



The effectiveness of brain wave synchronization in the theta band on depression and anxiety in opioid-dependent patients

Sahar Yari Oskouei¹, Nastaran Mansouriyeh^{2*}

¹Department of Clinical Psychology, Faculty of Medicine, Tabriz Medical Sciences, Islamic Azad University, Tabriz, Iran

²Neuroscience Research Centre, Tabriz Medical Science, Islamic Azad University, Tabriz, Iran

*Corresponding Author: Nastaran Mansouriyeh, Email: n.mansoreye1984@gmail.com

Abstract

Background: Addiction is one of the most common psychiatric disorders and is closely related to depression and anxiety disorders. The presence of these disorders makes the process of addiction treatment difficult. Binaural beats are the representation and perception of a stimulus that does not exist in the outside world but is the brain's mental perception error of a virtual third sound, that is, the slight frequency difference between the two sounds.

Methods: The present study was conducted to assess the effectiveness of brain synchronization using binaural beats in the theta band on depression and anxiety in opioid-dependent patients in Tabriz city. The method of conducting quasi-experimental research with two test and control groups is pretest-posttest. The statistical population was all opioid-dependent people referring to outpatient clinics in Tabriz city. The research sample included 30 opioid-dependent people who completed the informed consent form and Beck's depression and anxiety questionnaire. The subjects were randomly assigned to two experimental and control groups and received eight sessions of 7.5 Hz binaural beats, 20 minutes each, by headphones. The questionnaires above were administered again after the completion of the treatment sessions.

Findings: This study analyzed the obtained data by ANCOVA using SPSS20 software. The result showed binaural beat in Theta band (7.5 Hz) have a significant effect on depression and anxiety ($P=0.000$).

Conclusion: According to the results, the binaural beats in the theta band reduce anxiety and depression in opioid-dependent patients.

Keywords: Binaural beats, Depression, Anxiety, Opioids

Citation: Yari Oskouei S, Mansouriyeh N. The effectiveness of brain wave synchronization in the theta band on depression and anxiety in opioid-dependent patients. *Addict Health*. 2024;16(4):248–252. doi:10.34172/ahj.1529

Received: January 31, 2024, **Accepted:** July 10, 2024, **ePublished:** October 29, 2024

Introduction

Addiction is an emerging global challenge, reshaping societal structures across various domains.¹ According to a national survey, drug use is on the rise, particularly among adolescents and young adults, raising significant societal concerns. Data from the survey indicates that 8% of individuals reported having used drugs at least once in their lifetime.² According to the statistics from the Ministry of Health of Iran in 2011, the number of individuals with a permanent addiction was two million and two hundred thousand people.¹ As stated by world statistics, Iran has the highest consumption of opioids because it is located near Afghanistan,² which is the largest producer of opium in the world. Drugs have been in transit from Afghanistan and Pakistan through Iran for about a century.³ The first substance use disorder is a multidimensional disease that includes cognitive, behavioral, and psychological symptoms and involves a constant repetition of behaviors that lead to serious complications.¹ Addiction is a disease that affects almost the entire body, with the brain as the

primary organ involved. This phenomenon is associated with structural and functional damage to the brain. Volko proposes four brain systems for addiction: the reward system, motivation system, memory and learning system, and cognitive control system. The center of drug addiction is the reward system.⁴ Individuals with substance addiction often experience a resurgence of pleasurable memories associated with previous drug use when confronted with the drug or related cues (how enjoyable it was the last time they used the substance), activating the reward system, making the person anticipate a reward for consuming the substance. This motivation propels a person towards substances. Therefore, in people with addiction behaviors, there is an increase in the activity of reward, motivation, memory, and learning systems, while the activity of cognitive control decreases.⁴ The co-occurrence of mental disorders with substance use disorders is highly prevalent.⁵ About 90% of people who seek treatment for substance use disorders also suffer from psychiatric disorders, the most common being



depression and anxiety. Anxiety is an unpleasant emotion that manifests as worry, tension, and fear, originating internally.⁵ For individuals who attempt to quit, their most common complaint before and after detox is anxiety. Another disorder that individuals with addiction often experience is depression.⁵ Depression is characterized by symptoms such as low mood, sadness, unhappiness, hopelessness, tiredness, and loss of sleep quality.⁶ They commonly complain of feeling powerless, tired, and empty. This discomfort decreases the patient's quality of life, jeopardizing the individual's marital, social, and professional well-being. Additionally, suicidal thoughts are another issue commonly associated with depression. About 15% of individuals with opioid addiction attempt suicide at least once. Therefore, depression jeopardizes the mental health equilibrium of patients and increases the likelihood of treatment discontinuation and relapse.⁶ The current treatments in the field of drug abuse have not been very effective so far, often leading to relapse.⁷ To prevent the spread of drug abuse, we must consider more effective and comprehensive treatments. One of the newest treatment methods is brain synchronization, which involves synchronizing brain waves with the frequency presented to the person.^{7,8} The most widely used method for brain synchronization is auditory stimulation through binaural beats. Binaural beats do not exist externally but are a perceptual illusion created by the brain. Each ear is presented with slightly different frequencies, and the brain perceives the difference between these frequencies as a third sound that appears to originate within the brain itself, i.e., a binaural beat.^{8,9} Each of the brain waves is associated with a specific state of consciousness. The theta frequency band includes the range of 4–8 Hz. Theta waves are associated with creativity and improving problem-solving skills. The theta band modulates brain serotonin and melatonin levels, reduces cortisol levels, and promotes relaxation while reducing anxiety.⁸ The effect of brainwave synchronization has been investigated in previous research. Sung et al¹⁰ reported significantly reduced depression in older individuals within five days of using brainwave synchronization in the alpha band. In another study, Gantt et al¹¹ found that combining theta waves with music reduced soldiers' anxiety under stressful conditions by increasing parasympathetic responses. The effects of binaural beats on drug addicts have also been investigated. The results have shown that providing binaural beats to patients reduces anger, confusion, and tension.^{5,8} During the research involving music therapy combined with brain synchronization of the theta band, cravings, depression, and stress were evaluated in drug-dependent patients. Due to participant dropout, they did not achieve reliable results, but it can be said that the experimental group experienced a greater reduction in depression and stress compared to the control group. However, further research with larger samples is needed

to reach definitive results.⁹ Previous research has shown that long-term meditation and deep meditative states over an extended period led to the emergence of theta waves. This has been linked to a significant decrease in the desire to use drugs. Therefore, this study suggests that short-term exposure to theta waves can help prevent relapse by addressing key factors contributing to relapse among patients.⁹ Considering the issues above, individuals often experience significant neuropsychological discomfort during the withdrawal process. Consequently, individuals with a history of drug cessation may feel anxious at the mere thought of quitting again and may actively avoid re-experiencing withdrawal symptoms. Therefore, the current research aims to determine whether brain synchronization in the theta band is effective in addressing drug addiction, depression, anxiety, and physical pain in individuals with opioid addiction.

Methods

The current research is a quasi-experimental pretest-posttest study with a control group. The statistical population of the present study included all individuals with opioid addiction who were referred to outpatient substance use treatment clinics in Tabriz city in 2023. Thirty individuals were selected using purposive sampling and then randomly assigned to two groups: experiment and control. The exclusion criteria for the study were taking psychiatric drugs, a history of brain trauma, a history of epilepsy or currently suffering from it, and heart disease. The collected data were analyzed in SPSS software (version 20). After explaining the research to the participants and obtaining their written consent to implement the brainwave synchronization method, the subjects were evaluated in the pretest stage using Beck's Depression and Anxiety questionnaires. Subsequently, they were randomly assigned to either the experimental or control groups. Then, binaural beats were played for the experimental group through headphones for 20 minutes twice a week for eight sessions. In the posttest stage, both groups were evaluated again using the aforementioned questionnaires. The following ethical considerations have been addressed in the present research:

1. Written consent was obtained from the participants before the research began, so they voluntarily participated.
2. Subjects signed the ethical consent form.
3. Subjects could leave the study whenever they wanted without incurring any penalties.
4. At the subject's request, the results will be interpreted for them.
5. The principle of confidentiality of the subjects' secrets was respected, and no information was published without the subject's consent. This research was also governed by the code of ethics IR.IAU.TABRIZ.REC.1402.84, officially issued by the Ethics

Committee.

Beck Depression Questionnaire

The Beck Depression Questionnaire consists of 21 four-choice statements scored from 0 to 3. They are divided into three groups of seven items, including emotional, cognitive, motivational, vegetative, and physical symptoms. Scoring and reporting the severity of depression in this test is based on Beck's depression inventory, which categorizes the depression levels as follows: no depression (0–9), mild (10–18), moderate (19–29), and severe (30–63). The validity and reliability of Beck's questionnaire have been investigated in domestic studies. Cronbach's alpha coefficient was determined to be 0.96 in Dobson and Mohammadkhani's study.¹²

Beck Anxiety Inventory (BAI)

This questionnaire, designed by Beck et al, measures anxiety and consists of 21 statements. Each phrase reflects one of the symptoms of anxiety. These symptoms are typically experienced by two groups: clinically anxious individuals and those who are in an anxiety-provoking situation. To implement the questionnaire, an individual must read the list of symptoms and rate them quantitatively. The range of scores is from 0 to 63. High scores indicate more intense anxiety. Beck et al found the internal consistency of this scale to range between 0.73 and 0.92. They reported similar reliability for the short form.^{13,14}

Binaural beats

The sound stimulus in the theta band (7.5 Hz) was generated using specialized G-Neural software and delivered to the subjects through high-quality stereo headphones. The base frequency of 174 Hz was used to generate the 7.5 Hz band.⁸ The treatment protocol was standardized for all participants.

Results

In the current study, 30 individuals with opioid addiction participated. All participants in the current study were male. The average age of the subjects was 37.13 in the experimental group and 37.46 in the control group. The minimum age was 24 in the experimental group and 27 in the control group. The maximum age was 51 in the experimental group and 50 in the control group. All the subjects were evaluated in the pretest stage for cravings and physical pain using Beck's Depression and Anxiety questionnaires. Analysis of covariance (ANCOVA) was used for the statistical analysis. The presuppositions of the covariance analysis test for the variables of depression and anxiety in the opioid-dependent individuals were upheld. The Kolmogorov-Smirnov test indicated that the data had a normal distribution. In terms of depression, the results showed that the interaction effect of the pretest and the

group on the dependent variables was not significant with an F -value of 0.305 at a level of 0.750. Therefore, the non-significance of this interaction supports the hypothesis of homogeneity of regression slopes in these data.

In terms of anxiety, the results showed that the interaction effect of the pretest and the group on the dependent variables was not significant, with an F -value of 2.793 at a level of 0.119. Therefore, the non-significance of this interaction supports the hypothesis of homogeneity of regression slopes in these data.. Also, Levene's test was valid for the variables (depression $F=0.927$, P value = 0.008; anxiety $F=0.425$, P value = 0.520). Descriptive indices of depression and anxiety in the pretest and posttest in the studied groups are presented in Table 1.

Descriptive findings show a decrease in depression and anxiety scores in the experimental group's posttest stage. ANCOVA covariance analysis was used to check the significance of the scores, as shown in Table 2.

Discussion

The present study was conducted to investigate the effect of synchronizing brainwaves in the theta band using binaural beats on depression and anxiety in individuals with opioid addiction. The results of covariance analysis showed that binaural beats are effective in reducing depression and anxiety in individuals with opioid addiction. They reduced the average of the experimental group compared to the control. The current research is consistent with Asimakopoulos,⁹ Sung et al,¹⁰ Gantt et al,¹¹ McConnell et al,¹⁵ Garcia et al,¹⁶ Menziletoglu et al,¹⁷ Ölçücü et al,¹⁸ Silva et al,¹⁹ and Chackboondee²⁰ and inconsistent with the studies on Daengruan et al.²¹ The research by Sung et al¹⁰ demonstrated that binaural beats led to a reduction in depression among elderly

Table 1. Descriptive indices of depression and anxiety in the pretest and posttest in the studied groups

Variable	Group	Pretest		Posttest	
		Mean	Standard deviation	Mean	Standard deviation
Depression	Experiment	30.33	8.30	11.26	5.82
	Control	34.66	6.67	37.80	7.66
Anxiety	Experiment	27.47	8.43	10.00	5.31
	Control	29.00	8.77	32.00	7.93

Table 2. Results of inter-subject effects

Variable	Source of variable	Mean	df	F	P value	Eta squared
Depression	Group	3807.481	1			
	Error	21.501	27	177.083	0.000	0.818
	Total	24634.000	30			
Anxiety	Group	3092.369	1			
	Error	7.940	27	389.455	0.000	0.949
	Total	18138.000	30			

participants. Specifically, participants experienced a significant decrease in depression levels 30 minutes after listening to 10 Hz (alpha) beats. This reduction was still evident five days after the treatment, indicating a long-term effect. The difference between the current study and the abovementioned research lies in the frequency band. The main problem that exists in depressed patients is sleep because people with depression are not able to go into the deep stages of sleep and, therefore, complain of a lack of energy. Therefore, listening to theta waves allows them to go into deep sleep.⁸ Gantt et al¹¹ investigated the effect of theta band pulses on soldiers after deployment. The results showed that those who received theta band pulses exhibited sympathetic responses. When the subjects were exposed to an acute stressor, listening to binaural beats in the alpha band resulted in a reduction in sympathetic response and an increase in parasympathetic response. McConnell et al¹⁵ conducted a study on the effectiveness of the theta band on the autonomic system. The research involved 21 subjects who, after exercising to increase sympathetic function, listened to the theta frequency for 20 minutes in a room where their heart rate was monitored. The results showed that theta frequency led to an increase in parasympathetic activation and a decrease in sympathetic activity.

Garcia et al¹⁶ investigated the effectiveness of binaural beats on anxiety and pain perception. The results showed that the intervention reduced the subjects' anxiety and perception of pain. Menziletoglu et al¹⁷ utilized binaural beats in the alpha band to alleviate dental anxiety. The study revealed that binaural beats at 10 Hz led to a decrease in dental anxiety. No research contradicting these results was found.

Additionally, Ölçücü and colleagues' research¹⁸ demonstrated that the theta frequency band significantly reduced anxiety scores in male patients undergoing cystoscopy with local anesthesia. Da Silva et al¹⁹ conducted a study to investigate the effects of binaural beats at a frequency of 5 Hz over ten sessions, each lasting 20 minutes. The study revealed that the beats of the binaural beats in the theta band reduced anxiety and aided in alleviating other psychological issues, such as negative mood. Chockboondee et al²⁰ conducted a study on 60 individuals to compare the effects of two types of beats on relaxation over both short and long periods. The results showed that listening to 6 Hz for at least 4 minutes helps improve relaxation and increases the duration of the parasympathetic response.

On the other hand, the results of research conducted by Daengruan et al²¹ are not in line with those of the current study. In this research, there were two experimental and two control groups, each consisting of 18 randomly assigned participants. The subjects in the experimental group listened to the designated song thrice for 30 minutes using stereo headphones. In the first week, there was

no significant difference between the two groups, but a slight difference, although not statistically significant, was observed in the fourth and eighth weeks. Considering that the subjects themselves were responsible for conducting the experiment in their own homes, the results of the above research may be attributed to issues in the research process, the quality of the headphones, or the impact of binaural beats through neuroplasticity. Lastly, if binaural beat treatments are implemented less than twice a week, they will have little effect. Therefore, this treatment must be implemented more accurately.⁸ When interpreting the results, it is important to note that binaural beats originate from the inferior colliculus in the midbrain, then travel to the medial geniculate nucleus and thalamus, and ultimately reach the primary auditory cortex for processing. The cortical areas affected by theta band binaural beats include parietal, frontal, and temporal regions. Budzynski's²² studies show that when theta brain waves predominate, a person is in their most receptive state, and the brain is ready to be reprogrammed and imprinted. Theta brain waves also help improve problem-solving skills and facilitate quick retention of information. They strengthen cognitive control and reduce negative mood. Research shows that gamma band electroencephalogram or type 3 beta has excellent diagnostic capabilities for diagnosing depression.²³ In anxious patients, the beta wave shows a significant increase.²⁴ The Theta band is also associated with relaxation.⁸ Therefore, based on the research hypotheses confirmed in the study, it can be suggested that the beta rhythm likely increased when subjects were exposed to 7.5 Hz,⁸ a wave that falls between alpha and theta waves, inducing relaxation and reducing scores of depression and anxiety.

Study limitations

One of the limitations of the research is that it was conducted on opioid addicts who were referred to outpatient addiction treatment centers, which limits its generalizability to other segments of society. Additionally, due to time constraints, this research lacks follow-up procedures. Another limitation is the absence of access to electroencephalography (EEG), indicating that EEG should be utilized before, during, and after interventions in future studies.

Conclusion

The results of the present study showed that synchronizing brain waves in the theta band is effective in reducing anxiety and depression in individuals dependent on opioids. In order to generalize the results of this research, it is suggested that future studies be conducted in other centers, assess more variables, and include follow-up steps.

Acknowledgments

The authors would like to thank The Ofogh MMT Clinic and all the patients who assisted in conducting this study.

Authors' Contribution

Conceptualization: Sahar Yari Oskoueï, Nastaran Mansouriyeh.

Data curation: Sahar Yari Oskoueï.

Formal analysis: Sahar Yari Oskoueï.

Investigation: Sahar Yari Oskoueï.

Methodology: Sahar Yari Oskoueï, Nastaran Mansouriyeh.

Project administration: Nastaran Mansouriyeh.

Resources: Sahar Yari Oskoueï.

Software: Sahar Yari Oskoueï.

Validation: Sahar Yari Oskoueï.

Visualization: Sahar Yari Oskoueï.

Writing—original draft: Sahar Yari Oskoueï.

Writing—review & editing: Sahar Yari Oskoueï, Nastaran Mansouriyeh.

Competing Interests

The authors have no conflicts of interest.

Ethical Approval

This article is part of the master's thesis in clinical psychology at Azad University of Tabriz, registered with the Ethics Committee under the ethical code IR.IAU.TABRIZ.REC.1402.84; there is no conflict of interest, and no financial aid was received from any organization for this research.

Funding

None.

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