Original Research

Effects of Combined Binaural Beats on Sleep Quality, Insomnia Severity, and Sleep Hygiene Improvement in Insomniac Students

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Abstract

Background and Objective: In previous studies, multiple interventions to improve sleep quality were suggested in students with insomnia based on different results. The present study aimed to investigate the effects of combined binaural beat treatment on improving sleep quality in students with insomnia.

Materials and Methods: This was a randomized clinical trial, which included all students living in Neyshabur, Khorasan Razavi Province, Iran, in 2020. In terms of inclusion criteria, 34 students (12 women) were assigned randomly into two control (n = 17) and experimental groups (n = 17). A combined binaural beat treatment (α, θ, and δ) and sleep hygiene guidelines were given to the experimental group, but the control group only received the same sleep hygiene guidelines. Insomnia Severity Index, Sleep Hygiene Index, and Pittsburgh Sleep Quality Index were research instruments for this purpose. The results were analyzed with SPSS software.

Results: The effect of the combined binaural beats on ISI ($F = 31.16$, $P < 0.001$), sleep hygiene ($F = 39.15$, $P < 0.001$), and sleep quality ($F = 14.15$, $P < 0.001$) of students with insomnia was apparent during multivariate analysis of covariance (MANCOVA). The highest and lowest effects on the total value of sleep (effect size = 0.58) and the SHI (effect size = 0.35) were achieved by combined binaural beat treatment.

Conclusion: The combined binaural beats (α, θ, and δ) improve total sleep quality, sleep hygiene, and ISI of students with insomnia. Besides, such a treatment can be utilized as a modern non-invasive intervention.

Keywords: Insomnia; Sleep; Sleep hygiene; Students

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Introduction

University students have psychological distress, which can raise many problems such as interpersonal relationship problems (1), academic failure (2), the orientation toward drug abuse (3), and loss of routine performance (4). One of their most important issues is insomnia (5), a complaint of insufficient sleep that has been identified by some initial problems in sleep maintenance and a wake-up period of at least three months (6). According to Taylor et al., 9.5% of university students are diagnosed with insomnia (7). A meta-analytical study has revealed that around 56 percent of Iranian students sleep less (8). This emphasizes the need for further research and proper interventions among university students for less sleep and insomnia.

Several interventions were proposed to improve students' sleep quality, most frequently pharmacotherapy (9) and psychological therapy (10). However, sometimes the operations are longitudinal and costly and cause different effects (11). Latest reports tend to indicate low-cost, short-term treatments with fewer side effects. One of the modern interventions is the non-invasive impact of binaural beats on brain waves (12). Binaural beats are sound wave types that can induce wave patterns by their rate (13). The waves are made to become an illusion if two tones reach

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each ear with small frequencies (13). If a ton of 210 Hz reaches the right ear, for example, and a tone of 216 Hz reaches the left ear, a binaural beat of 6 Hz is created (in theta range). Frequency is of concern, as many studies have shown that each frequency area has specific psychological properties (14). Therefore, the alpha (8-12 Hz), beta (rapid brain waves, above 12 Hz), delta (< 4 Hz), and theta (4-8 Hz) waves were related to meditation and relaxation, to thinking, focusing, and processing information, to information thought, focus, and processing, and to deep sleeping and deep meditation and fantasy, respectively (15).

The brain wave pattern plays a vital role in the erosion of consciousness mode (16); therefore, the frequency of dominant brain waves varies depending on the type of activity, such as studying, working, and sleeping. Several studies investigated the effects (in various frequencies) of binaural beats on people with clinical disorders or healthy people. The combination of theta binaural beats and Autonomous Sensory Meridian Response (ASMR) was considered in a study, which showed that it could affect non-rapid eye movement (NREM) sleep phase 1 in healthy individuals (17). This study shows that binaural beats can be a modern method to improve sleep quality (17). The effects of binaural beats on the quality of mental sleep and the improvement in physical and mental health (combined 2-9 Hz binaural beat for eight weeks) were examined by Abeln et al. The results indicated that in the binaural intervention group, mental quality and mode of incentive sleep significantly increased (18). Bavafa et al. carried out a study to analyze the effect of theta binaural beats on the pattern of brain waves of people with stage 1 insomnia. The study showed that theta binaural beats could change brain wave patterns in clinical population through training. They also suggested more research to explore the impact of binaural beats on people with insomnia (19).

When the brain wave frequency decreases slowly before sleep (20), combined binaural beats appear to help change people's brain waves who have insomnia. A literature review revealed that there was limited research on this subject. Therefore, the purpose of the present study was to assess the efficacy of combined binaural beats to improve sleep quality and insomnia in students.

Materials and Methods

Participants: The trial was a randomized clinical trial. The students with insomnia studying at the Islamic Azad University of Neyshabur, Neyshabur, Iran, were studied in 2020 as the statistical population. Thirty-four students with insomnia (12 women) studying at the Islamic Azad University of Neyshabur were included, taking into account the inclusion and exclusion criteria. The inclusion criteria were informed consent, the severity of clinical insomnia [Insomnia Severity Index (ISI) > 15], the diagnosis of insomnia in a clinical interview by a psychiatrist, lack of severe psychiatric and neurologic comorbid disorders which necessitate taking psychiatric medicines, absence of alcohol and drug abuse, normal hearing, absence of cardiovascular diseases (CVDs), absence of pregnancy in female participants, and not residing in dormitories. The exclusion criteria were not proceeding with the testing technique, exciting any discomfort when the binaural beats were detected, taking additive materials during the research stage, and not enforcing the intervention protocol more than two consecutive days a month (overall intervention period). Participants were randomly assigned into control (n = 17) and experimental (n = 17) groups by picking up the packages with CG (control group) and EG (experimental group) letters (Figure 1).

Intervention protocol: The pretest was distributed following the decision of the community of participants. Experimental students were asked to listen to the blended binaural beats (α, θ, and δ) before falling asleep at 22:00 for 30 days for 30 minutes and follow sleep hygiene guidelines (Table 1). The participants were recalled by text messaging every night at 21:30 for bedtime. A mixture of α, θ, and δ waves is available on YouTube (https://www.youtube.com/watch?v = HePF0xlKzE&t = 100s). Only 30 minutes of this track was used in this research.

Table 1. Sleep hygiene rules [Soleimani et al. (21)]

Sleep hygiene rules
Wake up every day at a specified time (even at the weekend)
Do not take a nap in the daytime
Do not take alcohol, caffeine, or nicotine, particularly in the last hours of the day
Do not have heavy meals
Provide appropriate environmental conditions (light, sound, normal bed, etc.)
Do physical activities, e.g., daytime exercises or walking, on a regular basis
Take a warm shower before sleeping
Avoid any activity in the bed (e.g., watching TV), except for sleeping or sex

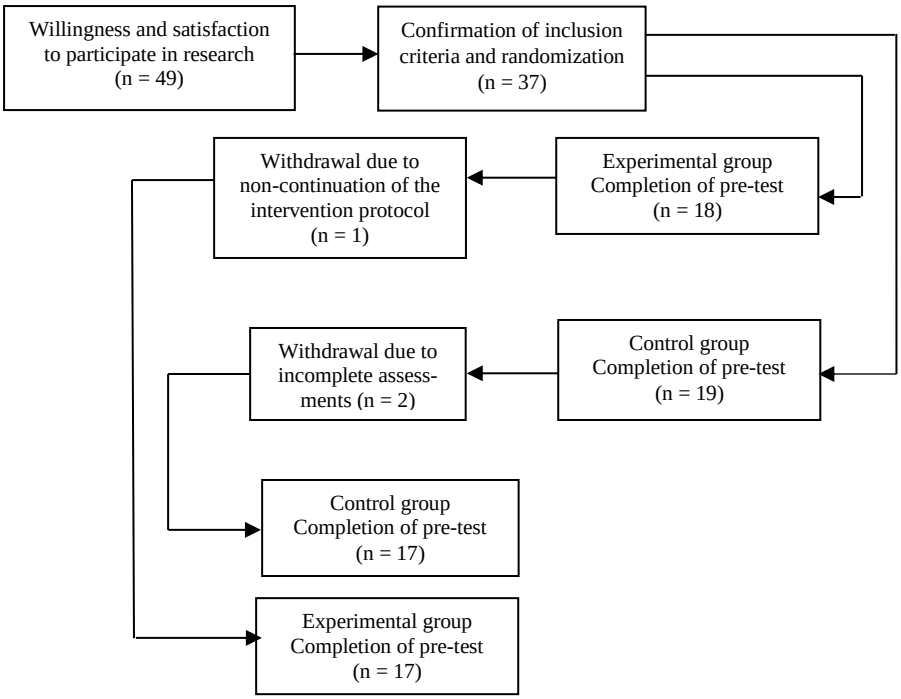

Figure 1. The diagram of participants in the pretest and posttest steps

The control group did not undergo a binaural beat, but the other words were the same for all groups. Therefore, a combined binaural beat treatment (α, θ, and δ) and sleep hygiene guidelines were given to the experimental group, but the control group only received the same sleep hygiene guidelines.

Research instruments

ISI: In the last couple of weeks, the index tested insomnia magnitude. The index comprises five elements with minimum and maximum values of 0 and 28 (22). The cumulative outcome is the following: lack of insomnia (0-7), sub-threshold insomnia (8-14), mild insomnia (15-21), and severe insomnia (22-28).The construction validity for the accurate, extreme, and satisfying indices of this index was seen to be 0.72 in one analysis. The reliability of the indices was from 0.74 to 0.78 in other experiments, taking account of Cronbach's alpha coefficient (22, 23).

Pittsburgh Sleep Quality Index (PSQI): The index distinguished between high sleep quality and low sleep quality over the last month (24). PSQI comprises 19 elements and seven components. Each object is rated by a Likert scale varying between 0 and 3, and the total of the seven components is proportional to the overall score (0-21). On this scale, scores ≥ 6 represent poor sleep quality (25). Using Cronbach's alpha coefficient, the validity of the PSQI was reported to be 0.80, and its test-retest reliability ranged between 0.93 and 0.98 (26). The PSQI has revealed high validity and reliability in different studies (26, 27).

Sleep Hygiene Index (SHI): This index is developed by Mastin et al. (28) to assess sleep hygiene behaviors. The SHI contains 13 items (scored based on a five-point Likert scale) which measure the frequency (ranging from never to always) of exhibiting behaviors related to biological rhythms and bedroom environment (29). The total scores vary from 0 to 52, with higher scores indicating inappropriate sleep hygiene. Using Cronbach's alpha coefficient, the internal consistency of this scale was reported to be 0.66, and its test-retest reliability was reported to be 0.71 (28). The Persian version of the index revealed high reliability and validity (29).

Statistical analysis: SPSS software (version 24, IBM Corporation, Armonk, NY, USA) was used for independent studies to compare (in years) the subjects' age and education level and the proportion of women in trials and classes of controls. Besides, multivariate analysis of covariance (MANCOVA) and some measures connected to their theory were used to assess the intervention's scale and importance. MANCOVA is one of the inferential statistics tests, that examines the effect of the intervention at the same time by controlling the covariates (30).

Table 2. Comparing the demographic information and pre-test target variables of experimental and control group

Characteristics	Experimental group	Control group	P-value
Age (year)	24.15 ± 3.11	24.07 ± 3.22	0.11
Gender			
Men	25.07 ± 3.15	24.97 ± 3.24	0.09
Women	23.26 ± 3.16	23.19 ± 3.32	0.11
Female gender	6 (35.29)	6 (35.29)	> 0.99
Education (year)	15.24 ± 2.11	14.89 ± 2.02	0.07
Marital status			
Single	12 (70.58)	11 (64.70)	0.19
Married	5 (29.42)	6 (35.30)	0.13
ISI (pre-test)	19.31 ± 2.15	18.72 ± 2.55	0.08
PSQI (pre-test)	8.83 ± 1.31	8.02 ± 1.44	0.10
SHI (pre-test)	38.11 ± 7.15	34.15 ± 8.77	0.06

Data are reported as mean ± standard deviation (SD) or number and percentage
ISI: Insomnia Severity Index; PSQI: Pittsburgh Sleep Quality Index; SHI: Sleep Hygiene Index

Ethical considerations: Informed consent forms were filled out, and details about the essence and safety of binaural beat music were obtained. The confidentiality of study details was promised to participants. The Ethics Committee of the Islamic Azad University, Neyshabur Branch, has confirmed this report (IR.IAU.NEYSHABUR.REC.1399.028).

Results

The demographic information of the participants is depicted in table 2; according to this table, there was no significant difference between the two experimental and control groups in terms of age, gender, level of education, and marital status. The mean values of the participants' age and level of education were 24.55 ± 2.99 and 14.92 ± 2.30 years, respectively. The table also shows that there was no significant difference between the control and experimental groups based on the variables of ISI, sleep quality, and sleep hygiene in the pre-test stage.

Table 3 shows the mean value and standard deviation (SD) of the total scores of ISI, sleep quality, and sleep hygiene, indicating that the mean value of the target variables is decreased in both groups. MANCOVA was used to determine the effectiveness of the combined binaural beat intervention.

To run this statistical test, several assumptions should be met. The first assumption is the normality of the research data, which was tested and confirmed by the Kolmogorov-Smirnov test ($P < 0.05$). The second assumption is the homogeneity of variances, for which Levene's test revealed no significant difference in variance for the target variables ($P < 0.05$). Hence, the assumption was met. The third one is associated with the analysis of homogeneity of regression slope of variables, indicating no significant correlation between dependent and independent variables. The third assumption was also met in the present study ($P < 0.05$). Table 4 shows the results of the MANCOVA.

In table 4, the effect of the combined binaural beat on the ISI, sleep quality, and sleep hygiene of students with insomnia by controlling the covariates is significant. The combined binaural beats therapy had the greatest and the least profound effects on the total value of sleep quality (the effect size of 0.58) and SHI (the effect size of 0.35), respectively. Therefore, according to this table, the effect of combined binaural beats therapy on the total sleep quality was greater than other target variables.

Discussion

The study examined the effect of combined binaural beats on the sleep quality of students with insomnia.

Table 3. Mean value and standard deviation (SD) of the total scores of Insomnia Severity Index (ISI), sleep quality, and sleep hygiene

Variable	Experimental group		Control group	
	Pre-test (mean ± SD)	Post-test (mean ± SD)	Pre-test (mean ± SD)	Post-test (mean ± SD)
ISI	19.31 ± 2.15	15.21 ± 2.32	18.72 ± 2.55	16.98 ± 2.72
PSQI	8.83 ± 1.31	5.91 ± 1.18	8.02 ± 1.44	6.55 ± 1.65
SHI	38.11 ± 7.15	18.88 ± 9.82	34.15 ± 8.77	19.04 ± 10.33

ISI: Insomnia Severity Index; PSQI: Pittsburgh Sleep Quality Index; SHI: Sleep Hygiene Index; SD: Standard deviation

Table 4. Multivariate analysis of covariance (MANCOVA) results

Dependent variable	F	P-value	Effect size	Statistical power
ISI	31.16	< 0.001	0.45	0.88
PSQI	39.15	< 0.001	0.58	0.91
SHI	14.15	< 0.001	0.35	0.81

ISI: Insomnia Severity Index; PSQI: Pittsburgh Sleep Quality Index; SHI: Sleep Hygiene Index

The findings showed that combined binaural beats (alpha, theta, and delta) had a significant effect on insomnia severity, sleep quality, and sleep hygiene indices. The findings of many studies are consistent with the findings of this research. Bavafa et al. conducted a study to analyze the effect of theta binaural beats on changing the brain wave pattern in individuals with insomnia stage 1 in Iran and documented that theta binaural beats could change the brain wave pattern of individuals with insomnia stage 1 more significantly than white noises by inducing a certain frequency (theta range) (19). In South Korea, Lee et al. combined theta binaural beat music with ASMR to enhance the effect of this music. The results of their study showed that hearing stimulants could induce sleep in 15 healthy individuals (17).

Another study showed that listening to the combined binaural beats (2-8 Hz) for two months could improve sleep and mental quality in German athletes (18). Hence, the positive effect of binaural beats has been confirmed in the literature; however, some studies have also reached different findings. For example, in a randomized double-blind control study, Bang et al. suggested that theta binaural beats in combination with music could not improve sleep chaos more significantly than pure music. However, they could improve daytime alertness in individuals with subclinical insomnia (1).

Lopez-Caballero and Escera used 40 samples of healthy students and revealed that the binaural beat frequencies (alpha, beta, theta, and gamma) could not make a significant variation in the heartbeat and skin conductance as the signs of emotional arousal of individuals, compared to the acoustic beats. Moreover, they found no significant change in the electroencephalography (EEG) of students in the group receiving the binaural beats, compared to those receiving acoustic beats (31). These studies can challenge the effectiveness of the binaural beats even though the inconsistencies in other studies should not be ignored. In this regard, the inconsistencies in previous studies were aroused by differences in the statistical population (normal individuals with different clinical disorders), intervention protocol (the beat frequency and the presented time, compared to other interventions), the effect of comorbid psychiatric symptoms, type of target variables, and research conditions. To support this claim, Gkolias et al. noted that the role of other variables affecting sleep quality (e.g., pain) should not be neglected when examining the effectiveness of binaural beats (32).

Each person experiences a range of brain wave frequencies during the daytime based on the type of activity, the type and severity of the clinical disorder, and the perceived stress level (33). When it is about sleeping time, the frequency is gradually decreased (20, 34). When individuals with insomnia make attempts to fall asleep, they think about their daily and future problems, and this can make a problem with the gradual reduction of the frequency (35). Hence, the insomnia severity in these individuals is high, sleep hygiene is low, and their sleep quality is dramatically low. Considering the gradual reduction of frequency and the induction of the reduction range, the present study seemed to have a positive and significant effect on the sleep quality pattern of students. Entrainment is the process of synchronizing brain activities with different frequencies (36), some examples of which are synchronizing human sleep-wake cycles with the 24-hour cycle of light and dark, synchronizing heartbeats with a cardiac pacemaker, and synchronizing with particular music frequencies (37). The synchronization process induces different brain frequencies (38) and can be the main factor affecting the results of this study.

Limitations: Like other studies, this research had some limitations. Reminding the students of their sleeping time was performed via text messaging, and this could affect the results of the research. It is recommended to use other monitoring methods such as a daytime appointment with participants or phone calls. The target variables were measured subjectively (by questionnaire); however, further studies can use objective methods such as polysomnography (PSG) or EEG due to the different responses of different brain lobes to each frequency. The financial problems of the research limited the larger sample size and the generalization of the findings.

Conclusion

Regardless of the research limitations, the

combined binaural beats (alpha, theta, and delta) improved the ISI, sleep hygiene, and total sleep quality of students suffering from insomnia. Moreover, this type of treatment can be used as a modern non-invasive intervention.

Conflict of Interests

Authors have no conflict of interests.

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References

1. 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.
2. Behnam B, Paknazar F, Mirmohammadkhani M, et al. Personal, familial and social factors associated with academic failure in university students: A case-control study in Iran. International Journal of Learning, Teaching and Educational Research 2020; 19: 36-47.
3. Blank C, Brunner J, Kreische B, et al. Performance-enhancing substance use in university students: Motives, attitudes, and differences in normative beliefs. J Subst Use 2017; 22: 324-30.
4. Knapstad M, Sivertsen B, Knudsen AK, et al. Trends in self-reported psychological distress among college and university students from 2010 to 2018. Psychol Med 2021; 51: 470-8.
5. Marques DR, Gomes AA, Gellis LA. Insomnia in college students: Specificities regarding psychological treatment. Sleep Hypn 2019; 21: 175-87.
6. Association AP. American psychiatric association. 2019; 7:1.
7. Taylor DJ, Bramoweth AD, Grieser EA, et al. Epidemiology of insomnia in college students: relationship with mental health, quality of life, and substance use difficulties. Behav Ther 2013; 44: 339-48.
8. Ranjbaran M. Prevalence of poor sleep quality in college students of Iran: Systematic review and Meta-analysis. Razi J Med Sci 2016; 23: 1-7. [In Persian].
9. Alshogran OY, Alzoubi KH, Khabour OF, et al. Patterns of self-medication among medical and non-medical University students in Jordan. Risk Manag Healthc Policy 2018; 11: 169-76.
10. Friedrich A, Schlarb AA. Let's talk about sleep: A systematic review of psychological interventions to improve sleep in college students. J Sleep Res 2018; 27: 4-22.
11. Yusufov M, Nicoloro-SantaBarbara J, Grey NE, et al. Meta-analytic evaluation of stress reduction interventions for undergraduate and graduate students. Int J Stress Manag 2019; 26: 132-45.
12. Birba A, Ibanez A, Sedeno L, et al. Non-invasive brain stimulation: A new strategy in mild cognitive impairment? Front Aging Neurosci 2017; 9: 16.
13. Turow G, Lane JD. Binaural beat stimulation: altering vigilance and mood states. In: Berger J, Turow G, editors. Music, science, and the rhythmic brain: Cultural and clinical implications. New York, NY: Routledge; 2012. p. 131-45.
14. Sharma S, Rewadkar S, Pawar H, Deokar V, Lomte VM. Survey on binaural beats and background music for increased focus and relaxation. Proceedings of 2017 International Conference on Emerging Trends and Innovation in ICT (ICEI); 2017 Feb 3-5; Pune, India. Piscataway, NJ: IEEE; p. 98-103.
15. Thatcher RW. EEG evaluation of traumatic brain injury and EEG biofeedback treatment. In: Budzynski TH, Budzynski HK, Evans JR, et al., editors. Introduction to quantitative EEG and neurofeedback. 2nd ed. San Diego, CA: Academic Press; 2009. p. 269-94.
16. Murat ZH, Taib MN, Kadir RSSA, et al. Comparison between the Left and the Right Brainwaves for Delta and Theta Frequency Band after Horizontal Rotation Intervention. Proceedings of the 3rd International Conference on Computational Intelligence, Communication Systems and Networks; 2011 July 26-28; Bali, Indonesia. Piscataway, NJ: IEEE; p. 368-72.
17. 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.
18. Abeln V, Kleinert J, Struder HK, et al. Brainwave entrainment for better sleep and post-sleep state of young elite soccer players - a pilot study. Eur J Sport Sci 2014; 14: 393-402.
19. Bavafa A, Foroughi A, Jaberghaderi N, et al. Binaural beat theta and its impact on primary insomniacs: A randomized clinical trial. Med J Mashad Univ Med Sci 2019; 62: 138-46. [In Persian].
20. Carskadon WC, Dement MA. Normal human sleep: An overview. In: Principles and practice of sleep medicine. 5th ed. St. Louis, MO: Elsevier Saunders; 2011. p. 16-26.
21. Soleimani F, Motaarefi H, Hasanpour-Dehkordi A. Effect of sleep hygiene education on sleep quality in hemodialysis patients. J Clin Diagn Res 2016; 10: LC01-LC04.
22. Yazdi Z, Sadeghniiat-Haghighi K, Zohal MA, et al. Validity and reliability of the Iranian version of the insomnia severity index. Malays J Med Sci 2012; 19: 31-6.
23. 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.
24. Bavafa A, Foroughi AA, Khaledi B, et al. The comp-

arison of effects of state and trait anxiety on the components of sleep quality. J Sleep Sci 2019; 3: 95-101.
25. Buysse DJ, Reynolds CF 3rd, Monk TH, et al. The Pittsburgh Sleep Quality Index: A new instrument for psychiatric practice and research. Psychiatry Res 1989; 28: 193-213.
26. Backhaus J, Junghanns K, Broocks A, et al. Test-retest reliability and validity of the Pittsburgh Sleep Quality Index in primary insomnia. J Psychosom Res 2002; 53: 737-40.
27. Farrahi MJ, Nakhaee N, Sheibani V, et al. Reliability and validity of the Persian version of the Pittsburgh Sleep Quality Index (PSQI-P). Sleep Breath 2012; 16: 79-82.
28. Mastin DF, Bryson J, Corwyn R. Assessment of sleep hygiene using the Sleep Hygiene Index. J Behav Med 2006; 29: 223-7.
29. Chehri A, Kiamanesh A, Ahadi H, et al. Psychometric properties of the Persian version of Sleep Hygiene Index in the general population. Iran J Psychiatry Behav Sci 2016; 10: e5268.
30. Zimmermann G, Pauly M, Bathke AC. Multivariate analysis of covariance when standard assumptions are violated. arXiv 2019:190210195. [Preprint].
31. Lopez-Caballero F, Escera C. Binaural beat: A failure to enhance EEG power and emotional arousal. Front Hum Neurosci 2017; 11: 557.
32. Gkolias V, Amaniti A, Triantafyllou A, et al. Minimal effects of binaural auditory beats for subclinical insomnia. Does pain play a role? J Clin Psychopharmacol 2020; 40: 320-1.
33. von Stein A, Sarnthein J. Different frequencies for different scales of cortical integration: from local gamma to long range alpha/theta synchronization. Int J Psychophysiol 2000; 38: 301-13.
34. Fernandez GA, Achermann P. Brain dynamics during the sleep onset transition: An EEG source localization study. Neurobiol Sleep Circadian Rhythms 2019; 6: 24-34.
35. Carciofo R, Song N, Du F, et al. Metacognitive beliefs mediate the relationship between mind wandering and negative affect. Pers Individ Differ 2017; 107: 78-87.
36. Wahbeh H, Calabrese C, Zwickey H. Binaural beat technology in humans: a pilot study to assess psychologic and physiologic effects. J Altern Complement Med 2007; 13: 25-32.
37. McConnell PA, Froeliger B, Garland EL, et al. Auditory driving of the autonomic nervous system: Listening to theta-frequency binaural beats post-exercise increases parasympathetic activation and sympathetic withdrawal. Front Psychol 2014; 5: 1248.
38. Lachaux JP, Rodriguez E, Martinerie J, et al. Measuring phase synchrony in brain signals. Hum Brain Mapp 1999; 8: 194-208.