Afebrile Seizures in Infants, 74 (2): 150-6, 2010.

17- CHIARION G., SPARACINO L., ANTONACCI Y., FAES L. and MESIN L.: Connectivity Analysis in EEG Data: A Tutorial Review of the State of the Art and Emerging Trends., 10 (3): 372, 2023.

18- ELKHOLY M.M.: Disruption of EEG Resting State Functional Connectivity in Patients With Focal Epilepsy, 59 (1), 2023.

19- BERNHARDT B.C., HONG S., BERNASCONI A. and BERNASCONI N.: Imaging Structural and Functional Brain Networks in Temporal Lobe Epilepsy, 7, 2013.

20- COITO A., PLOMP G., GENETTI M., ABELA E., WIEST R., SEECK M., et al.: Dynamic Directed Interictal Connectivity in Left and Right Temporal Lobe Epilepsy, 56 (2): 207-17, 2015.

21- BARTOLOMEI F., LAGARDE S., WENDLING F., MCGONIGAL A., JIRSA V., GUYE M., et al.: Defining Epileptogenic Networks: Contribution of <scp>SEEG</Scp> and Signal Analysis, 58 (7): 1131-47, 2017.

22- LAGARDE S., ROEHRI N., LAMBERT I., TREBUCHON A., MCGONIGAL A., CARRON R., et al.: Interictal Stereotactic-Eeg Functional Connectivity in Refractory Focal Epilepsies, 141 (10): 2966-80, 2018.

23- MILJEVIC A., BAILEY N.W., VILA-RODRIGUEZ F., HERRING S.E. and FITZGERALD P.B.: Electroencephalographic Connectivity: A Fundamental Guide and Checklist for Optimal Study Design and Evaluation. Biol Psychiatry Cogn Neurosci Neuroimaging, 7 (6): 546-54, 2022.

24- SRINIVASAN R., WINTER W.R., DING J. and NUNEZ P.L.: EEG and MEG coherence: Measures of functional connectivity at distinct spatial scales of neocortical dynamics. Journal of neuroscience methods, 166 (1): 41, 2007.

25- DK R., DEVI S. and KRISHNAMOORTHY S.G.: Wavelet analysis of EEG for seizure detection: Coherence and phase synchrony estimation. Biomedical Research (India), 26: 514-24, 2015.

26- DOUW L., DE GROOT M., VAN DELLEN E., HEIMANS J.J., RONNER H.E., STAM C.J., et al.: 'Functional Connectivity' Is a Sensitive Predictor of Epilepsy Diagnosis After the First Seizure, 5 (5): e10839, 2010.

27- WIJAYANTO I., HARTANTO R. and NUGROHO H.A.: Quantitative Analysis of Inter- and Intrahemispheric Coherence on Epileptic Electroencephalography Signal. Journal of Medical Signals and Sensors, 12 (2): 145, 2022.

28- ELM E.V., ALTMAN D.G., EGGER M., POCOCK S.J., GØTZSCHE P.C. and VANDENBROUCKE J.P.: Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies, 35 (7624): 806-8, 2007.

29- COHEN M.X.: Analyzing Neural Time Series Data: Theory and Practice: The MIT Press, 2014/01/17/, 2014.

30- FRISTON K.J.: Functional and effective connectivity: A review. Brain Connect, 1 (1): 13-36, 2011.

31- ADEBIMPE A., AARABI A., BOUREL-PONCHEL E., MAHMOUDZADEH M. and WALLOIS F.: Functional Brain Dysfunction in Patients With Benign Childhood Epilepsy as Revealed by Graph Theory, 10 (10): e0139228, 2015.

32- MATOS J., PERALTA G., HEYSE J., MENETRE E., SEECK M. and MIERLO P.V.: Diagnosis of Epilepsy with Functional Connectivity in EEG after a Suspected First Seizure. Bioengineering, 9 (11): 690, 2022.

33- CASTELLANOS N.P. and MAKAROV V.A.: Recovering EEG brain signals: Artifact suppression with wavelet enhanced independent component analysis. Journal of Neuroscience Methods, 158 (2): 300-12, 2006.

34- LACHAUX J.P., RODRIGUEZ E., MARTINERIE J. and VARELA F.J.: Measuring phase synchrony in brain signals. Hum. Brain Mapp., 8 (4): 194-208, 1999.

تحليل الاتصال الوظيفى:
نهج واعد لفهم الصرع الطفولى مجهول السبب

الخلفيـة: الصـرع هـو اضطـراب عصبـى شـائع يصيـب حوالـى ٥٠ مليـون شـخص حـول العالـم، ويتضمـن نوبـات متكـررة وتغيـرات معقدة فـى الدمـاغ. تركـز هـذه الدراسـة علـى الصـرع فـي مرحلـة الطفولـة، حيـث يكـون الدمـاغ غيـر الناضـج أكثـر عرضـة للنوبـات بسـبب عوامـل تطوريـة فريـدة. الأدوات التشـخيصية الحاليـة مثـل تخطيـط الدمـاغ الكهربائـى (EEG) والتصويـر بالرنـين المغناطيسـى (MRI) لهـا قيـود فـى تقييـم الاتصـال الدماغـى بشـكل شـامل. رغـم أن بعـض الدراسـات أظهـرت تغيـرًا فـى تزامـن نشـاط الدمـاغ لـدى مرضـى الصـرع، إلا أن نتائجهـا غالبًـا مـا تكـون غيـر متسـقة بسـبب تنـوع المنهجيـات المسـتخدمة.

هـدف الدراسـة: مقارنـة الاتصـال الدماغـي بـين الأطفـال غيـر المعالجـين المصابـين بالصـرع مجهـول السـبب وأقرانهـم الأصحـاء، باسـتخدام معامـل الترابـط (Coherence) وتأخـر الطـور (Phase Lag) للحصـول علـى فهـم أوضـح

المنهجيـة: أجريـت هـذه الدراسـة مـن نـوع الحالة–الشـاهد فـى مستشـفى جامعـة بنـي سـويف، وفقًـا لإرشـادات STROBE، وشـارك فيهـا ٦٠ طفـلًا تتـراوح أعمارهـم بـين ٦–١٤ عامًـا. ضمـت المجموعـة الأولـى ٣٠ حالـة جديـدة مشـخصة بالصـرع الطفولـى مجهـول السـبب (١٥ حالـة صـرع عـام و١٥ حالـة صـرع بـؤرى)، بينمـا ضمـت المجموعـة الثانيـة ٣٠ طفـلًا سـليمًا كمجموعـة ضابطـة. تم اختيـار المشـاركين بشـكل رجعـى، وأُجريـت لهـم تقييمـات ديموغرافيـة وسـريرية، بالإضافـة إلـى مراقبـة EEG وتحليـل الاتصـال الوظيفـى. تم تحليـل بيانـات EEG باسـتخدام تحويـل فوريـيه السـريع (FFT) مـع قيـاس معامـل الترابـط وتأخـر الطـور عبـر نطاقـات التـردد المختلفـة. أُجريـت التحليـلات الإحصائيـة باسـتخدام برنامـج SPSS، باعتبـار قيمـة الدلالـة الإحصائيـة $p<0.05$. حصلـت الدراسـة علـى الموافقـات الأخلاقيـة، وتم أخـذ موافقـات مسـتنيرة مـع ضمـان سـرية وحقـوق المشـاركين.

النتائـج: قارنـت الدراسـة معامـل الترابـط وتأخـر الطـور عبـر ثـلاث مجموعـات (الصـرع العـام، الصـرع البـؤري، والمجموعـة الضابطـة) ضمـن نطاقـات تـردد متعـددة. لـم تُظهـر البيانـات الديموغرافيـة فروقًـا ذات دلالـة إحصائيـة فـي العمـر أو الجنـس. فـى نصـف الكـرة الأيسـر، أظهـرت مجموعـة الصـرع العـام انخفاضًـا ملحوظًـا فـي معامـل الترابـط فـى نطـاق بيتـا (F7-F3) وارتفاعًـا فـي نطاقـى دلتـا (F7-F3) وثيتـا (T5-P3) مقارنـة بالمجموعـات الأخـرى. أمـا فـى نصـف الكـرة الأيمـن، فقـد أظهـرت المجموعـة العامـة ارتفاعًـا ملحوظًـا فـى معامـل الترابـط فـى نطـاق ثيتـا عنـد (F8-F4). كمـا أظهـرت نتائـج الترابـط بـين نصفـى الدمـاغ ارتفاعًـا ملحوظًـا فـى معامـل الترابـط فـى المجموعـة العامـة عبـر نطاقـات ألفـا وبيتـا ودلتـا (F4-F3، P4-P3، T6-T5). كشـفت نتائـج تأخـر الطـور عـن انخفـاض فـى تأخـر الطـور فـى نطاقـى ألفـا وبيتـا لـدى مجموعـة الصـرع العـام، خاصـة فـى أزواج النصـف الأيسـر (T5-P3) مقارنـة بمجموعتـى الصـرع البـؤرى والمجموعـة الضابطـة، ممـا يشـير إلـى أنمـاط نشـاط دماغـى مميـزة عبـر طيـف الصـرع.

الاسـتنتاج: حـددت دراسـتنا فروقًـا ملحوظـة فـي الاتصـال الدماغـي لـدى الأطفـال المصابـين حديثًـا بالصـرع غيـر المعالـج. أظهـر الصـرع العـام انخفاضًـا فـى معامـل الترابـط، خاصـة فـى نطاقـى بيتـا ودلتـا، مقارنـةً بالصـرع البـؤرى والمجموعـة الضابطـة. كمـا أكدت نتائـج تحليـل تأخـر الطـور أن الصـرع العـام يسـبب اضطرابـات أكبـر فـي الاتصـال الدماغـى، مـع وجـود تغيـرات غيـر طبيعيـة بـين نصفـى الدمـاغ فـى نطاقـى ألفـا ودلتـا، ممـا يؤكـد أهميـة تحليـل الترددات المفلترة.