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The Effect of Alpha Binaural Beats Auditory Stimulation on Quantitative Electroencephalography (QEEG) and Pain Intensity among Tension-Type Headache Patients

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ABSTRACT
Tension-type headaches, the most prevalent primary headaches affecting 2-5% of the population, significantly impact sufferers' well-being. These headaches present a persistent health challenge, constituting a considerable portion of neurologist outpatient visits. Effectively managing tension-type headaches remains challenging and can lead to notable morbidity if untreated. Treatment typically involves prophylactic pharmacological therapy alongside non-pharmacological interventions. Among non-medication therapies, brainwave entrainment using binaural beats emerges as a promising option for chronic headaches. This experimental research employed a pre-test and post-test design over a 5-day period (30 minutes daily) to assess Alpha Binaural Beats Auditory stimulation's impact on the QEEG pattern and pain intensity reduction in tension-type headache patients. The study, involving 32 participants, revealed a statistically significant increase in relative alpha wave power (p-value of 0.000) and a significant decrease in relative beta wave power (p-value of 0.045) after exposure to alpha binaural beats. Additionally, the Numerical Rating Scale (NRS) recorded a statistically significant decrease in pain intensity (p-value of 0.000). These findings suggest that Alpha binaural beats contribute to increased alpha wave activity, decreased beta wave activity in the QEEG pattern, and a substantial reduction in pain intensity associated with tension-type headaches. However, further research is needed to explore cumulative effects and long-term sustainability in tension-type headache patients, advancing our understanding and application of this therapy.
Keywords: Binaural beats auditory, Quantitative electroencephalography, Numerical rating scale, Tension-type headache

INTRODUCTION

Headache is pain and discomfort in the head area, extending from the orbit to the back of the head (occipital area and part of the neck area) (Benali et al., 2023; Gautier et al., 2023; Robertson & Benarroch, 2023; Roncone, 2020; Waldman et al., 2022). Studies in Indonesia show that headaches constitute the largest proportion of outpatient neurologist visits (Fan et al., 2023; Fernández-de-Las-Peñas et al., 2023). Primary headaches include Migraines, Tension-

Type Headaches, Cluster Headaches, and other Trigeminal-Autonomic cephalalias from Other Primary Headaches (Al-Khazali et al., 2023; Latorre et al., 2023).

The estimated lifetime prevalence of headache is 66%: 14% to 16% for migraine, 46% to 78% for Tension-Type Headache (TTH), and 0.1% to 0.3% for cluster headache (10). In a population-based study in Denmark, the lifetime prevalence of TTH is high (78%), but most experience episodic infrequent TTH without specific medical needs. About 24% to 37% experience TTH several times a month, 10% experience it weekly, and 2% to 3% of the population has chronic TTH disease, usually lasting most of their lifetime. Tension-type headaches are primary headaches with the greatest prevalence, around 2-5% of the general population (Atalar et al., 2024; Bentivegna et al., 2021; Rangel et al., 2021).

Therapy management remains a challenge due to significant morbidity if not treated effectively and immediately (Goyal et al., 2024; Mehta et al., 2020; Sharma et al., 2020; Wood et al., 2022). Although several therapeutic approaches have shown success, chronic tension-type headaches are often difficult to manage (Argyriou et al., 2021; Sait et al., 2021; Shahverdi et al., 2024). Chronic tension-type headache becomes a risk factor for the overuse of analgesic drugs, and only 20% of patients visit a doctor. Prophylactic pharmacological therapy in conjunction with non-pharmacological therapy should be considered. Non-pharmacological therapy has been reported to have benefits with minor side effects (Argyriou et al., 2021; Dimitriou et al., 2020; Moisset et al., 2020). Brainwave entrainment therapy using binaural beats is a non-medication therapy that can be considered for managing chronic headaches as an alternative or complementary therapy (Vasiliou et al., 2021).

RESEARCH METHODS

This study is an experimental study conducted at Wahidin Sudirohusodo Hospital. The research sample was determined by consecutive sampling, where all subjects who came and met the research criteria were included in the study until the required number of subjects was fulfilled. This study received ethical clearance from the Faculty of Medicine Ethics Commission, Hasanuddin University. Data collection was carried out during August until the sample was fulfilled.

The inclusion criteria for the study were patients who met the International Headache Society diagnostic criteria for frequent episodic or chronic tension-type headache, aged 18-50 years, not using analgesics in the last 1 day. Subjects were cooperative and willing to participate in the study by signing a consent form to be a research sample. The exclusion criteria were patients with a history of epilepsy, head trauma, and other brain disorders, patients with hearing impairments, patients using sedatives, psychoactive drugs, or analgesics, and subjects with anxiety disorders or other psychiatric disorders. Each subject meeting the inclusion criteria had their identity data recorded and underwent anamnesis and general and neurological physical examinations.

If the subjects qualified under the inclusion criteria and were willing to participate in the study, they were asked to sign a consent form to follow the research procedures. Subjects were asked to complete the pain scale using the Numerical Rating Score (NRS) Instrument. The examination was carried out in a quiet and cool place. The subjects were arranged to sit as comfortably as possible while closing their eyes to reduce external stimulation. Subjects were instructed to relax and breathe regularly. The researcher conducted a QEEG (Quantitative EEG) examination on the research subjects to understand the brain wave dynamics before the Alpha Binaural Beats Stimulation was given.

Earphones were placed on both ears of the patients. Subjects were given Alpha Binaural Beats using a brainwave auditory stimulation application on a computer (Dell). Recording began by calibrating the device for 30 seconds. The first stimulation continued for 30 minutes without intervention, stimulation was given for 5 consecutive days, and QEEG recording was done on the sixth day. Subjects were asked to fill out the pain scale using the Numerical Rating Score (NRS) instrument after the QEEG was performed. The auditory stimulation was alpha wave stimulation, with the volume adjusted to the patient's comfort. QEEG recording data were analyzed using Brain QEEG software (Neuroguide). All obtained data were recorded and then analyzed.

RESULTS AND DISCUSSION

A total of 31 subjects met the inclusion and exclusion criteria. The most common age range among subjects was 31-40 years (59.4%), while the least common was <20 years (3.1%). Regarding gender, females were more prevalent than males (75% vs 25%), with 24 females and 8 males. The median Z score FFT relative power of alpha waves before listening to alpha binaural beats was -1.26 uV Squ (SD ± 1.81), which then increased to -0.30 (SD ± 1.34) after listening to alpha binaural beats. The mean Z score FFT relative power of beta waves before listening to alpha binaural beats was -0.43 uV Squ (SD ± 2.48), which decreased to -1.20 (SD ± 1.68) after listening to alpha binaural beats. This also indicates a change in the Numerical Rating Scale (NRS) scores, shown by a decrease in the mean Numerical Rating Scale (NRS) score from 6.00 (SD ± 0.80) before listening to alpha binaural beats to 0.00 (SD ± 0.57) after listening to alpha binaural beats.

Table 2. Research Subject Characteristics

Characteristics	Frequency (n=32)	Percentage (%)
Age		
<20 years	1.00	3.10
21-30 years	8.00	25.00
31-40 years	19.00	59.40

Characteristics	Frequency (n=32)	Percentage (%)
41-50 years	4.00	12.50
Gender		
Female 24 75	24.00	75.00
Male 8 25	8.00	25.00
Occupation		
Teacher	1.00	3.10
Student	1.00	3.10
Doctor	6.00	18.70
Nurse	6.00	18.70
Midwife	2.00	6.20
Entrepreneur	3.00	9.30
Lecturer	2.00	6.20
Pharmacist	2.00	6.20
Administrative Staff	2.00	6.20
Office Worker	7.00	21.80
Headache		
Frequent Episodic Tension-Type Headache	23.00	71.90
Chronic Tension-Type Headache	9.00	28.10

Comparison of Z score FFT Relative Power alpha waves before and after listening to Binaural Beats Alfa

Comparison of Z scored FFT Relative Power Alpha Waves before and after listening to alpha binaural beats. P-value indicates Wilcoxon test, Error bars indicate standard deviation (SD) shows the median Z score FFT relative power of alpha waves before listening to alpha binaural beats was -1.26 uV Squ (SD ± 1.81), which then increased to -0.30 (SD ± 1.34) after listening to alpha binaural beats. The increase in the relative power of alpha waves is statistically significant between before and after listening to alpha binaural beats with a p-value of 0.000 ($p < 0.050$). This indicates that with the increase in Z score FFT relative power of alpha, clinically, patients become more relaxed after listening to alpha binaural beats compared to before listening to alpha binaural beats.

Comparison of Z Score FFT Relative Power of Beta Waves Before and After Listening to Alpha Binaural Beats

Comparison of Z score FFT Relative Power Beta Waves before and after listening to alpha binaural beats. p-value indicates Paired t-test, Error bars indicate standard deviation (SD) shows the mean Z score FFT relative power of beta waves before listening to alpha binaural beats was -0.43 uV Squ (SD ± 2.48), which decreased to -1.20 (SD ± 1.68) after listening to alpha binaural beats. The decrease in the relative power of beta waves is statistically significant between before and after listening to alpha binaural beats with a p-value of 0.045 ($p < 0.050$). This indicates that with the decrease in Z score FFT relative power of beta, clinically, the headache intensity of patients is reduced after listening to alpha binaural beats compared to before listening to alpha binaural beats.

Comparison of Brain Mapping Z-Score FFT Relative Power Alpha Waves (median value) and Beta (mean value) before and after listening to alpha binaural beats.

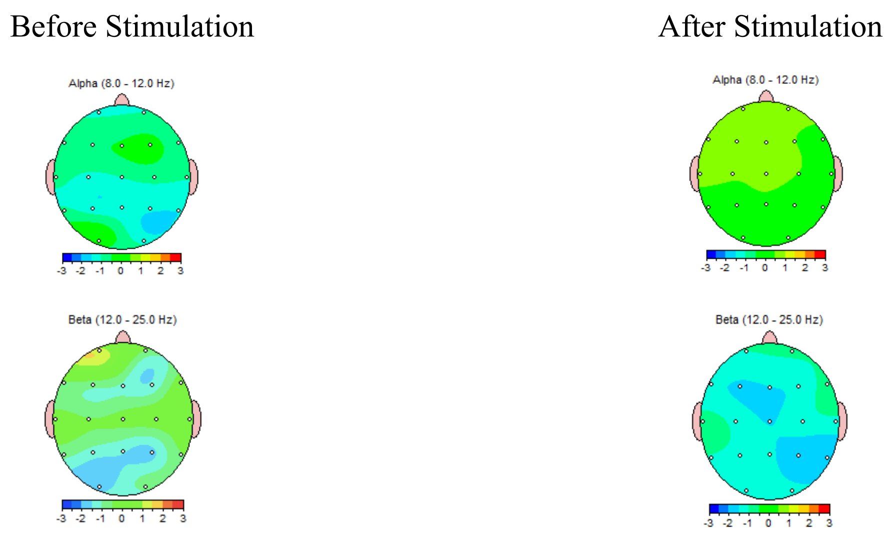

Figure 1. Comparison of Brain Mapping Z-Score FFT Relative Power Alpha Waves (median value) and Beta (mean value) before and after listening to alpha binaural beats.

Figure 1 compares brain mapping based on Z-Score FFT on the relative power of brain waves. A Z-Score of 0, represented by green, indicates normal values. Decreasing Z-Score values (-1 to -3) are represented by turquoise to dark blue colors. Conversely, increasing Z-Score values (1 to 3) are represented by yellow to red colors. Before stimulation, the brain mapping of alpha relative power was dominated by turquoise. After stimulation, the brain mapping of alpha relative power was dominated by green, indicating an increase in Z-Score value. This shows an increase in alpha relative power; clinically, patients become more relaxed after listening to alpha binaural beats. In the same condition, before stimulation, the brain mapping of beta relative power was dominated by green to turquoise. After stimulation, the brain mapping of beta relative power was dominated by turquoise to blue, indicating a decrease in Z-Score value. This shows a decrease in beta relative power, and clinically, the headache intensity of patients is reduced after listening to alpha binaural beats compared to before.

Comparison of Headache Numerical Rating Scale (NRS) Scores Before and After Listening to Alpha Binaural Beats

Figure 2 shows the change in Numerical Rating Scale (NRS) scores indicated by a decrease in the mean Numerical Rating Scale (NRS) score from 6.00 (SD ± 0.80) before listening to alpha binaural beats to 0.00 (SD ± 0.57) after listening to alpha binaural beats. The change in NRS scores before and after listening to alpha binaural beats is statistically significant, with a p-value of 0.000 ($p < 0.05$).

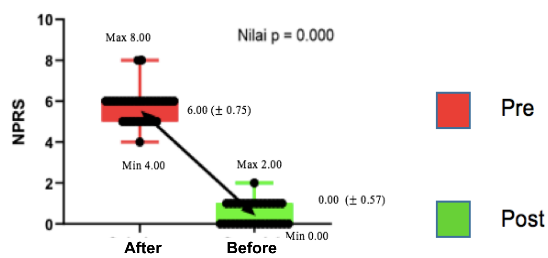

Figure 2. Comparison of Headache Scores as Indicated by the Numerical Rating Scale Scores Before and After Listening to Alpha Binaural Beats. The p-value indicates the Wilcoxon test, and the error bars represent the standard deviation (SD).

This study determined the effect of listening to alpha binaural beats on the Quantitative EEG (QEEG) representation of alpha and beta wave activities and the Numerical Rating Scale (NRS) in young adults experiencing headaches. During the study period, 32 subjects met the inclusion and exclusion criteria. The sample consisted of 8 males (25%) and 24 females (75%), with the most common age range being 31-40 years (59.4%). The youngest subject was 18 years old, and the oldest was 50, aligning with the inclusion criterion of age range between 18 and 50.

This age range was chosen due to the differences in frequency regulation and amplitude across various age groups, such as the decrease in alpha wave frequency with aging. The sample's occupations included 1 teacher (3.1%), 1 student (3.1%), 6 nurses (18.7%), 2 midwives (6.2%), 3 entrepreneurs (9.3%), 2 lecturers (6.2%), 2 pharmacists (6.2%), 2 parliamentary staff (6.2%), and 7 office workers (21.8%), with office workers being the most common occupation

(21.8%). The type of headache among the study samples consisted of 23 individuals (71.9%) with frequent episodic tension-type headaches and 9 individuals (28.1%) with chronic tension-type headaches, with frequent episodic tension-type headaches being the most common. This is because frequent episodic tension-type headache is the most common type in the population.

In this study, a Quantitative EEG (QEEG) examination was conducted on 32 research subjects to observe the activities of alpha and beta waves before and after listening to alpha binaural beats. The subjects underwent a 30-minute EEG recording for 5 days. The EEG recordings were then converted into Quantitative EEG using the Neuroguide computer application, focusing on the Z score FFT relative power of alpha and beta wave activities.

An increase in the median Z score FFT relative power of alpha waves was observed after listening to alpha binaural beats compared to before, with this increase being statistically significant ($p = 0.000$, $p < 0.05$). This indicates that the increase in Z score FFT relative power of alpha waves clinically led to greater patient relaxation after listening to alpha binaural beats. This finding aligns with research by McMurray et al. in 2006 on 20 healthy elderly subjects aged 65 years with decreased neurocognitive abilities, where a significant increase in alpha power was observed after a 25-minute exposure to alpha binaural beats, demonstrated by an increase in Mini-Mental State Examination/MMSE scores after the intervention compared to before (Perchtold-Stefan et al., 2020). Theoretically, alpha waves dominate the human brain and play a crucial role in cognitive function, with an increase in alpha power closely related to improved access to information and semantic orientation (Hutchinson et al., 2021; Nicolás et al., 2021).

A decrease in the mean Z score FFT relative power of beta waves was also found after listening to alpha binaural beats compared to before, with this decrease being statistically significant ($p = 0.045$, <0.05). This indicates that the reduction in Z score FFT relative power of beta waves clinically reduced headache intensity after listening to alpha binaural beats. This aligns with systematic observation research on EEG recording as a perception of pain by Panagiotis Zis et al. in 2022, where beta power was associated with subjective pain intensity, showing an increase in beta activity, especially in the temporal region. Theoretically, the beta waves associated with active thinking or stress can trigger muscle spasms, generating pain. The administration of a 10Hz binaural beats stimulus can change and synchronize brain activity with this frequency, with beta brain waves related to normal awake and alert consciousness. Thus, a decrease in beta brain waves indicates the subject is not awake and alert, implying greater calmness after listening to the binaural beat (Puzi et al., 2013).

Binaural beats influence the entrainment of both cerebral hemispheres at the same frequency, establishing an equivalent electromagnetic environment and maximizing intra- and inter-hemispheric neural communication. Binaural beats are considered a challenging auditory situation with binaural perception conflict, overcome by the auditory system through enhanced communication between both auditory cortices. The effect of alpha binaural beats is selective for alpha frequency waves, with the alpha wave's spontaneous oscillation being the primary interaction among cortical areas.

This study also found a significant increase in the mean Numerical Rating Scale (NRS) score, indicating a decrease in headache intensity before and after listening to alpha binaural beats. This is consistent with a study by Alya et al. in 2022 on 60 patients with orthodontic pain after archwire installation, where the sensory and psychological aspects of pain intensity significantly decreased in the binaural beat music (BBM) group compared to the control group, measured by the Visual Analog Scale (VAS) after the fifth day (Aly et al., 2023).

Alpha binaural beats with a 10 Hz Frequency Following Response (FFR) have also been proven to induce relaxation in research subjects. A 30-minute duration was used for listening to alpha binaural beats in this study, with an average of 15-20 minutes needed to observe the FFR effect on EEG waves. Alpha binaural beats at 10 Hz for 30 minutes can increase relaxation levels, thereby reducing headaches in individuals, making it a viable psychoacoustic instrument in daily life for healthy people. Binaural beats devices are inexpensive and available in computer applications, making them easy to use independently. A limitation of this study is that headache assessment was conducted after 24 hours of the last therapy cycle of listening to alpha binaural beats, meaning the researchers did not follow how long the effect of pain reduction induced by alpha binaural beats could last.

CONCLUSION

The application of Alpha Binaural Beats Auditory stimulation yields noteworthy outcomes across various domains. It is observed that this stimulation significantly enhances alpha wave activity, as evidenced by an increase in Z Score FFT relative power in the QEEG representation. Simultaneously, there is a substantial reduction in beta wave activity, indicated by a significant decrease in Z Score FFT relative power in the QEEG representation. Furthermore, the application of Alpha Binaural Beats Auditory stimulation exhibits a significant therapeutic impact, notably reducing the intensity of tension-type headaches, as measured by the Numerical Rating Scale. These findings collectively underscore the multifaceted benefits of Alpha Binaural Beats Auditory stimulation in modulating neural activities and alleviating tension-type headache symptoms.

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