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Comparison of Relative α-Power Spectral Electroencephalogram Activity Analysis According to Electrical Stimulation Levels in Normal Adults

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Abstract

Objective: To investigate the effect of interferential current (IFC) stimulation level on electroencephalogram (EEG) activation.

Method: An adhesive 2-pole electrode pad was placed at the T1~T4 spinal cord segment level and electrical stimulation was applied for 20 minutes to 45 healthy male and female adults recruited from N University located in Gwangju Metropolitan City. Changes in EEG activation were analyzed before stimulation, immediately after stimulation and at 30 minutes after stimulation. This study was performed in three groups: sensory level stimulus group (100 bps, 10~12 mA), exercise level stimulus group (5 bps, 45~50 mA), and noxious level stimulus group (100 bps, 80~90 mA).

Results: After IFC stimulation, subjects in each group showed significant differences in terms of the retention time of relative alpha power from each brain region and between-group interaction effects. Changes in EEG activation were different depending on the type of IFC stimulation ($p<0.05$).

Conclusion: Electrical stimulation parameters in clinical practice should be selectively applied based on diverse changes and conditions.

Keywords: Interferential current; Sensory-level stimulus; Exercise-level stimulus; Noxious-level stimulus

Introduction

Electrical stimulation serves as a therapeutic method to relieve bone disorders or neurological pain, expands the size of the receptive field in the cerebral cortex, and enhances the sensitivity of the somatosensory system [1].

Transcutaneous application of electrical currents leads to the activation of neuronal membranes, and the resulting physiological, pathological changes elevate blood circulation and muscular activity via muscular metabolism [2]. Thus, numerous studies have indicated that electrical stimulation is an effective treatment for various purposes, including pain control, muscle re-education, muscle strengthening and wound healing, while emphasizing the introduction of more diverse and suitable approaches for electrical stimulation [3]. Previous studies have found that the stimulation of peripheral sensory receptors affecting the excitability of the motor cortex can differ depending on the type of electrical stimulation applied and the intervention time in the absence of any regular index [4]. Since the diverse therapeutic effects of electrical stimulation tend to be evaluated based on a patient's subjective pain intensity, the application of electrical stimulation at an appropriate level is a daunting task not only for achieving the maximum effect under specific conditions, but also for minimizing pain intensity and unpleasantness [5]. Thus, these research outcomes have implied that more effective and suitable evidence-based approaches for electrical stimulation conditions and intensity are crucial [6]. Interferential current (IFC) is a treatment modality used primarily for pain control. Wider use of IFC in clinical settings is due to its physiological mechanism through which higher maximum total current can be delivered to specific tissues, with greater penetration because of less resistance to the skin or tissue [3]. IFC is an amplitude modulated alternating current with a medium-frequency of 1~100 kHz produced when two independent alternating currents of slightly different frequencies intersect and deliver a biologically acceptable bust frequency under the flow of a sustained electric charge [7]. However, the proposed mechanism for the pain-relieving properties associated with the use of IFC has yet to be fully elucidated by previous studies. For this reason, diagnosis and assessment of the intervening effects of electrical stimulation are emerging as the crucial factors in clinical practice [3].

Electrodiagnostic tests have been proposed to measure nerve conduction velocity and physiological excitability in a quantitative manner. By measuring the electrical activity, these tests contribute to objectively determining the variability of the current threshold and the adaptability of the peripheral nerve induced by electrical stimulation [8]. The excitability of neuronal cells in the form of physical stimulation can also increase the muscular motor evoked potential [9]. The cerebral cortex is responsible for sensing and interpreting input from various sources and maintaining cognitive function. Brain waves also determine the electrical signal generated from the cerebral cortex. Among brain lobes, the frontal lobe is involved in memories and planning resulting from current actions. The parietal lobe is involved in the reception and processing of sensory information from the body [10]. Thus, many researchers have studied electroencephalography (EEG) signals and identified the electrical excitability of sensory or peripheral nerves and changes in electrophysiological potential associated with noxious stimulation based on the electrical signal generated by the cerebral

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cortex [5]. EEG signals also play a role in analyzing the brain's electrical activity, which is balanced between and modulated by the central nervous system and local factors. Specific EEG patterns that vary depending on mental state or activity, cerebral disease, and stimulation are used extensively in various medical fields [11]. However, the current conductivity is not applied evenly to all tissues, so actual EEG response patterns to maximum electrical stimulation have been reported to be diverse and irregular [12]. Brain-computer interface (BCI) is a computer-based system that acquires brain signals, analyzes them, and translates them into commands that are relayed to an output device to carry out a desired action. People disabled by neuromuscular disorders such as stroke or spinal cord injury can use electrical signals from their brain activity to interact with, influence, or change their environments [13]. Improvement in motor function may be possible through frequent access to one's environment. Studies have shown that a patient's own active thinking is of much help to his/her rehabilitation process, unlike passive rehabilitation [14]. Taking into consideration the fact that diverse level-based electrical stimulation parameters are applied differently to the human body's biorhythm activation mechanism, it is crucial to choose the appropriate electrical stimulation conditions [3]. To evaluate the impact of a patient's psychological state on the brain's neurophysiological changes in this study, we investigated the effect of the level of electrical stimulation on EEG activation by recording the brain's electrical signals from the motor cortex region depending on the type of IFC stimulation applied.

Methods

Subjects

Forty-five healthy male and female students at N university located in Gwangju Metropolitan City were included in this study. Subjects were excluded if they had a history of disease that might affect changes in blood flow, vital signs (blood pressure, pulse, body temperature and respiration rate), blood examination and this experiment, had any metal implants in the body, were ineligible for electrical stimulation intervention, had brain disorders, or were considered inappropriate for participation in the study by the investigator. Subjects were instructed not to engage in severe exercise and intake of tobacco, drinks or food that might affect the autonomic system was restricted 1 hour prior to the experiment. After recording age, gender and body weight as the main parameters, the subjects were allocated randomly to one of the following 3 groups: sensory level stimulus group (n=15), exercise level stimulus group (n=15) and noxious level stimulus group (n=15). After full explanation of the nature of the study, the subjects voluntarily submitted written informed consent to participate in the study. The three groups were considered homogenous after assessment of demographic characteristics in each group (Table 1 and Figure 1).

The QEEG-8 system (PolyG-I, LAXTHA Inc., Korea) was used to obtain EEG measurements. EEC recordings were obtained by placing electrodes on the scalp in accordance with the international 10/20 electrode system. Brain signals detected along the scalp by EEG contained several frequency components, although unnecessary artifacts were removed. For this reason, the combined signals was filtered using a band-pass filter of 0~50Hz that accepted frequencies within the specified range, while rejecting frequencies outside that range. Raw EEG data were digitalized via an analog-digital converter (12-bit AD conversion), with a digital sampling rate of 256 Hz per second. Time courses for all waveforms detected in the scalp EEG were observed using the computer signal recording mode and all artifacts from the subject and other frequencies were minimized [15]. EEG electrodes were attached to eight locations on the scalp. The eight locations were: the pre-frontal 1 (Fp1), pre-frontal 2 (Fp2), frontal 3 (F3), frontal 4 (F4), central 3 (C3), central 4 (C4), parietal 3 (P3) and parietal 4 (P4). Furthermore, a reference electrode and a ground reference electrode were placed behind the right earlobe and the left earlobe, respectively. Gold-plated disc-shaped electrodes were used and they were attached using paste applied from a gauze for EEG electrodes. For EEG data analysis, quantitative analysis was conducted using the TeleScan software program. Alpha waves at a frequency band of 8-13 Hz were analyzed. Raw EEG data were converted into frequencies using fast Fourier transform (FFT), representing the quantitative relationship between frequency components and their brain wave intensities. Power spectrum analysis (PSA) was performed on the components of different frequencies to compute the relative power values of each frequency. In this study, relative band power, which indicates the ratio of the absolute band power at a total frequency to the absolute band power, was calculated in order to correct absolute differences among the subjects in EEG [10]. To prevent eye-induced artifacts (e.g. eye blinks) during the EEC recording, subjects were instructed to close their eyes. Each subject rested comfortably on a bed for 10 minutes to minimize posture- or action-induced EEG artifacts and measurement errors before the experiment. Although spectrum analysis-based relative power values could be computed by recording the EEG signal over a short period of time, the computation of relative power values was performed for 20-30 seconds to 3 minutes per frequency band using purified brain waves with the artifacts removed in order to evaluate the brain's electrical activity more accurately. The room temperature and humidity were controlled. During the experiment, lighting and noise within the room or from the outer environment were reduced to the lowest possible level. From 220 seconds of EEG raw data obtained before electrical stimulation, immediately after IFC stimulation and at 30 minutes after IFC stimulation, 180 seconds of each measurement was analyzed, excluding the first and last 20 seconds (Figures 2 and 3).

Procedures

Each subject lay on a bed in a comfortable position for 10 minutes before the experiment to enhance his/her psychological stability [13]. A pad electrode (4×4 cm, Protens Electrodes, Bio-Protech INC. Korea) was attached to the transverse process at a distance of about 2 cm from the left side of the spinous processes corresponding to the T1~T4 spinal

Characteristics		[a]SSL	[b]ESL	[c]NSL	F	p
Gender	Male	7	8	9		
	Female	8	7	6		
Total		15	15	15		
Age (years)		[d]22.00 ± 1.41	22.45 ± 1.44	22.64 ± 1.63	0.53	0.596
Height (cm)		166.27 ± 7.46	167.09 ± 10.50	170.64 ± 11.08	0.62	0.653
weight (kg)		62.55 ± 4.55	60.82 ± 4.08	65.09 ± 6.93	3.21	0.260

[a]SSL: sensory stimulus level; [b]ESL: exercise stimulus level; [c]NSL: noxious stimulus level ; [d]Mean ± SD.

Table 1: General characteristics of the subjects.

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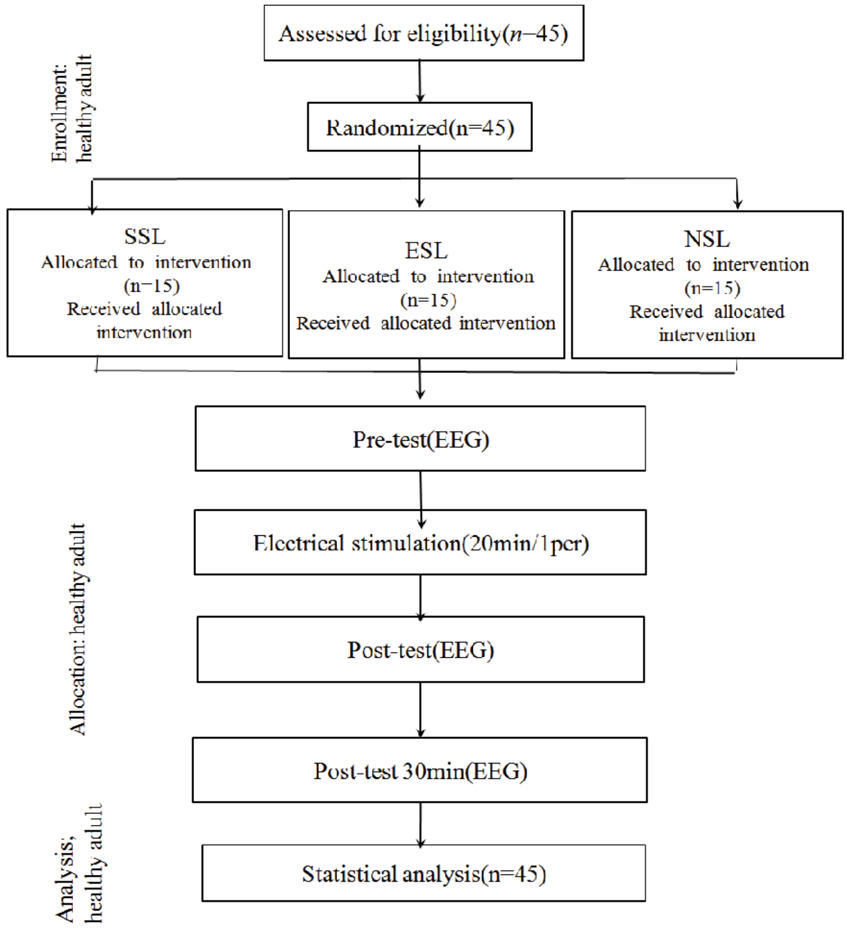

Figure 1: Diagram of expermental procedure.

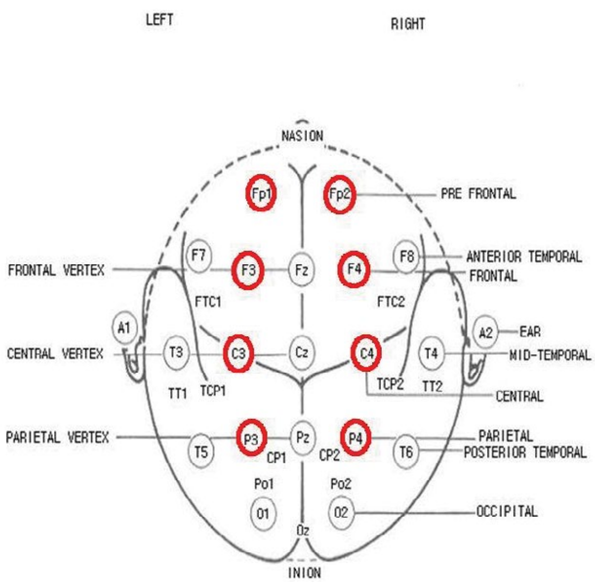

Figure 2: International 10/20 electrode system.

Fp1: left pre-frontal lobe, Fp2: right pre-frontal lobe, F3: left frontal lobe, F4: right frontal lobe, C3: left central lobe, C4: right central lobe, P3: left parietal lobe, P4: right parietal lobe

cord segment levels. IFC stimulation was applied for 20 minutes using ENDOMED 582 (Enraf Nonius, Netherland) as the IFC equipment. Following preliminary tests, the experiment was performed in three groups: sensory level stimulus group (burst frequency; 100 bps, intensity; 10-12 mA), exercise level stimulus group (burst frequency; 5 bps, intensity; 45-50 mA) and noxious level stimulus group (burst frequency; 100 bps, intensity; 80~90 mA).

Electroencephalogram (EEG) data analysis

All statistical analyses were conducted using SPSS 12.0 software version. The Shapiro-Wilks test was performed, assuming normal distribution of the demographic characteristics of the subjects and each test item. Since the normal distribution was identified, one-way analysis of variance (ANOVA) was used to compare the demographic characteristics in each group. Time-course changes in EEG activation in each group were subject to two-way repeated measures ANOVA. The significance in testing items was analyzed by Tukey HSD test.

Results

Changes in EEG-based relative alpha power per brain region

Changes in between-group relative alpha power values following IFC stimulation showed that relative alpha power increased in the sites (Fp1, Fp2, F3, F4, C3, C4, P3, and P4) of the exercise level stimulus group immediately after IFC intervention, whereas it decreased in the noxious level stimulus group. When the experimental results were analyzed using repeated measures ANOVA, the Mauchly's test of sphericity was statistically significant ($p<0.05$). Multivariate test results also revealed that there were significant differences in between-groups interaction effects at different time intervals of IFC stimulation in each group ($p<0.05$). In a multivariate approach to the within-subjects test used to analyze the relative alpha power during the different intervals of IFC stimulation in the 3 groups. significant differences in the relative alpha power were noted at F3, F4, C3, C4, P3, and P4 sites immediately after IFC stimulation and at 30 minutes after IFC stimulation ($p<0.05$) (Table 2).

Discussion

IFC stimulation affects the excitability of the neuronal membrane, and a short pulse duration can activate motor neurons [14].To induce the maximal volitional contraction (MVC) in muscle, the amplitude of the stimulating current (20-50 mA) during exercise is delivered to subjects depending on their muscle contraction and compliance [15]. For sensory stimulation, the amplitude is delivered at 2.5~4.0 mA. The appropriate level of stimulating current is applied at noxious stimulus levels in terms of pain control derived from the endogenous opioid theory [3]. Based on the fact that the sympathetic ganglia is effective in elevating peripheral blood flow, an adhesive 2-pole electrode pad was placed on the T1~T4 spinal cord segment levels of each subject [16]. In this study, the authors investigated the direct effect of 3 stimulation types (sensory level stimulus, exercise level stimulus, and noxious level stimulus) on EEG activation using the frequency and intensity of IFC stimulation as the main parameters. The brain's electrical activity, which is reflected in EEG signals, indicates that biochemical interactions in the brain's neurons result from ionic currents within neuronal cells, glia cells, and the blood-brain barrier [17]. EEG is an excellent time-resolution diagnostic tool that provides space-time information regarding the brain's electrical activity originating from the neural cell population of the cerebral cortex [18].

Alpha waves increase during comfortable rest [19]. Decreased alpha and beta waves in stroke patients are closely associated with cognitive impairment. Motor learning is facilitated when appropriate levels of brain waves are stimulated. The appearance of alpha waves indicates brain relaxation, with a reduction in mental and physical tension and stress. Comprehensive judgment is then possible with improved concentration. For this reason, alpha waves are crucial in situations where a higher level of concentration is required [20,21]. In this study, significant changes in relative alpha power observed in each group following electrical stimulation demonstrated that exercise level stimulus was more effective for a high level of performance, compared with sensory level and noxious level stimuli. This study revealed that alpha waves were maintained more effectively after sensory level stimulation than after other types of IFC stimulation. This suggests that the outcomes of this study may be used as a strategy to effectively control alpha waves, which are vital to cognitive and mental processes, for successful achievement of a given task [22]. A study on the tract of the motor center indicated that significant loss of alpha waves was observed in the spinal cord after electroacupuncture at the low-frequency of 80 Hz [23]. When electrical stimulation at low current levels is applied to the skin surface where sensory receptors are embedded in motor nerve fibers or myofibers, it reaches a sensory threshold and induces a positive effect and modulatory functions

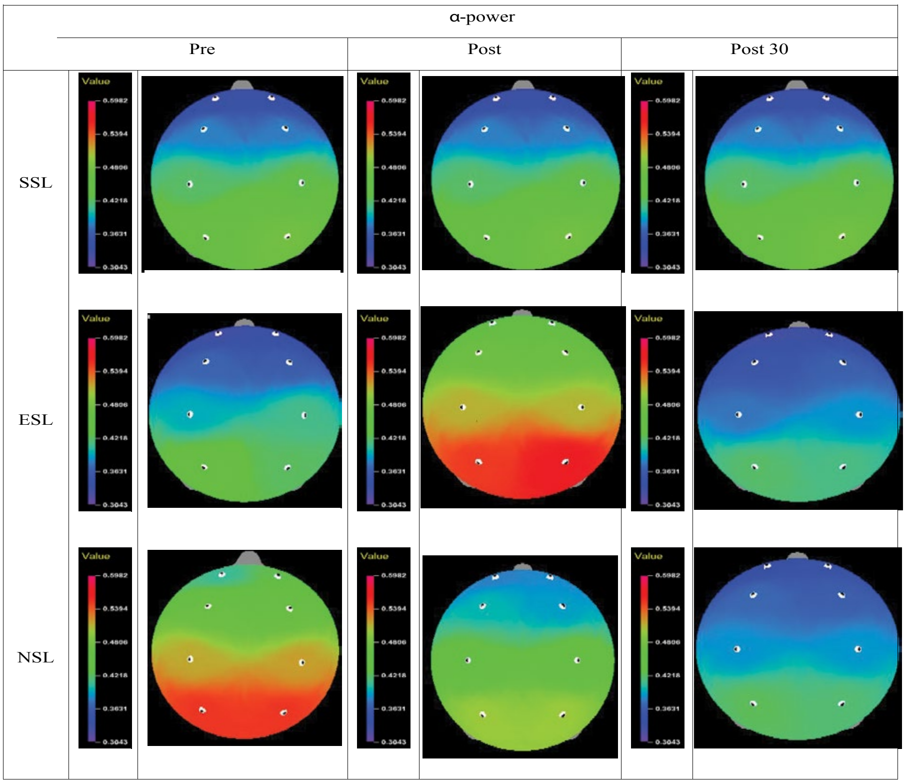

Figure 3: Brain mapping of electroencephalogram (EEG) activity in α-power.
Scale range: Min. value (0.31) ~ Max. value (0.54), Interval (0.03); Data expression: Electrodes, Head object; value of relative power were expressed by color in high-to-low order: red, orange, yellow, green, blue, and violet

Variable	Group	Pretest (M ± SD)	Posttest (M ± SD)	Post30 (M ± SD)	F(p)		
					Group	Period	Group x Period
Fp1	SSL (n=15)	0.32 ± 0.15	0.32 ± 0.12	0.40 ± 0.10	0.76 (0.47)	2.83 (0,08)	1.75 (0.18)
	ESL (n=15)	0.33 ± 0.14	0.43 ± 0.10	0.37 ± 0.10			
	NSL (n=15)	0.31 ± 0.15	0.32 ± 0.13	0.33 ± 0.09			
Fp2	SSL (n=15)	0.33 ± 0.14	0.33 ± 0.14	0.42 ± 0.09	0.65 (0.52)	0.90 (0.38)	1.95 (0.13)
	ESL (n=15)	0.33 ± 0.12	0.43 ± 0.10	0.38 ± 0.09			
	NSL (n=15)	0.32 ± 0.16	0.33 ± 0.14	0.35 ± 0.09			
F3	SSL (n=15)	0.38 ± 0.13	0.36 ± 0.12	0.46 ± 0.08	0.64 (0.53)	3.31 (0.04*)	2.89 (0.04*)
	ESL (n=15)	0.38 ± 0.15	0.46 ± 0.11	0.39 ± 0.09			
	NSL (n=15)	0.38 ± 0.16	0.35 ± 0.12	0.37 ± 0.09			
F4	SSL (n=15)	0.37 ± 0.13	0.36 ± 0.13	0.46 ± 0.10	0.57 (0.57)	3.34 (0.04*)	2.90 (0.04*)
	ESL (n=15)	0.37 ± 0.15	0.46 ± 0.11	0.39 ± 0.11			
	NSL (n=15)	0.35 ± 0.17	0.36 ± 0.14	0.35 ± 0.11			
C3	SSL (n=15)	0.42 ± 0.15	0.42 ± 0.18	0.40 ± 0.18	0.97 (0.38)	3.18 (0.04*)	3.34 (0.02*)
	ESL (n=15)	0.39 ± 0.14	0.51 ± 0.11	0.37 ± 0.11			
	NSL (n=15)	0.51 ± 0.13	0.43 ± 0.11	0.38 ± 0.09			
C4	SSL (n=15)	0.42 ± 0.15	0.51 ± 0.12	0.51 ± 0.12	1.10 (0.34)	3.33 (0.04*)	2.67 (0.04*)
	ESL (n=15)	0.42 ± 0.18	0.50 ± 0.12	0.44 ± 0.13			
	NSL (n=15)	0.39 ± 0.17	0.38 ± 0.13	0.38 ± 0.09			
P3	SSL (n=15)	0.46 ± 0.18	0.45 ± 0.15	0.47 ± 0.13	1.08 (0.34)	4.83 (0.01*)	3.08 (0.03*)
	ESL (n=15)	0.45 ± 0.21	0.55 ± 0.17	0.50 ± 0.13			
	NSL (n=15)	0.42 ± 0.20	0.42 ± 0.13	0.42 ± 0.09			
P4	SSL (n=15)	0.45 ± 0.17	0.42 ± 0.14	0.55 ± 0.13	1.05 (0.35)	4.89 (0.01*)	3.44 (0.02*)
	ESL (n=15)	0.47 ± 0.22	0.56 ± 0.14	0.50 ± 0.15			
	NSL (n=15)	0.44 ± 0.19	0.41 ± 0.14	0.41 ± 0.10			

*p<0.05; pre test: before electrical stimulation; post-test: After electrical stimulation directly; post 30: After 30 minutes from immediately the electrical stimulation

Table 2: The change of relative value α-power.

[24]. This can be inferred from our results demonstrating significant changes in the alpha waves of the sensory level stimulus group. In addition, another study showed that increased cerebral blood flow resulted in the enhancement of cognitive function in elderly patients with frontal lobe degeneration complicated by cognitive dysfunction [25]. This also coincides with our results, demonstrated in changes of EEG activation in the frontal lobe and other brain regions, indicating that proper electrical stimulation can activate the frontal lobe and that change in EEG activation induced by exercise level stimulus may be effective for the enhancement of cognitive function. Further, in a study where a sleep-awakening cycle was induced using electroacupuncture, functional exercise enabled the activation of alpha waves in parietal and occipital regions [26]. In this study, increased alpha activity was identified in the exercise level stimulus group. More specifically, changes in skeletal muscle associated with electrical stimulation reflect significant activity in the motor cortex region that governs the stimulating muscle. The results of our study are supported by existing reports suggesting that physical exercise leads to increased secretion of brain derived neurotropin factor, preventing the destruction of normal brain cells and aiding in the generation of new brain cells [27,28]. By considering the changes in EEG activation according to types of electrical stimulation, we can infer that time-course changes in alpha activity in each brain region may affect the activity in the motor region as well as in the sensory region of the cerebral cortex. Further, the same levels of alpha waves are generated from both the left and right brain in normal individuals. A study related to spatial cognitive activity reported that there are no differences in EEG activity between the left and right brain (frontal, temporal, parietal and occipital lobes) and the left and right hemispheres of the cerebrum [29]. Our brain maps found no differences in alpha activity from both the left and right brain of all subjects when exposed to electrical stimulation. The breakdown of the endogenous pain control system is a potential mechanism underlying increased pain [5]. When noxious electrical stimulation is applied to alleviate severe pain, a high level of pain catastrophizing is inversely related to the brain's electrical activity in the cortex region including a downward pain control network [30]. An experimental study showed that EEG activity in the alpha band is lower in pain-induced normal subjects [31]. Nevertheless, our EEG data failed to identify significant changes in the alpha band from the noxious level stimulus group, which can be inferred by the previous study report [32] that a noxious level of electrical stimulation leads to the secretion of endogenous opioids within the central nervous system that may result in downstream pain control. More specifically, receptor-based skin pressure stimulation and skin stretching show the highest sensitivity at the frequencies of 0.3-3 Hz and 25-400 Hz respectively, thus generating various excitations such as sensation, exercise and pain [33]. The electrical stimulation used in this study is a therapeutic intervention method designed to achieve more effective tissue stimulation without pain or unpleasantness during application, using amplitude modulated alternating current in IFC stimulation mode. Significant differences exist between previous reports and our results in that this study does not fully elucidate the changes in cortical potentials per frequency related to muscle contraction training in each cerebral cortex region. Therefore, EEG activation needs to be measured as a therapeutic approach for each brain wave by mutual linkage of important brain wave bands for analysis in various diseases. In addition, since the criteria for brain development and aging vary depending on the age of the subjects, which may affect brain waves, changes in EEG signals should be investigated in objective age brackets.

Conclusion

In this study, we investigated the effect of different types of IFC stimulation in the sympathetic ganglia of normal healthy adults on EEG activation. Significant changes in the relative alpha power during different intervals of IFC stimulation were observed in each group at Fp1 and Fp2 sites before electrical stimulation and at 30 minutes after IFC stimulation. Further, significant differences in the relative alpha power were noted at F3, F4, C3, C4, P3, and P4 sites immediately after IFC stimulation and at 30 minutes after IFC stimulation. We found diverse brain wave changes depending on the type of IFC stimulation, significant effects of electrical stimulation level on EEG activation, and the patient's psychological stability during rehabilitation, which could not be quantitatively measured. The results of our study may be used as raw data for the rehabilitation of patients if adequate levels of electrical stimulation are applied depending on the patient's condition.

Conflict of Interests

The authors declare that there are no conflicts of interest regarding the publication of this article.

References

1. Dhruv NT, Niemi JB, Harry JD, Lipsitz LA, Collins JJ (2002) Enhancing tactile sensation in older adults with electrical noise stimulation. Neuroreport. 16: 597-600.
2. Valeriani M, Tonali P, Le Pera D, Restuccia D, De Armas L, et al. (2006) Modulation of laser-evoked potentials by experimental cutaneous tonic pain. Neuroscience 140: 1301-1310.
3. Robertson V, Ward A, Low J, Reed A, Ward A, et al. (2006) Electrotherapy explained: principles and practice, 4th ed, Elsevier Butterworth-Heinemann.
4. Kottink AI, Oostendorp LJ, Buurke JH, Nene AV, Hermens HJ, et al. (2004) The orthotic effect of functional electrical stimulation on the improvement of walking in stroke patients with a dropped foot: a systematic review. Artif Organs 28: 577-586.
5. Sullivan MJ, Lynch ME, Clark AJ (2005) Dimensions of catastrophic thinking associated with pain experience and disability in patients with neuropathic pain conditions. Pain 113: 310-315.
6. Bogduk N (2003) Spinal manipulation for neck pain does not work. J Pain 4: 427-428.
7. Indergand HJ, Morgan BJ (1995) Effect of interference current on forearm vascular resistance in asymptomatic humans. Phys Ther 75: 306-312.
8. Nangini C, Ross B, Tam F, Graham SJ (2006) Magnetoencephalo graphic study of vibrotactile evoked transient and steady-state responses in human somatosensory cortex. Neuroimage 33: 252-262.
9. Kaelin-Lang A, Luft AR, Sawaki L, Burstein AH, Sohn YH, et al. (2002) Modulation of human corticomotor excitability by somatosensory input. J Physiol 15: 623-633.
10. Niemiec A, Lithgow B (2005) Alpha-band characteristics in EEG spectrum indicate reliability of frontal brain asymmetry measures in diagnosis of depression. Conf Proc IEEE Eng Med Biol Soc 7: 7517-7520.
11. Wang L (2007) Brain Plasticity: Dynamic Changes of the Cerebral Activity as Effect of Pain Modulation, Aalborg University, Ph. D. Thesis.
12. Low J, Reed A (2007) Electrotherapy Explaind: Priniciples and Practice, Edition 3. Elsevier Health Sciences, 2000. 13. Dornhege G, Millán JR, Hinterberger T, McFarland, Müller KR, Toward brain-computer interfacing, Cambridge, MA: MIT Press.
13. Ward AR, Lucas-Toumbourou S, McCarthy B (2009) A comparison of the analgesic efficacy of medium-frequency alternating current and TENS. Physiotherapy 95: 280-288.
14. Selkowitz DM (1985) Improvement in isometric strength of the quadriceps femoris muscle after training with electrical stimulation. Phys Ther 65: 186-196.
15. Woolf CJ (1989) Segmental and afferent fibre-induced analgesia: Transcutaneous electrical nerve stimulation(TENS) and vibration. In Text book of pain, New York, Churchill Livingstone 884-896.
16. Sadock BJ, Sadock VA, Kaplan & Sadock's (2007) Synopsis of Psychiatry: Behavioral Sciences. Clinical Psychiatry, 10thed. Lippincott Williams & Wilkins 117.
17. Schoffelen JM, Oostenveld R, Fries P (2005) Neuronal coherence as a mechanism of effective corticospinal interaction. Science 308: 111-113.
18. Fairclough SH, Venables L, Tattersall A (2005) The influence of task demand and learning on the psycho physiological response. Int J Psychophysiol 56: 171-184.4.
19. Mouraux A, Iannetti GD, Colon E, Nozaradan S, Legrain V, et al. (2011) Nociceptive steady-state evoked potentials elicited by rapid periodic thermal stimulation of cutaneous nociceptors. J Neurosci 2031: 6079-6087.
20. Weingerg RS, Gould D (1999) Foundations of sport and exercise psychology. Champaigh, IL: Human Kinetics.
21. Salazar W, Landers DM, Petruzzello SJ, Han M, Crews DJ et al. (1999) Hemispheric asymmety, cardiac response, and Performance in elite archers. Res Q Exerc Sport 61: 351-359.
22. Anna W (1995) High Performance mind. New York: Tarcher Putnam.
23. Ridding MC, McKay DR, Thompson PD, Miles TS (2001) Changes in corticomotor representations induced by prolonged peripheral nerve stimulation in humans. Clin Neurophysiol 112: 1461-1469.
24. Ludlow CL, Humbert I, Saxon K, Poletto C, Sonies B, et al. (2007) Effects of surface electrical stimulation both at rest and during swallowing in chronic pharyngeal Dysphagia. Dysphagia 22: 1-10.
25. Rovio S, Kåreholt I, Helkala EL, Viitanen M, Winblad B, et al. (2005) Leisure-time physical activity at midlife and the risk of dementia and Alzheimer's disease. Lancet Neurol 411: 705-711.
26. Başar E (2012) A review of alpha activity in integrative brain function: fundamental physiology, sensory coding, cognition and pathology. Int J Psychophysiol 86: 1-24.
27. Brown P, Salenius S, Rothwell JC, Hari R (1998) Cortical correlate of the Piper rhythm in humans. J Neurophysiol 80: 2911-2917.
28. Roth CL (2008) How to protect the aging workforce. Occupational Hazards 67: 52-54.
29. Larson CL, Davidson RJ, Abercrombie HC, Ward RT, Schaefer SM, et al. (1998) Relations between PET-derived measures of thalamic glucose metabolism and EEG alpha power. Psychophysiology 35: 162-169.
30. Seminowicz DA, Davis KD (2006) Cortical responses to pain in healthy individuals depends on pain catastrophizing. Pain 120: 297-306.
31. Chen AC (2001) New perspectives in EEG/MEG brain mapping and PET/fMRI neuroimaging of human pain. Int J Psychophysiol 42: 147-159.
32. Cheing GL, Chan WW (2009) Influence of choice of electrical stimulation site on peripheral neurophysiological and hypoalgesic effects. J Rehabil Med 41: 412-417.
33. Bolanowski SJ, Verrillo RT, McGlone F (2004) Passive, active and intra-active (self) touch. Behav Brain Res 148: 41-45.

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