Research Paper

Interferential Current Ability to Change the Pattern of Brain Activity in Patients With Nonspecific Low Back Pain

Nahid Hooshmand[1], Abbas Soltani Someh[1*], Ali Jahan[2], Bahram Amirshakeri[1]

1. Department of Physiotherapy, Faculty of Rehabilitation, Tabriz University of Medical Sciences, Tabriz, Iran.
2. Department of Speech Therapy, Faculty of Rehabilitation, Tabriz University of Medical sciences, Tabriz, Iran.

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ABSTRACT

Objectives: Chronic low back pain (CLBP), along with physical limitations that affect the quality of life, is one of the most important problems in the health community. The pain causes a wide range of structural, functional, and neurological changes in the brain. However, these changes have not been well studied, as brain changes in other chronic pains. This study aimed to evaluate the changes in the electroencephalogram (EEG) of patients with nonspecific CLBP, and also to evaluate the effects of interferential current (IFC), as one of the common treatment methods in these patients, on the EEG.

Methods: This randomized control trial was performed in the Physiotherapy Clinic of Rehabilitation Faculty of Tabriz University of Medical Sciences from July 2021 to February 2022. A total of 20 patients with nonspecific CLBP and 20 healthy individuals participated in this study. Healthy subjects were in the control group, and the patients were randomly divided into two groups: intervention and placebo. Participants' EEG and pain intensity were recorded before and after one session of IFC.

Results: The results of statistical analyses to compare the EEG of patients and healthy individuals did not show a significant difference between the two groups. The results of statistical tests to evaluate the effects of IFC on participants' EEG showed a significant increase in alpha frequency in all three groups. In addition, a significant increase in theta frequency was recorded in the placebo group, and an increase in the beta frequency in the intervention group. Pain intensity showed a significant decrease only in the intervention group.

Discussion: The results of this study suggest that changes in EEG in patients with low back pain may be related to the severity of pain and neurological involvement. In addition, the increased power of EEG following the application of IFC may be due to sensory stimulation of the skin surface.

*** Corresponding Author:**
Abbas Soltani Someh, PhD.
Address: *Department of Physiotherapy, Faculty of Rehabilitation, Tabriz University of Medical Sciences, Tabriz, Iran.*
Tel: *+98 (912) 3764388*
E-mail: *ab.soltani@yahoo.com*

Highlights

• Chronic low back pain can cause structural, functional, and neurological changes in the brain that can be detected using an electroencephalogram (EEG).

• In cases where the pain intensity is low or there is no nerve involvement, no significant changes are seen in the EEG of patients with chronic low back pain compared to healthy individuals.

• The changes seen in the EEG after one session of interferential current may be due to skin irritation and are not related to the pain relief mechanism.

Plain Language Summary

Chronic low back pain is the fourth most common disease in the world, which in addition to physical limitations, and the persistence of pain, causes extensive structural, functional, and neurological changes in the brain. Electroencephalogram (EEG) is one of the tools that can help detect these changes in the brain. In addition, it may be possible to use this tool to evaluate the effectiveness of the treatments used in this disorder. In this study, the electroencephalograms of 20 people with chronic nonspecific low back pain were compared with those of 20 healthy people. It seems that at low pain intensities and when the nerve roots in the lower back are not involved, there is no difference in the EEG of the two groups. In addition, the EEG of patients and healthy individuals were compared before and after one session of electrical stimulation, which is one of the most common treatments for pain relief in this disorder. The changes in the EEG after electrical stimulation appear to be due to skin irritations and are not related to the pain relief mechanism.

1. Introduction

Low back pain (LBP) is one of the most common musculoskeletal disorders, and one of the most important problems in the health community due to affecting the quality of life and daily activities of patients, which in addition to physical limitations, causes frequent absences from work and heavy economic costs [1]. It is estimated that 70% of adults have experienced low back pain at least once in their lifetime [2], and 30% of patients enter a chronic phase of the disease [3]. This prevalence ranks chronic low back pain among the four most common diseases in the world [4] and increases the risk of depression [5].

Low back pain is defined as pain, muscle tension, or stiffness localized below the costal margin and above the inferior gluteal folds, with or without leg pain (sciatica). It is known as chronic LBP if symptoms persist for more than 12 weeks. In some cases, the symptoms are caused by a specific pathophysiological mechanism which is classified as specific LBP. However, in about 90% of patients, there are non-specific causes of pain, which means that the symptoms occur without a specific origin [6], and the pain that is felt may be related to the pain control system and increased central sensitivity [1].

In chronic low back pain, the cortical response to painful stimuli and brain activity in response to non-painful stimuli increases. Also, the pain adjustment mechanism and brain activity at rest change compared to healthy people [7]. Thus, patients' reports of pain cannot provide sufficient information about the mechanisms involved in chronic pain, and the study of physiological markers that can reflect the main mechanisms of pain is an important issue for therapists [8]. Quantitative electroencephalography (QEEG) can be one of the most effective methods to detect such changes in the processing of central pain [9] and the role of the central nervous system in the onset of pain and its stability [8]. Also by detecting changes in the cerebral cortex after receiving and processing sensory inputs, QEEG can be a valuable and practical tool for assessing the modulation of cortical pain in clinical contexts [10].

Various studies in the EEG pattern of chronic pain show a general trend toward increased power at low frequencies in these patients at rest. In addition, neurological pain has been shown to increase the power of the theta band, and increased power in the alpha frequency band has also been observed in cancer patients [8].

Since chronic pain causes significant limitations in physical ability, if controlled, the patients will be more able to perform their activities, which justifies the use of electrotherapy. Electrotherapy is a non-invasive and non-pharmacological treatment and one of the common modalities in electrotherapy is interferential current (IFC) [11]. This current is produced by the interference of two currents with a medium carrier frequency (4000 Hz) which results in a low-frequency current (0-250 Hz) with amplitude modulation. The skin has a low impedance against high-frequency waves, so the penetration depth is high [12]. High penetration and greater patient comfort due to no side effects such as pain, discomfort, and skin irritation are among the benefits of interferential current (IFC) [5].

Considering the importance of chronic low back pain, the changes that the persistence of pain may cause in the brain, and the patient's inability to report brain changes to the therapist, the use of EEG as a diagnostic tool to detect changes has been established. Although examining the effectiveness of the performed treatments can be essential due to the wide range of structural, functional, and neurological changes in the brain following chronic low back pain, the treatments available for it have not been well studied [7]. So, this study was conducted with the following objectives:

1. Comparing the EEG of people with chronic nonspecific LBP with healthy people to evaluate the changes in the EEG following chronic LBP.

2. Evaluation of the effect of one session of IFC on EEG of patients with chronic nonspecific LBP.

2. Materials and Methods

Study design

This double-blind, randomized control trial was performed in the Physiotherapy Clinic of Rehabilitation Faculty of Tabriz University of Medical Sciences from July 2021 to February 2022. All experimental procedures were approved by the Ethics Committee (IR.TBZMED.REC.1399.1036). This trial was registered at the Iranian Registry of Clinical Trials (IRCT) (IRCT20210316050727N1).

Study participants

A total of 20 healthy individuals and 20 patients with nonspecific chronic low back pain participated in this study. All participants were informed about the purpose of the study and the study design, and all of them provided written informed consent.

Healthy subjects were 20-65 years old and did not report chronic pain and patients were 20-65 years old who had LBP of more than 3 months with or without pain radiating to the lower extremities above the knee and pain perception over 40 mm in the visual analogue scale (VAS) [13]. Healthy participants with metal implants in the lower back, having a history of neurological and psychological diseases, eating foods that affect the nervous system less than one hour before the test [14], taking drugs that affect the nervous system [10], sleep disorders [15], pregnancy, cancer patients and heart patients with pacemakers, and those with electrotherapy contraindications [13] were excluded from the study. Participants with LBP, in addition to the above, would be excluded from the study if they had serious spinal disorders such as fractures and inflammation or nerve root involvement, concomitant treatment [13], and using corticosteroids [12].

Study groups and interventions

Participants in this study were divided into three groups. Twenty healthy individuals were in the control group and 20 patients with nonspecific chronic LBP were randomly divided into placebo and intervention groups using sealed envelopes. Participants were blinded in this study. The sample size was estimated according to previous studies [16-18].

In the intervention group, the participants received one session of IFC for 30 minutes at a frequency of 4 kHz and a bit frequency of 100 Hz with a strong level of sensory stimulation [12]. The intensity of the current was increased to the point that the patient had a strong tingling sensation and at the same time felt comfortable; the intensity of the current was increased every 5 minutes. In the placebo group, patients received one session of IFC with similar frequencies to the intervention group, but with ineffective intensity, so that the current intensity did not reach the target point and every 5 minutes without increasing the intensity, the patient's comfort was questioned [4]. Controls received 30 minutes of IFC with effective intensity. To apply the interferential current, a 2-channel device model 520B made by Novin Company was used, and cross-electrode was performed in L3 and L5 levels, by a physiotherapist who was not involved in the study.

Data collection

First, the participants' pain intensity was measured by the VAS scale. Then, their electroencephalogram was recorded. In this study, a 32-channel device (made by Negar Andishegan Company) was used to record brain waves. The recording was done according to the conventional 10-20 system. In this device, the filtering was bandwidth (0.01 to 35 Hz) and the sampling rate was 500 Hz. The reference electrode was also connected to the eardrum of both ears and the impedance of the electrodes was maintained at values less than 5 kΩ. Finally, artifact and noise-free experiments were used to analyze the frequency spectrum.

After electrodes were placed on the participants' heads, they were asked to lie down and open their eyes. During the recording, snooze modes were detected by constantly monitoring the EEG signal, and if this occurred, the recording would be excluded from the test. This procedure was done for all participants. EEG recording was performed in both open and closed eyes conditions and was analyzed by Matlab software. At the end of the intervention, the pain intensity was measured again using VAS. In addition, the EEG was re-recorded. The assessors of this study were blind to the study.

Data analysis

After completing all tests before and after the treatment, using the Matlab 2020 software, the raw data of the EEG device, and the absolute power of the EEG frequencies in different lobes were calculated. EEG and pain intensity data were entered into SPSS 25 software and used at a significant level of 0.05 for statistical analysis. The Kolmogorov-Smirnov (K-S) test was used to check the normality of data distribution. To evaluate the EEG difference between patients and healthy people and to compare the effects of IFC on the EEG of participants, mixed model ANOVA was used. In addition, the independent t test and Mann-Whitney test were used to compare the EEG of healthy people and patients with low back pain before the intervention. Then, the paired t test and Wilcoxon test were used to compare the changes in EEG and pain intensity of the participants in the three groups before and after the application of interferential current.

3. Results

Twenty healthy individuals and 20 patients with nonspecific chronic low back pain participated in this study. The characteristics of the participants are presented in Table 1.

Evaluation of the EEG in healthy individuals and patients with chronic nonspecific LBP

In this section, the EEG records of 20 healthy individuals were compared with 20 patients with nonspecific chronic LBP. First, the K-S test and descriptive statistics were used to evaluate the normality of the distribution of contextual variables. Then, the independent t test and Chi-square test were used to determine the homogeneity of contextual variables between patients and healthy individuals. The results of the independent t test for the variables of age, height, weight, and body mass index (P>0.05) showed no significant difference between the two groups at the beginning of the study, which indicates the comparability of the groups. The Chi-square test was used to compare the groups in terms of the gender of the participants, and there was no statistical difference between the groups in this regard (P>0.05).

Table 1. Characteristics of the participants

Variable		Mean±SD/No.		
		Control	Intervention	Placebo
Age (y)		38.15±11.14	47.00±8.36	44.10±8.71
Height (cm)		166.65±9.21	168.10±8.72	172.00±7.43
Weight (kg)		70.95±10.97	77.30±6.65	79.30±9.67
BMI (kg/m^2)		25.48±2.74	27.49±3.12	26.79±2.49
VAS		0.80±1.05	6.40±2.06	6.20±1.54
Sex,	Male	7	2	5
	Female	13	8	5

Abbreviations: BMI, body mass index, VAS, visual analog scale

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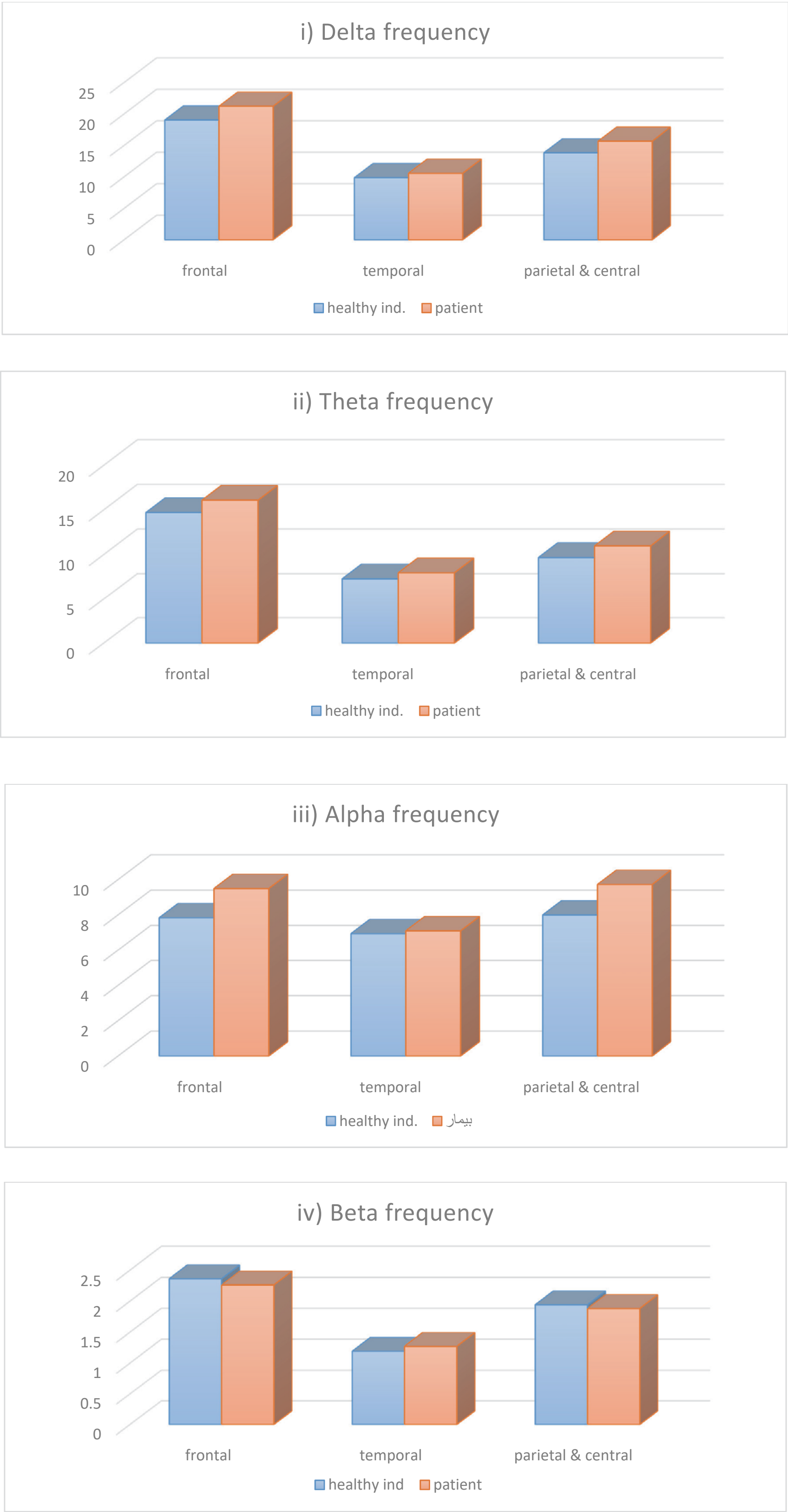

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Figure 1. Mean absolute power of i) Delta, ii) Theta, iii) Alpha, and iv) Beta frequencies in patients and healthy individuals

Analytical review of data

Initially, the mixed model ANOVA was used to evaluate the difference in the electrical activity of the brain between the healthy and patient groups. Frequency variables (delta, theta, alpha, beta) and brain areas (frontal, temporal, central, parietal) entered the test as "within-subjects variables", and group (pain, healthy) as "between-subjects factor". Due to the significance of Macaulay's statistic, the sphericity assumption was distorted, so the Greenhouse-Geiser statistic has been reported. The analysis showed that the interaction between the group × frequency × region was not significant ($F_{2.9}$=0.31, P=0.80). Thus, there is no difference in frequency distribution between the two groups of chronic low back pain and healthy individuals. Also, the interaction of the frequency × group was not significant ($F_{1.76}$=0.54, P=0.56). Finally, the interaction of the region × group did not reach a significant level ($F_{1.95}$=1.18, P=0.31). Thus, the electrical activity of the brain did not differ between the two groups in terms of frequency or region. The mean absolute power of each frequency in patients and healthy individuals are shown in Figure 1.

Despite the higher absolute power of the waves at all frequencies (except beta frequency in the frontal, central, and peritoneal lobes), a one-to-one comparison of frequencies in each lobe between the two groups did not show a significant difference between the two groups (P>0.05) using the independent t test and Mann-Whitney test after determining the normality of the variables using the K-S test.

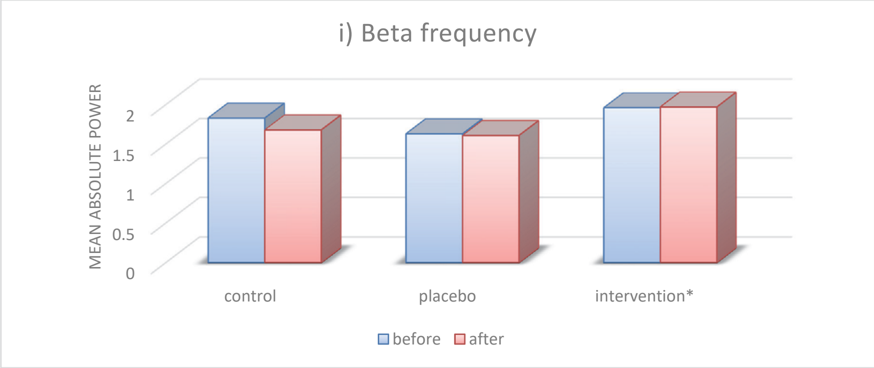
Evaluation of differences in EEG and pain intensity in three groups of intervention, control, and placebo before and after IFC

In this section, EEG and pain intensity of 20 healthy individuals in the control group and 10 patients with non-specific chronic LBP in the intervention group, and 10 patients with non-specific chronic LBP in the placebo group were compared before and after IFC. First, the K-S test and descriptive statistics were used to evaluate the normality of the distribution of contextual variables. A 1-way ANOVA test was used to determine the homogeneity of contextual variables between participants in the three groups. The results of this test for the variables of age, height, weight, and body mass index (P>0.05) show no significant difference between the study groups at the beginning of the study. The Chi-square test was used to compare the groups in terms of the gender of the participants, and there was no statistical difference between the groups (P>0.05).

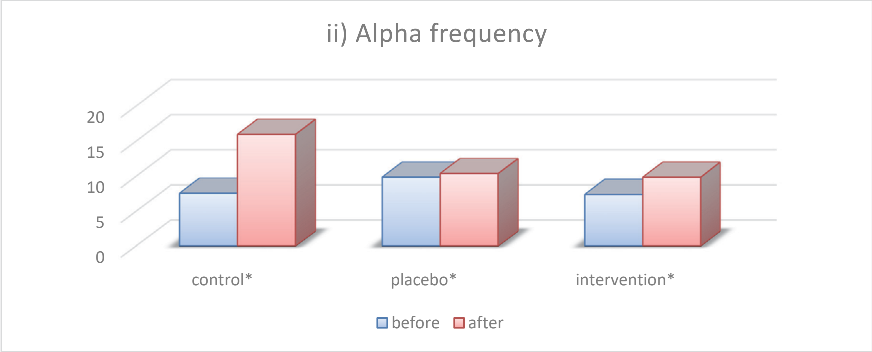
Analytical review of data

Initially, mixed model ANOVA was used to evaluate the difference in the electrical activity of the brain between control, placebo, and intervention groups before and after the intervention. Frequency variables (delta, theta, alpha, beta), brain areas (frontal, temporal, central, parietal), and EEG recording time (before and after the intervention) were entered into the test as "within-subjects variables", group (control, placebo, intervention) as "between-subjects factor", and age as a covariate. Due to the significance of Macaulay's statistic, the sphericity assumption was distorted, so the Greenhouse-Geiser statistic has been reported. The analysis showed that the interaction between the group × frequency × time × lobe is significant ($F_{6.2}$=2.30, P=0.037). Thus, there is a difference in frequency distribution between groups before and after the application of IFC. The mean absolute power of each frequency before and after the application of IFC is shown in Figure 2.

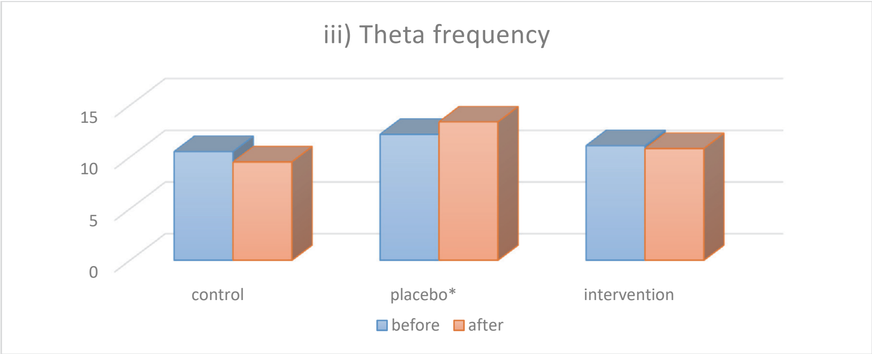
Then, to examine the frequencies in each lobe before and after the intervention, after the K-S test, the paired t test was used for the variables with a normal distribution and the Wilcoxon test for the variables without a normal distribution. The test results show that in the control group, the absolute power of the alpha frequency in the frontal, temporal, central, and parietal lobes increased significantly after the application of interference current: alpha frequency of the frontal lobe (before [mean rank: 0.00]; after [mean rank: 10.50]; P=0.00), alpha frequency of temporal lobe (before [mean rank: 6.75]; after [mean rank: 11.44]; P=0.00), alpha frequencies of parietal and central lobes (before [mean rank: 3.75]; after [mean rank: 12.19]; P=0.00). In the placebo group, the absolute power of alpha frequencies in the frontal lobe and theta frequency in the frontal and temporal lobes increased significantly after interferential current: alpha frequency of frontal lobe (before [mean:10.88]; after [11.72]; SD[0.97]; P=0.02), theta frequency of the temporal lobe (before [mean: 8.04]; after [9.27]; SD [0.91]; P=0.00), theta frequency of frontal lobe (before [mean rank: 2.00]; after [mean rank: 5.89]; P=0.00). In the intervention group, the absolute power of alpha frequency in the temporal, central, and parietal lobes and beta frequency in the temporal lobe had a significant increase after interferential current: beta frequency of temporal lobe (before [mean: 1.33]; after [mean: 1.64]; SD [0.30]; P=0.01), alpha frequency of temporal lobe (before [mean rank: 3.00]; after [mean rank: 5.78]; P=0.01), alpha frequencies of parietal and central lobes (before [mean rank: 1.50]; after [mean rank: 6.50]; P=0.01). Only in the intervention group, pain intensity showed a significant decrease: (before [Mean: 7.4]; after [Mean±SD: 6.20±1.54]; P=0.03).



*significant increase in the temporal lobe (P=0.01)



*In the control group: significant increase in the frontal (P=0.00), temporal (P=0.00), and parietal and central lobes (P=0.00).
*In the placebo group: significant increase in the frontal lobe (P=0.02).
*In the intervention group: significant increase in the temporal (P=0.01) and parietal and central lobes (P=0.01).



*Significantly increase in the temporal lobe (P=0.00) and frontal lobe (P=0.00).

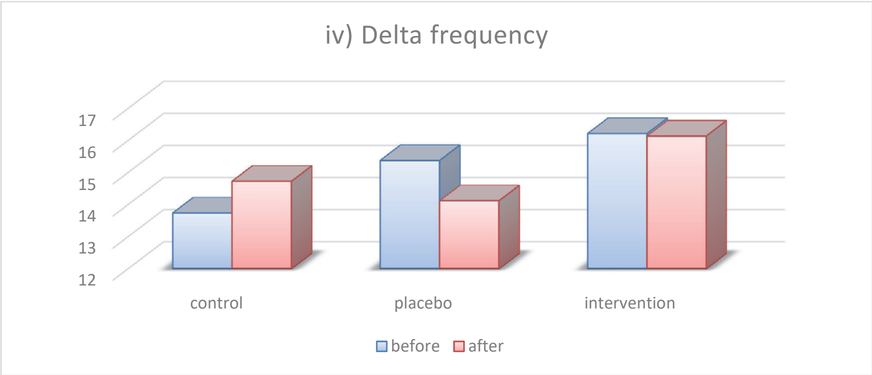


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Figure 2. Mean Absolute Power of i) Beta, ii) Alpha, iii) Theta, and iv) Delta frequencies before and after application of IFC

4. Discussion

This study was performed to compare the EEG changes in patients with chronic nonspecific LBP and investigate the effects of one session of interferential therapy on the EEG of patients and healthy individuals.

The first part of the results shows that chronic nonspecific LBP does not make a significant difference in the EEG of patients compared to healthy individuals, although the absolute power of waves at all frequencies in patients was higher than in healthy individuals, this difference did not reach a significant level. These findings are consistent with the results of previous studies, which show that in chronic pain, the power of brain waves increases at all frequencies, and the peak power shifts to lower frequencies [8]. However, these changes in chronic LBP reach a significant level when the pain intensity is very high and the pain is of neurological origin [18]. In this study, the average pain during the last three months, according to patients' reports was 6.3 on the VAS scale, and according to the inclusion criteria, pain is not of neurological origin.

The second part of the study compares the effects of one session of IFC on the EEG of healthy people and patients with chronic LBP. In this study, after interferential therapy, we saw a significant reduction in pain intensity only in the intervention group, which is consistent with the results of previous studies on the effect of IFC on reducing pain in patients with chronic LBP [5, 12, 13, 19]. However, it was in contrast to the results of Xiangjun Sun and Birgit Kettenmann's studies, in which brain wave activity decreased with decreasing pain [17, 20]. In this study, the alpha frequency power in the control group in the frontal, temporal, central, and parietal lobes and in the intervention group in the temporal, central, and parietal lobes, and in the placebo group only in frontal lobe shows a significant increase that can be due to sensory stimulus related to interferential current on the skin surface. EEG-alpha oscillations can be considered an indicator of the responsiveness of the central nervous system to sensory stimulation, in which the activity of this frequency also increases in proportion to the increase in current intensity [21]. In the intervention group, the beta frequency in the temporal lobe, and in the placebo group, the theta frequency in the frontal and temporal lobes also increased significantly after the application of interferential current, which shows that external stimuli to the skin can increase the activity of the brain in the beta range in excited and nervous states or tension [14].

5. Conclusion

In patients with chronic low back pain where the pain is not very severe and there is no nerve involvement, no changes are seen in the electroencephalogram. Furthermore, electrical stimulation can cause changes in the EEG with skin stimulation.

There are several limitations to this study. First, the state of brain development and age can affect the EEG signal, so future studies should examine EEG changes based on the age groups. Second, in this study, only one session of intervention was performed, which seems to be insufficient to investigate the relationship between pain relief and EEG changes. In future studies, more intervention sessions can be considered to examine this relationship.

Ethical Considerations

Compliance with ethical guidelines

This study was performed from July 2021 to February 2022 in the Physiotherapy Clinic of the Rehabilitation Faculty of Tabriz University of Medical Sciences and all experimental procedures were approved by the Local Ethics Committee (IR.TBZMED.REC.1399.1036). This trial was registered at the Iranian Registry of Clinical Trials (IRCT) (IRCT20210316050727N1). All participants were informed about the purpose of the study and the study design, and all of them provided written informed consent.

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Authors' contributions

All authors equally contributed to preparing this article.

Conflict of interest

The authors declared no conflict of interest.

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