Original Research

The Effectiveness of Brainwave Entrainment by Binaural Beats on the Sleep Quality

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Abstract

Background and Objective: Binaural beats are important because these methods are non-invasive intervention methods on sleep. The aim of this study was to investigate the effectiveness of brainwave entrainment via binaural beats on the improvement of sleep disorders.
Materials and Methods: An experimental method with pre-test and post-test design was adopted to fulfill the purpose of the present study. The population of the study included all the people aged 20 to 40 years who referred to psychiatric clinics due to insomnia in Tehran, Iran, in 2019. Among this population, a sample size of 24 people was selected using convenience sampling and randomly divided into experimental and control groups (12 people in each group). The Pittsburgh Sleep Quality Index (PSQI) and the Insomnia Severity Index (ISI) were used to collect the required data. An aural synchronizer was also used as an intervention in the experimental group. Analysis of covariance (ANCOVA) was used to analyze the hypotheses.
Results: The mean age of the participants in the experimental and control groups was 29.5 and 33.0 years, respectively. The calculated effect size of this treatment was 0.46 for sleep quality and 0.43 for the insomnia. Further, the findings showed that synchronization through binaural beats had the greatest effect on the sleep latency component of PSQI.
Conclusion: Synchronization of brain waves by binaural beats had a significant effect on improving the total score of sleep quality and insomnia.

Keywords: Brainwave feedback; Delta sleep; Slow-wave sleep; Sleep quality; Sleep wake disorders; Insomnia

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Introduction

Sleep as one of the most vital requirements of the human brain plays an important role in brain development (1). More specifically, it is one of the most significant mental functions which plays a kind of soothing role coping with daily problems (2). Despite the fact that sleep is important in terms of maintaining physical and cognitive functions in daily life, the imposed psychological stress by modern life has overshadowed the quality of sleep and increased the sleep disorders (3). Sleep disorders are untidiness in the order, quantity, and quality of sleep that can lead to impairments and defects in a person's daily functioning (4). Sleep disorders may disrupt the normal order of physiological sleep for many reasons and cause complications such as fatigue, tiredness, irritability, decreased physical and mental abilities, decreased concentration, headaches, etc. Each of these deficiencies can have many negative effects on the process of healthy, active, and constructive life (5). Hence, the sleep problems require a variety of treatments.

One of the techniques to change the activity level of brainwaves during sleep is to synchronize

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them. Brainwave entrainment refers to all the techniques and methods that generate specific brainwave frequency in a person's brain by creating rhythmic sensory stimuli (6). The most important sensory stimuli used to synchronize the brainwaves are auditory and visual stimuli which are induced in the brain by providing a rhythmic light or sound stimulus with the desired excitation frequency (7). Therefore, one solution to this problem is to induce sleep using an auditory stimulus. When we listen to the simultaneous beats of two people in each ear, synchronization of the two phones occurs, which induces brain signals at a specific frequency (8). However, listening to this auditory stimulus to induce sleep is uncomfortable. To overcome this problem, one can use the sense of calm caused by the perceptual phenomenon of the automatic sensitive peak reaction.

For example, in the method of synchronizing binaural beats, which is one of the techniques of auditory synchronization of brain waves, an auditory illusion is caused by listening to two tons of slightly different frequency, one in each ear. The difference in frequencies creates the illusion of a third sound - a rhythmic beat (9). For this purpose, it is necessary to listen to these sounds in stereo and with headphones (10). The most important sensory stimuli used in this technique are visual and auditory stimuli of which auditory stimuli have a wider variety and application. More than half of the frequencies of brain waves are below the auditory threshold. Thus, this synchronization has to be applied, and one of the most effective ways to synchronize is to do it through the ears with headphones (11). In general, brainwave synchronization techniques are considered non-invasive interventions (12).

One of the neurological methods for studying sleep disorders is brainwave assessment during sleep. In addition to the parameters related to the rhythm of activity/inactivity, the motion-recording device with the ability to record brain activity has the ability to measure the different stages of sleep by using leads connected to the head (13). The sleep mechanism is managed and processed by the brain and has steps that can be recorded by electroencephalography (EEG) device. Brainwave analysis shows that sleep consists of four stages:

The three stages (N1-3) include non-rapid eye movement sleep (NREM), and the fourth is the rapid eye movement (REM) stage, in which sleep is accompanied by rapid eye movements and dreams (14). It is usually difficult to wake up a sleeping person during stage 3 of NREM. However, he/she may wake up to a personal stimulus, such as hearing a familiar name. But an impersonal disturbance such as a loud noise cannot wake him up (15).

Much research has been done on the relationship between brain waves, relaxation, and sleep states (16-18). Research has shown that the proposed auditory stimuli can generate the brain waves needed for sleep. While at the same time, it keeps the person in a calm psychological state. This technology provides a convenient and important opportunity to develop a new method to increase sleep quality (19). Research also shows that relaxed mental states with an enjoyable trance in which the person is not anxious often occur at the same time as interstitial sounds, which is one of the main treatment protocols in the treatment of sleep disorders (20). In this regard, Alipour et al. in a study investigated the effectiveness of synchronization of brain waves by binaural beats in reducing anxiety. Their findings showed that the synchronization of brain waves by this method led to a significant reduction in anxiety (21).

Given the issues raised and the harmful effects of insomnia, the correct measures to reduce or eliminate these complications will be a step towards improving people's sleep. In this regard, we tried to find out whether the methods of synchronizing brain waves by binaural beats affect the quality of sleep. So far, no research has been conducted in Iran on the effect of brainwave entrainment by binaural beats on the sleep quality. Therefore, the aim of this study was to investigate the effectiveness of brainwave entrainment by binaural beats on the sleep quality.

Materials and Methods

This study aimed to investigate the effect of 0.5-Hz binaural beat on 174-Hz carrier tone on sleep stages by delivering binaural beat stimulus to participants in experimental group in a three-week treatment (Figure 1). Quantitative EEG (QEEG) and biofeedback parameters were utilized to score sleep.

The population of the study included all the people who referred to psychiatric clinics due to insomnia in Tehran, Iran, in 2019. Among this population, a sample size of 24 people was selected using convenience sampling and randomly divided into experimental and control groups

(12 people in each group). Because random sampling is not possible in the experimental work, the available sampling method was used; and for this reason, the population of 20 to 40 years was selected for the study because our goal was to study young people. Among those referred to psychiatric clinics for sleep disorders, people with insomnia, people who scored 5 or higher in the Pittsburgh Sleep Quality Index (PSQI), and those who had poor sleep quality were screened and then randomly divided into experimental and control groups.

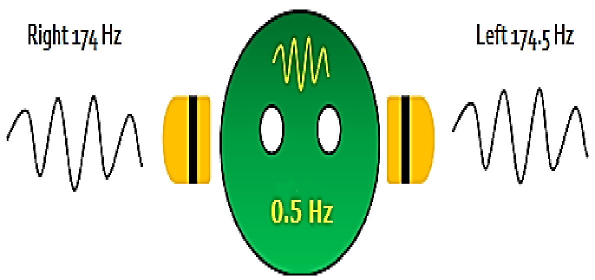

Figure 1. A 0.5-Hz binaural beat on a 174-Hz carrier tone generated in the brain

In a three-week treatment, the experimental group underwent binaural beats brainwave synchronization exercises tuned to the delta wave each night before going to bed, by two headphones. At the end of the sessions, the participants' sleep quality once again was assessed by a sleep quality and insomnia questionnaire and compared with the control group. The experimental procedures are shown in figure 2.

Written consent was obtained from all study participants and Ethical committee of Payame Noor University approved the study protocol.

Binaural beat stimulus: The stimulus used in this study was a 0.5-Hz binaural beat on a 174-Hz carrier tone, which was specifically generated for the experiment (Figure 1).

Participants: Twenty-four healthy participants with an average age of 31.25 years were included in this study (3 men and 21 women). The study population consisted of men and women aged 20 to 40 years who referred to psychiatric clinics in Tehran in 2019. The age distribution of the population ranged from a minimum of 23 years to a maximum of 37 years, of which 15% were men and 85% were women.

The participants were randomly divided into two groups, experimental and control groups. The purpose of this study and the experimental procedures were explained to all participants before participation, but participants were blinded to the details of the stimulus and group allocation. The experimental group was composed of 12 participants, while the control group was composed of 8 participants. However, four participants of the control group could not complete the protocol because of a personal issue unrelated to the control procedures, and therefore, they were excluded from the study.

In this study, the PSQI, developed by Buysse et al. at the Pittsburgh Psychiatric Institute, was used to assess sleep quality (22). Regarding the validity and reliability of the PSQI, Buysse et al. obtained the internal consistency of the questionnaire using Cronbach's alpha of about 0.83 (22). In the Iranian version of this questionnaire, the validity was 0.86 and the reliability was 0.89 (23). Moreover, in another study, the reliability of the questionnaire was 0.46 by Cronbach's alpha method and 0.52 by halving method (24).

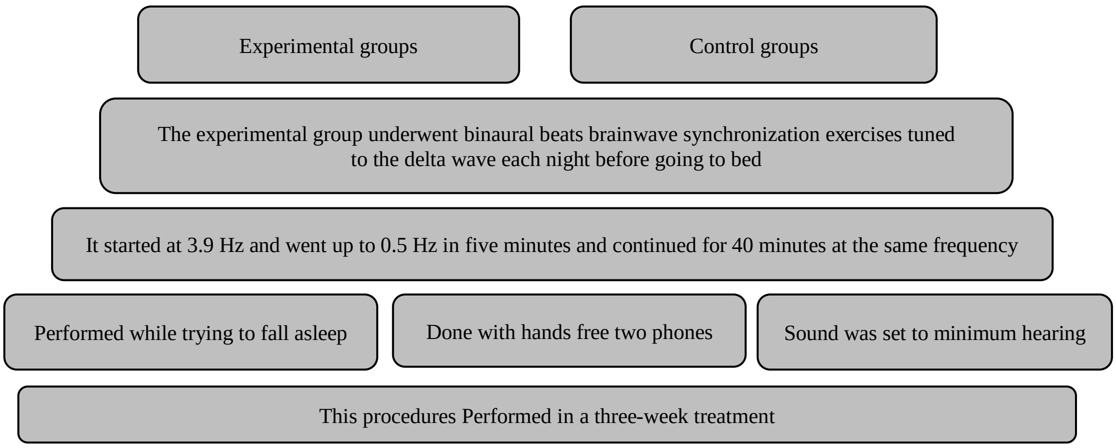

Figure 2. Experimental procedures: Performance procedures and duration

In addition to the PSQI, the present study used the Insomnia Severity Index (ISI) (25) to assess insomnia, which is a brief self-assessment tool that measures a patient's perception of insomnia. ISI includes seven items that include difficulty in starting sleep and problems with sleep continuity (waking up at night and suddenly waking). Higher scores indicate more insomnia. In Bastien et al. study (26) concerning the content validity, factor analysis led to three factors that were experimentally named sleep effect, sleep intensity, and sleep satisfaction. These findings provided empirical support for the content validity of the ISI and, in general, indicated that these components were the main diagnostic criteria for insomnia (26). Univariate and multivariate analysis of covariance (ANCOVA) using SPSS software (version 23, IBM Corporation, Armonk, NY, USA) was used to analyze the data.

Results

The demographic characteristics of the subjects are presented in table 1.

Table 1. Demographic characteristics of the study subjects

Parameters	Experimental group	Control group
Age (year)	29.50 ± 6.21	33.00 ± 5.68
Gender		
Men	2 (16.66)	1 (12.50)
Women	10 (83.34)	7 (87.50)
Education		
Doctoral degree	2 (16.0)	0 (0)
Master's degree	4 (33.0)	4 (50.0)
Bachelor's degree	5 (41.0)	1 (12.0)
Associate degree	1 (8.0)	1 (12.0)
Diploma	0 (0)	2 (25.0)

Data are presented as mean ± standard deviation (SD) or number (%)

Given the analyses, the demographic characteristics of the participants of the two groups had no significant difference. The mean age of the experimental and control groups was 29.5 and 33.0 years, respectively.

According to table 2, the average sleep quality pre-tests of the experimental and control groups were almost equal, but in the post-test phase, the average sleep quality disorders of the experimental group had a decrease from 10 to 7. Besides, the mean ISI of the experimental group decreased from 15.58 to 11.34. To compare these values statistically, ANCOVA was used.

Table 2 presents the mean and standard deviation (SD) of the scores of sleep quality and insomnia and biological factors in the experimental and control groups in the pre-test and post-test.

Before performing the ANCOVA, the assumptions of using this test were tested. First, the normal distribution of data was examined using Kolmogorov-Smirnov and Shapiro-Wilk tests. According to the results of both tests, the data of both variables of sleep quality and insomnia had a normal distribution in both groups. Another premise of the ANCOVA is the homogeneity of the variances of the groups. This means that the variance of the errors of the tested groups is the same. If the significance level is more than 0.05, the homogeneity of the variance of the groups can be confirmed. As the results of Levene's test in table 3 show, the significance level was more than 0.05; therefore, the assumption of homogeneity of variance in this study was established. Another premise of ANCOVA is the homogeneity of the regression line slope. This means that the interaction between the independent variable and the covariance variable (pre-test) should not be significant, or in other words, the significance level should be greater than 0.05 to confirm that the regression slope of the dependent variables is homogeneous at different levels of the independent variable.

In this study, according to the results of table 3, the significance level of all types of disorders was more than 0.05.

Table 2. Mean and standard deviation (SD) of research variables in experimental and control groups

Variables		Pre-test		Post-test	
		Mean ± SD	P-value	Mean ± SD	P-value
Sleep quality	Experimental	10.25 ± 3.22	0.11	7.01 ± 2.52	0.20
	Control	10.08 ± 3.57	0.11	9.33 ± 3.31	0.21
Insomnia	Experimental	15.58 ± 6.02	0.21	11.34 ± 5.22	0.20
	Control	12.25 ± 6.36	0.20	13.25 ± 6.78	0.22
Breath	Experimental	14.88 ± 0.95	0.20	12.44 ± 1.82	0.19
	Control	12.26 ± 1.31	0.09	13.14 ± 1.16	0.20
Skin temperature	Experimental	32.12 ± 2.69	0.26	34.88 ± 1.15	0.30
	Control	28.60 ± 5.66	0.10	32.42 ± 2.91	0.09
Skin conductivity	Experimental	0.91 ± 0.56	0.11	0.84 ± 0.52	0.20
	Control	1.89 ± 0.69	0.08	1.78 ± 0.99	0.22

SD: Standard deviation

Table 3. Results of homogeneity of regression slope and Levene's test results

Variables	Results of homogeneity of regression slope		Levene's test results	
	F	P-value	F	P-value
Subjective sleep quality	0.56	0.55	0.15	0.70
Sleep latency	1.25	0.12	0.16	0.71
Sleep duration	0.83	0.95	2.19	0.15
Sleep efficiency	0.95	0.87	1.32	0.26
Sleep disturbances	0.44	0.42	2.54	0.06
Use of sleep medications	0.19	0.93	1.62	0.09
Daytime dysfunction	0.27	0.80	0.01	0.91
Total sleep quality	0.18	0.98	0.27	0.60
Insomnia	23.62	0.43	0.55	0.56
Breath	7.48	0.15	2.85	0.08
Skin temperature	14.19	0.11	1.66	0.12
Skin conductivity	0.46	0.93	1.75	0.20

Therefore, the assumption of homogeneity of the regression line slope was established. To use the ANCOVA, its assumptions such as normality, linearity, homogeneity of regression slopes, and homogeneity of variances must be established. The results showed that these assumptions were valid.

As the results of the ANCOVA in table 4 shows, there was no significant difference in the variance of the variables between the two groups and the assumption of equality of variance was observed. Besides, the homogeneity of the regression slope of the research variables was observed in table 3. Based on this, it was possible to perform ANCOVA. ANCOVA is the most appropriate statistical test for pre-test and post-test design of two groups, and whenever we want to eliminate the effect of intervening variables in statistical methods in order to obtain more accurate results, ANCOVA is used (in this method, both statistical control and variance are used). Therefore, in this study, ANCOVA was used to control the effects of pre-test. In addition, multivariate ANCOVA (MANCOVA) was performed on the research variables to compare the results of the two stages of pre-test and post-test.

To test the hypothesis of the effectiveness of binaural beats on sleep quality disorders, ANCOVA was used and the summary of results are reported in table 4.

The results indicated that binaural beats significantly affected the variety of sleep quality components as subjective sleep quality with an effect factor of 0.36% and a difference ratio of F = 9.72 at the level of 0.005. Moreover, sleep latency with an effect factor of 0.56% and a difference ratio of F = 23.92 at the level of 0.001, sleep duration with an effect factor of 0.33% and a ratio of F = 10.78 at the level of 0.004, sleep disturbances with an effect factor of 0.21% and ratio of F = 4.22 at the level of 0.02, use of sleep medications with a coefficient effect of 0.69% and a ratio of F = 46.98 at the level of 0.0001, daily dysfunction with a coefficient effect of 0.32% and a ratio of F = 10.08 at the level of 0.005, and finally, the total score of sleep quality with a coefficient effect of 0.46% and a ratio of F = 17.91 at the level of 0.0001 were significant, while binaural beats did not have a significant effect only on the component of sleep efficiency (P = 0.070, F = 3.53). Therefore, based on the significance of the majority of components, due to the smaller significance level of 0.05, it can be concluded that there was a significant difference between the post-test scores of the experimental and control groups in various sleep quality components, which was rejected with 95% confidence.

Further, ANCOVA was used to test the hypothesis of the effectiveness of binaural beats on insomnia, the results of which are reported in table 5.

Table 4. Results of analysis of covariance (ANCOVA) to investigate the effect of binaural beats on sleep quality

Variables	Sum of squares	df	Mean square	F	P-value	Eta squared
Subjective sleep quality	4.29	1	4.29	9.72	0.005	0.36
Sleep latency	8.52	1	8.52	23.92	< 0.001	0.56
Sleep duration	6.72	1	6.72	10.78	0.004	0.33
Sleep efficiency	1.03	1	1.03	3.53	0.070	0.14
Sleep disturbances	3.82	1	3.82	4.22	0.020	0.21
Use of sleep medications	6.85	1	6.85	46.97	< 0.001	0.69
Daytime dysfunction	5.73	1	5.73	10.08	0.005	0.32
Total sleep quality score	87.79	1	87.79	17.91	< 0.001	0.46

Df: Degree of freedom

Table 5. Results of analysis of covariance (ANCOVA) to investigate the effect of binaural beats on insomnia

Variables	Sum of squares	df	Mean square	F	P-value	Eta squared
Insomnia	351.91	1	353.91	16.40	0.001	0.43
Error	453.01	21	21.57	-	-	-

Df: Degree of freedom

As can be seen in table 5, the results of ANCOVA showed that after controlling the effect of pre-test, binaural beats on insomnia had a significant effect at the level of 0.001, with a difference ratio of F = 16.40, and the effect size was 0.43. Therefore, due to the fact that the significance level was less than 0.05, it can be concluded that there was a significant difference between the experimental and control groups in the insomnia variable, which was rejected with 95% confidence of the null hypothesis and the second hypothesis of the research was confirmed.

To test the hypothesis of the effectiveness of binaural beats on biological factors, ANCOVA was used and the summary of results is reported in table 6.

The results indicated that binaural beats significantly affected the variety of biological factors such as breath with an effect factor of 0.44% and a difference ratio of F = 17.02 at the level of 0.001. Also, skin temperature with an effect factor of 0.20% with a difference ratio of F = 5.21 at the level of 0.02, skin temperature with an effect factor of 0.29% and a ratio of F = 7.85 at the level of 0.01. Therefore, based on the significance of the majority of components, due to the smaller significance level of 0.05, it can be concluded that there was a significant difference between the post-test scores of the experimental and control groups in various biological factors, which was rejected with 95% confidence.

Discussion

As reported in table 4, the results of ANCOVA in order to evaluate the effectiveness of binaural beats on sleep quality showed a significant effect of this treatment on improving sleep quality in the experimental group after removing the pre-test effect. Based on this, the effectiveness of this intervention on sleep quality was shown and it can be said that synchronization of binaural beats has a significant effect on reducing the score of sleep quality components, which include subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disorders, sleep medications, and daily dysfunction. Comparing the results of the present study with the findings of others, it can be said that this finding is somewhat consistent with the results of previous studies such as Lee et al. (12), Jirakittayakorn and Wongsawat (27), and Valizadeh et al. (28). For example, Lee et al. in a study entitled “Possible effects of combining aural synchronization with automatic sensory response stimuli to induce sleep” concluded that a combination of a 30:60 dB ratio of aural synchronization stimulated a balanced response to induce theta sleep and better mental stability (12). The results of their study showed that hybrid stimuli retained the benefits of using synchronization of binaural beats and solved the problem of short-term outcomes of using balanced response stimuli that include short-term psychological self-reports. Their findings showed that the proposed auditory stimuli could generate the brain waves needed for sleep, while at the same time, it keeps the person in a calm psychological state. This technology provides an important opportunity to develop a new way to improve sleep quality. Moreover, Valizadeh et al. in a study entitled “comparing the effects of reflexology and footbath on sleep quality in the elderly: a controlled clinical trial” investigated the effect of biofeedback on improving the quality of sleep in the elderly using the PSQI. They showed that there was a statistically significant difference in all components of the PSQI in the post-intervention stage by reflexology. They concluded that reflexology could be used as an easy and safe intervention to improve the quality of sleep in the elderly, especially problems with the onset of sleep and the duration of sleep (28).

Table 6. Results of analysis of covariance (ANCOVA) to investigate the effect of binaural beats on biological factors

Variables	Sum of squares	df	Mean square	F	P-value	Eta squared
Breath	23.12	1	23.12	17.02	< 0.01	0.44
Skin temperature	9.09	1	9.09	5.21	0.02	0.20
Skin conductivity	8.76	1	8.76	7.85	0.01	0.29

Df: Degree of freedom

Explaining the effect of binaural beats on sleep quality, it can be argued that when simultaneously focusing on two-tone beats in each ear, two ears are synchronized to induce brain signals at a specific frequency.

On the other hand, the findings of the present study are inconsistent with the results of previous studies such as Bang et al. (16), which found that synchronization of binaural beats and music did not significantly improve sleep disorders more than music alone, but could alter brain activity toward increasing daily alertness in subclinical insomnia, which should be tested in a clinical population.

In explaining the inconsistency of the findings of the present study with the results of the above study, it can be argued that semi-clinical disorders in their research community may not have determined the effectiveness of binaural beats. Because when a person has neither a disorder nor a weak disorder, the obtained results through this technique might not be reliable enough. In most of the studies, the researchers have suggested that this technique should be tested in a clinical population. Further, in explaining the difference between the results, it can be said that their research has combined synchronization of binaural beats and music. There may be an interaction between two types of synchronization techniques between two phones and simple music, which reduces the effectiveness of the intervention on sleep quality in the Bang et al.'s study. Because they have suggested that it is uncomfortable to listen to induction of sleep because of this auditory stimulus. To overcome this problem, we can use the feeling of calm and relaxation caused by the perceptual phenomenon of the automatic sensitive peak reaction.

The hypothesis of the effectiveness of binaural beats on insomnia was also confirmed. Besides, according to the results reported in table 5, it was found that the results of ANCOVA showed that after removing the pre-test effect, binaural beats had a significant effect on insomnia. Therefore, based on this result, it can be said that the second hypothesis of the research was also confirmed.

This finding is consistent with the results of Bang et al. (16) who showed that the severity of insomnia in both groups receiving synchronization of binaural beats and music reduced. In addition, the EEG wave analysis of this effect to reduce sleep and wake problems for the recipient group was much stronger than the effect for the recipient group of music alone. They concluded that binaural beats synchronization significantly improved sleep disorders, and could alter brain activity toward increased daily alertness in subclinical insomnia, which should be tested in a clinical population. Moreover, the findings of the present study are in line with the results of Kropotov (29) who concluded that people with sleep disorders entered the sleep mode within 10 to 15 minutes.

Explaining the effectiveness of synchronization of binaural beats on insomnia, it can be said that since in this method, two sound signals are given to the left and right ears in two different frequencies, this technique leads to a binaural signal of two ears in the delta wave. When these two beats are applied simultaneously, they automatically suppress the frequency of the alpha waves, increasing the spectrum of the delta waves in the brain and thus causing sleep. Jirakittayakorn and Wongsawat also concluded that biofeedback could be used as an easy and safe intervention to improve the quality of sleep in the elderly, especially problems with the onset of sleep and duration of sleep (27). Other practical suggestions that can be mentioned based on the results obtained in this study could be brainwave entrainment method that can be suggested as one of the effective non-pharmacologic treatments for people with insomnia in the community. It is suggested that the officials in the training centers introduce inexperienced and novice counselors and psychologists to the principles of this method, so that they can use it more effectively.

Limitations: Some limitations can be mentioned in this research. Due to the limited time of the research, the researcher could not use repeated measurements (follow-up tests) to measure the effects of brainwave entrainment. Because the sample size was small due to the structure of the experimental design used, the results of this study cannot be generalized to the statistical community. Moreover, the data collection of this study was questionnaire-based and individuals self-reported their information, which may be related to the phenomenon of bias in the research.

Among the research recommendations that could be suggested to other researchers, the following can be mentioned. The present research is quantitative and experimental and its weakness is that it cannot deal with the problem in depth. It is suggested that in future research, a qualitative method should be used to reflect on research; moreover, it is recommended that this educational method be applied to other dependent variables related to marital life. Further, this study should be repeated with long-term follow-up to determine the long-term effects of the intervention and the stability of the results. It is suggested that the sampling be done with a larger volume and the age group factor (separately) be taken into account to achieve more complete results by studying all age groups.

Conclusion

According to the findings of this study, it can be concluded that synchronization of brain waves by binaural beats has a significant effect on improving the total score of sleep quality and also improving insomnia. It can be used as a non-invasive intervention method to control and reduce anxiety in clinics and medical centers by psychologists, counselors, and psychiatrists.

Conflict of Interests

Authors have no conflict of interests.

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References

1. Bah TM, Goodman J, Iliff JJ. Sleep as a therapeutic target in the aging brain. Neurotherapeutics 2019; 16: 554-68.
2. Jenni OG. Typical sleep development. In: Hupp S, Jewell J, editors. The Encyclopedia of Child and Adolescent Development. Hoboken, NJ: Willey; 2020. p. 1-16.
3. Berthier ML, De-Torres I, Paredes-Pacheco J, et al. Cholinergic potentiation and audiovisual repetition-imitation therapy improve speech production and communication deficits in a person with crossed aphasia by inducing structural plasticity in white matter tracts. Front Hum Neurosci 2017; 11: 304.
4. Miller CB, Bartlett DJ, Mullins AE, et al. Clusters of insomnia disorder: An exploratory cluster analysis of objective sleep parameters reveals differences in neurocognitive functioning, quantitative EEG, and heart rate variability. Sleep 2016; 39: 1993-2004.
5. Wang P, Song L, Wang K, et al. Prevalence and associated factors of poor sleep quality among Chinese older adults living in a rural area: A population-based study. Aging Clin Exp Res 2020; 32: 125-31.
6. Tang HY, Riegel B, McCurry SM, et al. Open-loop Audio-Visual Stimulation (AVS): A useful tool for management of insomnia? Appl Psychophysiol Biofeedback 2016; 41: 39-46.
7. de Zambotti M, Bianchin M, Magazzini L, et al. The efficacy of EEG neurofeedback aimed at enhancing sensory-motor rhythm theta ratio in healthy subjects. Exp Brain Res 2012; 221: 69-74.
8. Ming-Hui MA, Hai-Yun GAI, Ya-E NIE, et al. Five-tone therapy plus head and face massage relieves insomnia of patients with heart and spleen deficiency. J Integr Nurs 2019; 1: 151-6.
9. Siever D. Applying audio-visual entrainment technology for attention and learning (Part 3). Biofeedback Mag 2008; 31: 1-15.
10. Siever D. Entraining tones and binaural beats. Mind Alive [Online]. [cited 2022]; Available from: URL: https://mindalive.com/pages/entraining-tones-and-binaural-beats
11. Park H, Ince RAA, Schyns PG, et al. Representational interactions during audiovisual speech entrainment: Redundancy in left posterior superior temporal gyrus and synergy in left motor cortex. PLoS Biol 2018; 16: e2006558.
12. Lee M, Song CB, Shin GH, et al. Possible effect of binaural beat combined with autonomous sensory meridian response for inducing sleep. Front Hum Neurosci 2019; 13: 425.
13. Iranzo A. Sleep and neurological autoimmune diseases. Neuropsychopharmacology 2020; 45: 129-40.
14. Krainin J, Morrison AA, Russo MB. Sleep/wake disturbances in mild traumatic brain injury patients. In: Tsao JW, editor. Traumatic brain injury: A clinician's guide to diagnosis, management, and rehabilitation. Cham, Switzerland: Springer International Publishing; 2020. p. 129-50.
15. Atkinson RL, Atkinson RC, Smith EE, et al. Hilgard's introduction to psychology. Trans. Baraheni MT, Birashk B, Beik M. Tehran, Iran: Roshd Publications; 2014.
16. Bang YR, Choi HY, Yoon IY. Minimal effects of binaural auditory beats for subclinical insomnia: A randomized double-blind controlled study. J Clin Psychopharmacol 2019; 39: 499-503.
17. Fang Z, Ray LB, Owen AM, et al. Brain activation time-locked to sleep spindles associated with human cognitive abilities. Front Neurosci 2019; 13: 46.
18. Easwaran K. Karuppathal E,Kalpana R, Srinivasan AV. Brainwave entrainment using visual auditory stimulationas therapy for sleep disorders. Research Reports 2018; 2: e1-e7.
19. Zieleniewska M, Duszyk A, Rozanski P, et al. Parametric description of EEG profiles for assessment of sleep architecture in disorders of consciousness. Int J Neural Syst 2019; 29: 1850049.
20. Gruzelier J. A theory of alpha/theta neurofeedback, creative performance enhancement, long distance functional connectivity and psychological integration.

Cogn Process 2009; 10 (Suppl 1): S101-S109.
21.Alipour A, Orki M, Yazdian Sabet M. The effectiveness of synchronization of brain waves by binaural beats on reducing anxiety. Kermanshah Univ Med Sci 2014; 18: 26-19. [In Persian].
22.Buysse DJ, Reynolds CF, Monk TH, et al. The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. Psychiatry Res 1989; 28: 193-213.
23.Morin CM, Belleville G, Belanger L, et al. The Insomnia Severity Index: Psychometric indicators to detect insomnia cases and evaluate treatment response. Sleep 2011; 34: 601-8.
24.Heidari AR, Ehteshamzadeh P, Marashi M. The relationship between insomnia intensity, sleep quality, sleepiness and mental health disorder with educational performance in female adolescences of Ahwaz City. Woman and Culture 2010; 1: 65-76. [In Persian].
25.Morin CM. Insomnia: Psychological assessment and management. New York, NY: Guilford Publications; 1993.
26.Bastien CH, Vallieres A, Morin CM. Validation of the Insomnia Severity Index as an outcome measure for insomnia research. Sleep Med 2001; 2: 297-307.
27.Jirakittayakorn N, Wongsawat Y. A novel insight of effects of a 3-Hz binaural beat on sleep stages during sleep. Front Hum Neurosci 2018; 12: 387.
28.Valizadeh L, Seyyedrasooli A, Zamanazadeh V, et al. Comparing the Effects of Reflexology and Footbath on Sleep Quality in the Elderly: A Controlled Clinical Trial. Iran Red Crescent Med J. 2015; 17:e20111.
29.Kropotov J. Quantitative EEG, Event-related potentials and neurotherapy. Amsterdam, Netherlands: Elsevier Science; 2010.