e-ISSN: 0975-1556, p-ISSN:2820-2643

Available online on www.ijpcr.com

International Journal of Pharmaceutical and Clinical Research 2023; 15(9); 879-883

Original Research Article

An Electroencephalographic Analysis of Real and Imaginary Motor Task by Gamma Power Coherence

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Received: 19-06-2023 / Revised: 18-07-2023 / Accepted: 20-08-2023
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Conflict of interest: Nil

Abstract:

Background: Real motor movement and motor imagery both facilitate motor cortical excitability, exhibit the imagined movement engage identical brain regions. EEG coherence between the right and left hemispheres reflects the degree of coordination across the brain during resting, real, and imagined movements**.**

Objective: The purpose of this study was to evaluate and compare the power spectrum coherence of the gamma band during the resting state, actual motor movement, and imagined motor movement.

Methods: This laboratory-based comparative analytic observational investigation was conducted at S.M.S. Medical College and Attached Hospitals in Jaipur. A total of 56 healthy males between the ages of 18 and 40 were recruited from Jaipur city. The gamma band coherence was recorded by EEG for resting, real, and imaginary motor tasks and the coherence was compared. The gamma coherence power was analyzed. The significance was set at p-value<0.05.

Results: Different brain regions, with the exception of the C3-C4 central region, exhibited good inter-spectral coherence-based connectivity when comparing the baseline coherence value with real and imagined movements.

Conclusion: The coherence of gamma power shows no significant difference between resting, motor, and imagined movement, except in the central region, suggesting a high level of synchronization all over the brain areas.

Keywords: Coherence, Electroencephalography, EEG, Gamma Band Activity, GBA, Real Motor Task, Imagined Motor Task

Introduction

The primary focus of neuroscience research is the variations in power of voltage in the brain caused by real and imagined movements. Alteration in brain activity can be represented by oscillatory power, source activation, or measures of interregional functional connectivity [1,2,3]. However, it is difficult to discover interconnected areas within the brain's mysterious functioning. Consequently, based on previous medical findings, scientists have paired specific tasks with the corresponding brain regions.

Motor imagery is a dynamic state in which representations of a given motor act are rehearsed in working memory without motor output [4,5]. In this mental task, participants are instructed to imagine themselves moving without actually executing the movement, i.e., without activating their muscles. According to the available evidence, actual and imagined movements share a substantial overlap of functional circuits [6,7]. Recent studies have placed significant emphasis on the motor function of the primary and supplementary motor regions of the brain. Studies of brain activity have demonstrated that brain conditions change during specific cognitive functions or mental states, such as reactions to a visual or auditory stimulus, real or imagined limb movements [8,9]. Data from Electroencephalography (EEG) can be used to infer the morphological, anatomical, and functional plasticity characteristics of the change [10].

EEG high frequency gamma band activity (GBA) is linked to cerebral functions such as perception, attention, memory, consciousness, synaptic plasticity, and motor control [11,12]. Furthermore, GBA has been suggested as the integrator of sensory and motor processes during movement planning and control [13,14]. The present research aimed to evaluate and compare the gamma band coherence by using EEG recordings for actual and imagined movement.

Materials and Methods

This laboratory-based comparative analytic observational investigation was conducted at S.M.S. Medical College and Attached Hospitals in Jaipur. 56 healthy males between the ages of 18 and 40 were recruited from a Jaipur city.

Inclusion Criteria

Healthy male individuals, who are Right-handed, belong to the age group of 18 to 40 years and gave written informed consent, were included in this study.

Exclusion Criteria

This study excluded patients with a history of neurological and psychotic disorder, drug addiction and misuse, acute and chronic illness, taking any drug/treatment, or neuromuscular disorder. Non-consenting or uncooperative participants were also excluded from this study.

EEG recording and stimulus protocol:

EEG data were recorded using BESS (Brain Electro Scan System) software version 4.0. Electrodes were placed on Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, Cz, T3, T4, T5, T6, P3, P4, Pz, O1, O2, Oz regions of the scalp according to the International 10/20 System. The reference electrode was applied on the left earlobe and the ground electrode was placed at the forehead. Once the EEG waves had stabilized, the stimulus protocol was loaded and data gathering began with the specified stimulus protocol. Participants were asked to be seated approximately 1 meter away from a computer screen in a sound-attenuated, dimly lit EEG room and rested their forearms on a table with the palms of their hands facing downward with the eye open. A target detection task on screen was explained to the subject, before starting it. Before start recording the subject practiced the exercise in a training session for both the imaginary motor task and the real motor task. The conducted experiment comprised three steps (Figure 1):

a) Baseline recording: Participants fixate their eyes on the centre of the screen (to prevent eye movement; they also attempt not to blink) and perform no motor or mental activity. Basal recording is the condition of relaxation. A total of 15 minutes of baseline activity was recorded, which was divided into 3 segments (each lasting 5 minutes) separated by approximately 1 minute of rest.

b) Real motor task: The subject performs an actual motor task of forearm extension followed by a brief period of relaxation.

(c) Imaginary motor task: The imagining of executing a motor task consisting of rapid wrist extension followed by brief relaxation without muscle activation.

The associations between the brain regions were evaluated by coherence. The interhemispheric coherence was computed pair-wise (FP1-FP2, F3-F4, F7-F8, C3-C4, T3-T4, T5-T6, P3-P4, O1-O2) between two different EEG electrodes by BESS software.

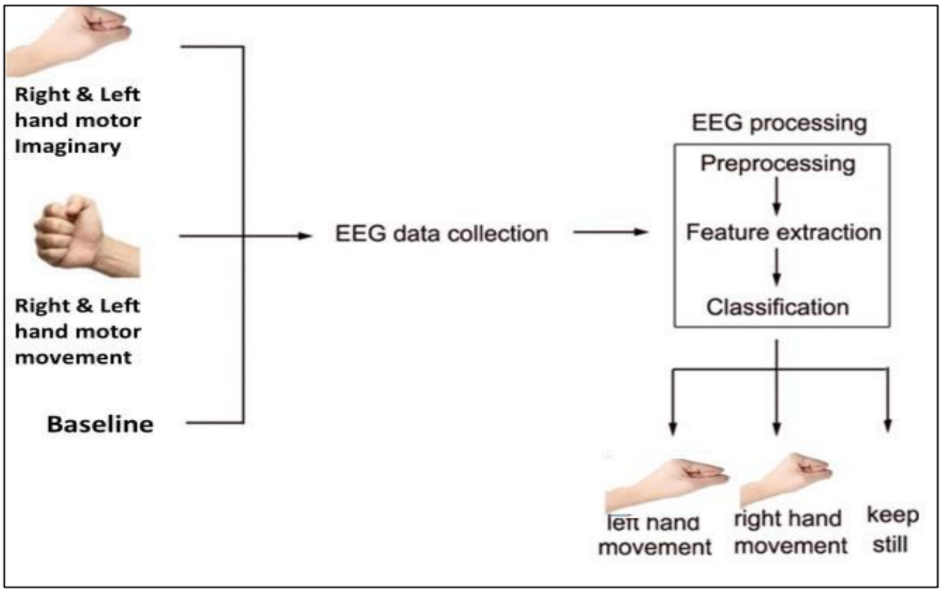

Figure 1: The baseline, real, and imagined movements of both hands during EEG recording as an experiment protocol.

Statistical Analysis: The study's data were stored in Excel and analysed using STATA version 14. The results of three groups (base, real, and imaginary) were compared using the Kruskal-Wallis test, and the Wilcoxon signed-rank test was used to determine the significance of the difference between real and imaginary (two groups). The significance of test results was set at p-values<0.05.

Results

All participants in the study (n=56) were male, and their average age was 24.40 years and their BMI was within the normal range (Table 1).

Table 1: Anthropometric measurements

Variable	Mean value	SD
Age	24.40	7.0
Height (m)	1.73	0.04
Weight	67.15	5.66
BMI	22.68	1.60

When comparing the baseline coherence value with real and imagined movements, a good inter-spectral coherence-based connectivity was observed in various brain regions with the exception of the C3-C4 central region during baseline, real and imaginary movements (Table 2). The central area of the brain shows a significant rise in the gamma band activity during both real and imaginary movements compared to baseline and no significant difference was observed between real and imaginary movement coherence (Table 3).

Table 2: Comparison of coherence of Gamma Frequency Band during baseline, imaginary and real movement of both hands

Channels	Coherence of Gamma Frequency Band			p-value
	Baseline	Real Movements	Imaginary Movements	
	Median (IQR)	Median (IQR)	Median (IQR)	
Frontal Area of Brain				
FP1-FP2	0.16(0.1-0.28)	0.15(0.11-0.25)	0.15(0.08-0.28)	0.923
F3-F4	0.1(0.07-0.21)	0.12(0.09-0.19)	0.13(0.09-0.2)	0.498
F7-F8	0.12(0.08-0.16)	0.12(0.08-0.16)	0.13(0.08-0.2)	0.714
Central Area of Brain				
C3-C4	0.11(0.08-0.18)	0.13(0.09-0.2)	0.14(0.1-0.18)	**0.049**
Temporal Area of Brain				
T3-T4	0.13(0.09-0.19)	0.15(0.1-0.19)	0.15(0.1-0.2)	0.334
T5-T6	0.11(0.08-0.19)	0.13(0.09-0.19)	0.13(0.09-0.19)	0.453
Parietal Area of Brain				
P3-P4	0.12(0.09-0.16)	0.14(0.1-0.21)	0.13(0.1-0.21)	0.172
Occipital Area of Brain				
O1-O2	0.14(0.1-0.22)	0.13(0.09-0.22)	0.14(0.09-0.22)	0.993

Table 3: Comparison of p-value of coherence of Gamma Frequency Band during baseline, imaginary and real movement of both hands

Areas of Brain	Channels	p-value		
		Baseline Vs Imaginary	Baseline Vs Real	Imaginary Vs Real
Frontal	**FP1-FP2**	0.724	0.771	0.831
	F3-F4	0.288	0.288	0.809
	F7-F8	0.585	0.833	0.444
Central	**C3-C4**	**0.030**	**0.043**	0.887
Temporal	**T3-T4**	0.188	0.167	0.952
	T5-T6	0.255	0.248	0.948
Parietal	**P3-P4**	0.125	0.068	0.734
Occipital	**O1-O2**	0.985	0.905	0.933

Discussion

The present study was conducted on 56 healthy male participants with a mean age of 24 years. All of the patients were of urban origin and represented the entire socioeconomic spectrum of the community. The present study evaluates gamma band power coherence during baseline, real, and imagined motor movements. Even during the quiescent phase (baseline), this study found a wide range of variability in gamma band voltage, so the median value and interquartile range (IQR) were considered for study analysis. Compared to the baseline, the median values of gamma band voltage were markedly elevated during both real and imagined movement.

A study conducted in Russia discovered an increase in gamma band voltage during both real and imagined movement, with the power of the gamma band increasing most in the central region of the cortex [15]. The Federal University of Rio de Janeiro, Brazil discovered that gamma band activity over the frontocentral region of the brain does not differ between real and imagined elbow joint movement [16]. Twelve healthy volunteers participated in an EEG (Cz channel) recording for a study conducted in Spain. The average gamma band activity values for real and imagined movement of both limbs were significantly greater than the resting value ($p = 0.007$). There was no statistically significant difference ($p = 0.242$) between the mean gamma band activity values during the imagined and actual movement [17]. In contrast, Kiroi et al. [15] discovered increased gamma band activity in the brain's central region. During imaginary movement, Lazurenko et al. [18] discovered an increase in gamma band voltage in the parieto-occipital cortex region and a decrease in the frontal and central regions. Smith et al. [16] found an increase in gamma band activity only in sensorimotor areas of the contralateral cortex. In the present study, the gamma band power also increased in the central area during real and imagined movements.

Similar to Carlos Amo Usanos et al. [17], the present study discovered a significant increase in mean gamma band activity during imagined ($p = 0.001$) and actual ($p = 0.003$) motor movement of both hands in the Cz channel. While there was no statistically significant difference between imagined and actual motor movement in the mean gamma band activity of both hands in the Cz channel ($p = 0.656$).

Research conducted in Turkey by Nurhan Gurselozmen (2021) observed that the supplementary motor area, the premotor, prefrontal, primary motor cortex, and the parietal cortex play good coherence in real and imaginary motor movements. Similarly, the present study found good coherence in the frontal, central, and parietal areas of brain during real motor and imaginary motor movements [19].

Conclusion

This research study found no difference in the coherence for extensive areas of the brain except the C3-C4 pair of channels, as the brain regions have similar neuronal oscillatory activity with each other. There was no statistically significant difference between imagined and actual motor movement coherence for the gamma band activity of both hands in the central area of the brain suggesting the increased neuronal activity during imagination is the same as in real motor tasks.

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