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Review

The Efficiency of Binaural Beats on Anxiety and Depression—A Systematic Review

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Abstract: Anxiety and depression are two of the most impactful diseases on quality of life and cause significant disability to patients. It burdens the medical system even as a stand-alone pathology or a secondary condition. These conditions can occur secondarily after a patient suffers from other illnesses, such as upper motor neuron lesions. Binaural beats are a new and emerging type of technology that can be used as an adjunct therapy for anxiety and depression as well as in neurologic conditions to some extent. We searched through the MEDLINE, PsychINFO, EMBASE, CENTRAL, ISRCTN, and ICTRP databases to identify studies using binaural beats as therapy for anxiety and depression. Twelve articles were declared eligible to be included in this review. Binaural beats, whether used in the form of pure beats or masked by another sound, have shown better results in alleviating symptoms of anxiety and depression compared to control conditions such as no music or the use of noise-canceling headphones alone. The results suggest that using binaural beats could be a promising and easy-to-use method to help alleviate the symptoms of anxiety and depression.

Keywords: binaural beats; anxiety; depression; neurologic disorders

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1. Introduction

Anxiety is among the most prevalent mental disorders and ranks as the ninth leading cause of disability globally [1]. Anxiety disorders are debilitating psychological conditions characterized by a diverse array of cognitive and somatic symptoms. Individuals diagnosed with anxiety disorders exhibit a higher lifetime prevalence of various medical comorbidities. Furthermore, the presence of chronic medical conditions elevates the risk of developing psychiatric disorders and contributes to overall functional impairment [2]. The primary symptoms of anxiety encompass a broad spectrum, including physical manifestations such as palpitations, tremors, and dyspnea. Additionally, anxiety may involve psychological symptoms like fear of losing control, agoraphobia, difficulty concentrating, and specific phobias related to objects, animals, and situations [3–5]. Another form of anxiety that is met under the medical spectrum is an unspecified anxiety disorder, which means that a patient is suffering a significant form of anxiety or phobias without meeting the specific criteria for any anxiety disorder [6].

Depression is also a significant factor of burden on the medical system worldwide. This pathology is one of the most significant causes of disability, which is increasing every year [7]. Additionally, 322 million people worldwide live with depression. Both anxiety and depression can have severe and long-lasting repercussions, including detrimental effects on mental health, alterations in sleep patterns, negative impacts on physical health, and the potential to trigger harmful behaviors such as substance abuse [8]. Being a widespread pathology, more than 20% of women and more than 7% of men suffered at least one episode of depression [9]. Depression is one of the most critical determinants of the quality of life scores obtained from patients admitted to the hospital [10].

Depression and depressive symptoms are very frequent in patients admitted to the hospital, as these patients suffer from other pathologies compared to the general population [10]. Depression is primarily present in association with oncology and hematology [11], neurological pathologies (e.g., stroke) [12], inflammatory diseases (arthritis) [13], and cognitive impairment [14].

Binaural beats are defined by an auditory illusion created by simultaneously presenting two audio tones with distinct frequencies to each auditory analyzer via stereo headphones. For instance, if a 410 Hz tone is delivered to the right ear and a second tone with a frequency of 400 Hz is presented to the left ear, the resulting binaural beat is represented by the 10 Hz difference between the original tones [15]. In the medical literature, it is believed that this type of binaural beat originates in the medial nucleus of the superior olivary cortex, the first nucleus in the auditory pathway to receive an input from both the auditive analyzers [16].

Binaural beats are characterized across several patterns as follows:

Delta Pattern: Binaural beats within the delta model typically oscillate at a frequency of 1–4 Hz, correlating with dreamless sleep states [17,18].

Theta Pattern: Binaural beats that are set according to the theta model operate within a 4–8 Hz frequency range. Theta patterns enhance meditation, foster creativity, and facilitate rapid eye movement (REM) sleep [17,18].

Alpha Pattern: Binaural beats characterized by the alpha pattern resonate at a frequency range of 8–13 Hz to induce relaxation [17,18].

Beta Pattern: Binaural beats aligned with the beta pattern exhibit frequencies ranging from 13 to 30 Hz. This range is conducive to promoting concentration and heightened alertness [17,18].

Gamma Pattern: Frequencies falling within the gamma pattern range from 30 to 70 Hz. These frequencies are conducive to sustaining arousal during wakefulness [17,18].

The effects of this new technology on anxiety and depression are a point of focus for scientists around the globe. In the specialty literature, several studies guarantee that sound effects cause a reduction in anxiety and depression symptoms [19,20]. At the same time, there are many reservations regarding this type of therapy. One limitation encountered in this therapy's research is the challenge of assessing its direct impact on brain waves. For a more accurate evaluation, it is essential to apply BB simultaneously with an electroencephalogram (EEG).

This literature review was undertaken to examine the impact of binaural beats on anxiety and depression and their potential to modulate neuroplasticity in individuals afflicted with neurological pathologies. Furthermore, this review seeks to enhance the understanding regarding the capacity of binaural beats to affect particular conditions and complement conventional treatment modalities for patients. Another objective of this review is to analyze which pattern of binaural beat is better to treat the symptoms of these pathologies.

2. Materials and Methods

2.1. Review Method

This study followed all the elements of the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) guidelines [21].

2.2. Search Strategy

This research was conducted on 27 April 2024 using the MEDLINE, PsychINFO, EMBASE, CENTRAL, ISRCTN, and ICTRP databases, where we used combinations of the following keywords: "Binaural AND Anxiety"—101 results; "Binaural AND Depression"—59 results; "Binaural AND Neuroplasticity"—18 results; "Binaural AND Stroke"—19 results; "Binaural AND Neuro* diseases"—47 results; "Binaural AND Neurological diseases"—2 results; "Binaural AND Injury"—48 results; and "Binaural AND Brain injury"—26 results. In total, we obtained 320 results.

We searched the databases and included all studies that used binaural beats as an adjunctive therapy in the treatment of anxiety as a standalone condition, as well as studies that treated anxiety as a secondary condition in conjunction with another medical procedure. The same criteria were applied to identify the effect of binaural beats on depression. The research had to be undertaken on adults, including both men and women. Studies using binaural beats to treat neurological disease were also introduced. We excluded review articles, meta-analyses, pilot studies, and feasibility studies. We also omitted studies in which treatment using binaural beats was employed for other disorders or in healthy individuals to improve cognitive performance.

After obtaining all of the results from the databases, we removed all duplicates. Then, we selected the studies by evaluating their titles and abstracts. The final step involved reading the entire texts and selecting the studies that were eligible for our review.

2.3. Study Selection

After checking the databases, a total of 320 studies were screened, which were subjected to the elimination of duplicates (78 in total), and then the articles were filtered by title. After completing this stage, 33 articles remained, and the abstracts were read in full. After reading the abstracts, 15 papers that did not meet the inclusion criteria were excluded, and the remaining 18 papers were read in full. After reading the complete texts, 12 articles were included in this review. All of the steps taken in this selection can be observed in Figure 1, and all of the reasons for eliminating studies from our review are pointed out in Table 1.

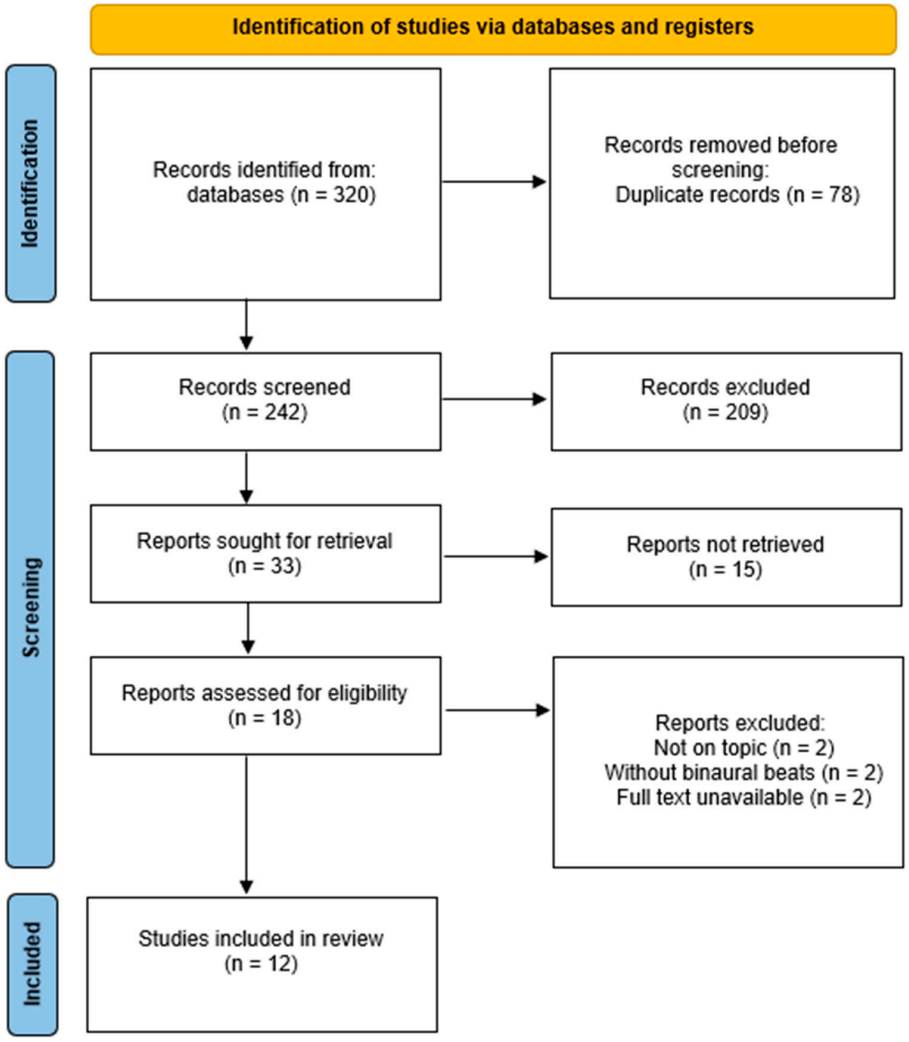

Figure 1. PRISMA diagram flow.

Table 1. Exclusion criteria.

Exclusion Reasons Based on Title and Abstract	***n* = 224**
Reviews	4
Pilot studies	4
Feasibility studies	1
Meta-analysis papers	2
Papers not using binaural beats to treat anxiety/depression/neurologic pathology	112
Papers using another technology (monaural beats or music)	20
Studies on binaural beats without any relation to the topic	46
Studies using animals	17
Papers where authors investigated the way a device works	18
Exclusion reasons after reading the whole text	***n* = 6**
Not being on topic (treating another pathology)	2
Not using binaural beats as the main intervention	2
Full text unavailable	2

2.4. The Quality of the Studies

We used the PEDro scale to evaluate the quality of the studies that met the inclusion criteria and were included in our review [22]. In Table 2, we examined all studies to assess the quality of the research.

Table 2. PEDro scale.

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Isik, BK et al. 2017 [19]	YES	YES	YES	YES	NO	NO	NO	YES	YES	YES	YES	7/10
Padmanabhan, R et al. 2007 [20]	YES	YES	-	YES	NO	NO	YES	YES	NO	YES	YES	7/10
Opartpunyasarn, P. et al. 2022 [23]	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	9/10
Menziletoglu, D et al. 2021 [24]	YES	YES	-	YES	YES	NO	YES	YES	YES	YES	YES	8/10
Loong, LJ et al. 2022 [25]	YES	YES	YES	YES	NO	NO	NO	YES	NO	YES	YES	6/10
Wiwatwongwana, D et al. 2016 [26]	YES	YES	YES	YES	NO	NO	NO	YES	NO	YES	YES	6/10
Olcucu, MT et al. 2021 [27]	YES	YES	YES	YES	NO	NO	NO	NO	NO	YES	YES	5/10
Parodi, A et al. 2021 [28]	YES	YES	YES	YES	YES	NO	YES	-	-	YES	YES	7/10
Daengruan, P et al. 2021 [29]	YES	YES	YES	YES	YES	NO	YES	YES	NO	YES	YES	8/10
Galvez, G et al. 2005 [30]	YES	NO	NO	YES	YES	YES	NO	YES	YES	YES	YES	7/10
Prasad, M et al. 2023 [31]	YES	YES	YES	YES	YES	YES	NO	YES	YES	YES	YES	9/10
Ligree N et al. 2023 [32]	YES	YES	YES	NO	NO	NO	NO	YES	YES	YES	YES	7/10

3. Results

3.1. Study Characteristics

A total of 1349 patients were evaluated across the 12 included studies. Ten of these studies utilized binaural beats to address anxiety in patients facing upcoming medical procedures. One study focused on evaluating anxiety as a secondary pathology in patients with Parkinson's disease, while another assessed depression in psychiatric patients.

Researchers typically divided participants into two or more groups to compare the effects of various interventions: pure binaural beats, binaural beats masked with other sounds, music without binaural beats, or no intervention at all. Evaluations were conducted within individual groups and between different groups to ascertain the relative effectiveness of each intervention. Table 3 summarizes the most important characteristics of each study.

Table 3. The main characteristics of the studies.

Article and Date	Groups	Intervention	Comparison	Measurements	Main Conclusions
Isik, BK et al. 2017 [19]	60 patients in 2 groups: CG = 30 EG = 30	EG, 9.3 Hz BB, 10 min before medical procedure + local anesthetic CG, local anesthetic + no intervention	9.3 Hz (alpha) binaural beats vs. no interventions Within-group comparison	VAS	EG obtained a lower score of anxiety after listening to binaural beats compared to CG with no intervention.
Padmanabhan, R et al. 2007 [20]	108 patients in 3 groups Binaural group, *n* = 36 Audio group, *n* = 36 No intervention, *n* = 36	Binaural group, 30 min of binaural beats Audio group, music without binaural beats, 30 min Last group, no intervention	Music + binaural beats vs. music only vs. no interventions	STAI	There was no difference between STAI-T scores of three groups. STAI-S scores were lower for every group at final evaluation. Binaural group showed improvement in anxiety symptoms.
Opartpunyasarn, P et al. 2022 [23]	112 patients in 3 groups Binaural beats, *n* = 38 Plain music, *n* = 38 No music, *n* = 36	20 Hz BB for first 5 min After that, frequency decreased gradually for 5 min to 10 Hz for next 50 min Plain music was played in plain groups for 60 min	Comparison between music + binaural beats vs. music vs. no intervention	STAI; BP, SBP, DBP; HR	STAI-S score decreased in binaural beats group more than in other groups. BP decreased for binaural beats group and was not modified for other groups. HR value increased for all groups, but binaural beats group obtained lowest average.
Menziletoglu, D et al. 2021 [24]	90 patients in 3 groups Binaural beats, *n* = 30 Music, 432 Hz, *n* = 30 Control group, *n* = 30	BB group listened to 10 Hz BB for 10 min Music group received 10 min. of music	Between groups and within groups	VAS	Significant differences between BB and control were identified. Significant differences between 432 Hz music and control were identified. No significant difference between BB and 432 Hz music was identified.
Loong, LJ et al. 2022 [25]	61 patients in 2 groups Binaural beats, *n* = 31 Sham group, *n* = 30	Binaural beats group listened to 10 Hz BB Sham group only wore headphones and did not receive any audio	Comparison between each group and within groups	VAS (pain); STAI-6; BP; HR Before and after medical procedure	The BB group had lower pain score than sham group. Significant difference was observed between first and second evaluations for STAI and HR in BB group Significant difference in control group for all except STAI. Experimental group had decreased BP and HR, while control group had increased scores.

Table 3. *Cont.*

Article and Date	Groups	Intervention	Comparison	Measurements	Main Conclusions
Wiwatwongwana, D et al. 2016 [26]	141 patients in 3 groups BB group, *n* = 47 Music group, *n* = 47 Control group, *n* = 47	20 Hz BB for the first 5 min; after, frequency decreased gradually for 5 min to 10 Hz for next 50 min Music group only received music for 1 h	Comparison between groups and within groups	STAI, BP, HR	At final verification, STAI scores were lower in music and BB groups than in control group. At 20 min mark, HR from BB group was lower than that in music and control groups. STAI-S score was lower in BB group vs. music group but not statistically significant.
Olcucu, MT et al. 2021 [27]	209 patients in DCG group: DCG-1, *n* = 61; DCG-2, *n* = 73; DCG-3, *n* = 75 143 patients in USRG group: USRG-1, *n* = 41; USRG-2, *n* = 50; USRG-3, *n* = 52	DCG-1 and USRG-1 listened to 10 Hz pure binaural beats for 10 min DCG-2 and USRG-2 listened to 10 min of music DCG-3 and USRG-3 were not exposed to audio	Comparison of DCG-1 vs. DCG-2 vs. DCG-3 Comparison of USRG-1 vs. USRG-2 vs. USRG-3	STAI; VAS	STAI-T scores were lower in DCG-1 and DCG-2 groups compared to DCG-3. In USRG-1 and USRG-2, scores were lower than that in USRG-3. For STAI-S, there were lower scores obtained for DCG-1 and DCG-2 compared with DCG-3. Significant differences in STAI-S between USRG-1 and USRG-2 compared to USRG-3.
Parodi, A. et al. 2021 [28]	60 patients in 3 groups BB group Music group Control group	DMSPS listened to binaural beats and music for 12 min	Comparison between groups and within groups	STAI-Y	STAI score was lower in BB group than in other 2 groups but was not statistically significant. In BB group and music group, last evaluation showed increase in anxiety compared to control condition.
Daengruan, P et al. 2021 [29]	18 patients in 2 groups: BB group, *n* = 9 Control group, *n* = 9	BB group received standard medication + music and 10 Hz BB for 20 min at clinic and 3 times/week at home Control group only received standard medication	Comparison between two groups	PHQ-9; EQ-5D; MARS scale at 0, 4, and 8 weeks	First evaluation showed no modification in any of the scales. On second and third evaluations, PHQ-9 scores were lower in BB group than in control group. EQ-5D and MARS evaluation showed no modifications at weeks 4 and 8.
Galvez, G et al. 2005 [30]	14 patients undergoing two separate sessions	Two different sessions on different days; binaural beats vs. music for 10 min each BB at 14 Hz frequency	Comparison between each session	STAI; EEG; EKG; Gait evaluation	No difference in STAI scores. In EEG assessment, experimental group exhibited decreased Theta band power, while control group did not show any changes. Gait evaluation showed no significant difference.

Table 3. *Cont.*

Article and Date	Groups	Intervention	Comparison	Measurements	Main Conclusions
Prasad, M. et al. 2023 [31]	225 patients in 3 groups Group A (BB), *n* = 75 Group B (intravenous midazolam + no music), *n* = 75 Group C (music of patients' choice), *n* = 75	Group A, BB at 3.5 Hz for 10 min before procedure, during surgery, and 30 min after procedure Group B wore NC headphones and received midazolam and no music Group C listened to their choice of music for same period as group A	Comparison made between all groups and within each group for initial and final evaluations	VAS-A at start, after 10 min, before and after spinal anesthesia, at 60, at skin closure, and 30 min after procedure VAS for pain score at 10, 30, 60, 90, and 120 min Patient satisfaction after surgery BP; HR	Statistically significant difference was seen between mean VAS score at all evaluations among all groups. Intragroup comparison showed statistically significant differences between groups A and B and between groups B and C but no statistical difference between groups A and C. Binaural tone music and music choice groups had comparable results, although binaural music was not superior to music choice.
Ligree N et al. 2023 [32]	108 patients in 3 groups Group A (BB), *n* = 36 Group B (noise cancelation), *n* = 36 Group C (no headphones), *n* = 36	Group A exposed to BB during entire surgery Group B wore noise cancelation headphones without music Group C did not use headphones	Authors made comparisons between all three groups and within them	STAI-6; VAS-S; BP; HR	Comparison between all groups showed that Group A had lower STAI-6 score than group C, $p < 0.001$. Comparison within same group showed a lower STAI-6 score in Group A than in Group B. VAS-S was better when comparing groups A and B with group C.

EG: Experimental Group; CG: Comparison Group; VAS: Visual Analog Scale; VAS-A: Visual Analog Scale—Anxiety; VAS-S: Visual Analog Score for Satisfaction; STAI: State-Trait Anxiety Inventory; STAI-S: State-Trait Anxiety Inventory—State; STAI-T: State-Trait Anxiety Inventory–Trait; BP: Blood Pressure; SBP: Systolic Blood Pressure; DBP: Dyastolic Blood Pressure; HR: Heart Rate; BB: Binaural Beats; STAI-6: State-Trait Anxiety Inventorysix-item short-form; STAI-Y: State-Trait Anxiety Inventory Y form; DCG: Diagnostic Cystoscopy Group; USRG: Ureteral Stent Removal Removalgroup; DMPS: Dynamic Multi-Spectrum Phase Shift; PHQ-9: Patient Health Questionnaire; EQ-5D: Euro Quality of Life Five-Dimension; MARS: Medication Adherence Rating Scale; EEG: Electroencephalogram; EKG: Electrocardiogram; NC: Noise Canceling.

3.2. Assessment Tools

In this literature review, eligible studies used several assessment tools to evaluate the effect of binaural beats on anxiety and depression and the effects of binaural beats on gait in a neurological pathology. EEG represents another type of assessment, evaluating how binaural beats can modulate the band power of a specific pattern.

3.3. Anxiety Evaluation

Recently, medical experts have been investigating the possible benefits of this new technology as an adjunct therapy for the treatment of anxiety.

Most of the studies included in this literature review included an anxiety evaluation using either the State-Trait Anxiety Inventory (STAI) [33] questionnaire or the Visual Analog Scale for anxiety [34,35]. Seven studies applied the STAI questionnaire [20,23,25–28,30], while VAS was only used in five papers [19,24,25,27,31]. For the studies using the STAI test as the primary evaluation standard, Padmanabhan, R. et al. [20] stated that in the initial assessment, no differences were found in the "trait" part of the questionnaire (STAI-T) between the three groups. In contrast, for the STAI-S (State) questionnaire, the binaural beats group scored highest on the initial assessment among the three groups. In the final assessment, patients in the group using binaural beats showed a decrease in the STAI-S score of 26.3% ($p = 0.001$ vs. audio group, $p < 0.0001$ vs. no intervention group) compared to the audio group, which showed a decrease of 11.1%, and the no intervention group showed a decrease of only 3.8%. In addition, Opartpunyasarn, P. et al. [23] obtained a significative reduction in the STAI-S score compared to the control condition ($p = 0.009$). Olcucu et al. [27] used the STAI-S evaluation to determine the change in anxiety symptoms for their two types of medical procedures. They showed a decrease in the STAI-S scores for both study groups when comparing the experimental condition with the control condition, and $p < 0.001$ for the DCG group and the USRG group. On the other hand, Wiwatwongwana, D. et al. [26] concluded that the anxiety score evaluated with the STAI questionnaire decreased and patients felt fewer anxious symptoms, but when the comparison between the experimental group and the music group was made, the result did not offer a significant value from a statistical point of view. Compared with the no-intervention group, the STAI-S score was statistically significant at $p < 0.001$.

The following method of evaluating the effect of binaural beats on anxiety was represented by VAS [36]; Isik et al. [19] used the VAS scale to evaluate the effects of binaural beats on anxiety before a medical procedure. An evaluation after the intervention showed that the patients in the experimental group felt an improvement in the degree of anxiety compared to the control group with $p < 0.001$. In another study conducted by Menziletoglu, D. et al. [25], it was found that between the binaural group and the control group, there was a statistically significant difference in the VAS score at $p = 0.003$, but at the same time, there were no differences between the binaural beats group and the music group with a p-value of 1.

Another form of assessment for anxiety involves measuring the blood pressure and heart rate. We found five eligible studies that used the BP and HR to assess the degree of anxiety felt by patients [23,25,26,31,32]. One of the studies was conducted by Opartpunyasarn, P. et al. [23]. They concluded that using binaural beats reduced systolic blood pressure by an average of 9.89 ($p = 0.002$) compared to the music and control groups, where they did not find significant differences in systolic blood pressure. In the same study, diastolic blood pressure decreased in the binaural group compared to the control group, with a p-value of $p = 0.016$. Wiwatwongwana, D. et al. [26] measured the heart rates of the patients undergoing cataract surgery to assess their anxiety symptoms. They noted that within the 20 min after the surgery began in the binaural group, the heart rates of the patients were lower compared to those of the music-only group ($p < 0.05$) and the control group ($p < 0.001$).

3.4. Depression Assessment

Among the studies under review, Daengruan et al. [29] examined the impact of binaural beats on individuals diagnosed with depression. The researchers employed the PHQ-9 [37] scale to compare outcomes between groups and across multiple assessments. Their analysis of the PHQ-9 scores revealed a decrease in depression symptoms during the second and third evaluations, conducted at 4 weeks and 8 weeks, respectively, for the group exposed to binaural beats. Additionally, to support their conclusion regarding the efficacy of binaural beats in alleviating depression symptoms, they did not observe significant differences in the PHQ-9 scores among the other two groups at any point during the study [29].

3.5. Gait Assessment in Neurologic Pathology

Among the studies eligible for this review, one investigated the use of binaural beats as a therapeutic intervention for individuals diagnosed with Parkinson's disease. Galvez et al. [30], in addition to assessing anxiety levels, explored the potential impact of binaural beats on the gait patterns of patients. Upon conducting their assessments, they did not observe any significant association between binaural beats and gait, except for an increase in patients' cadence when exposed to music tuned at 120 beats per minute (bpm).

3.6. Binaural Beat Pattern

A crucial consideration in implementing binaural beat therapy is the choice of a pattern that aligns with the specific objectives of the researchers. Across the articles examined in this literature review, various binaural beat models have been employed despite the authors sharing similar goals.

In this literature review, the researched studies used different patterns of binaural beats, including five that used the alpha pattern [19,24,25,27,29], two that used a combination of alpha and beta patterns [23,26], one that used the beta pattern [30], and one that used the delta pattern [31], and there were two studies in which the authors did not disclose the type of binaural beat pattern used [20,32]. In the case of Parodi et al.'s [28] study, the authors used DMSPS software, an algorithm that uses more than one frequency inside of a band, which changes automatically.

3.7. Carrier Frequencies

It is apparent that a broad spectrum of carrier tones exists across different studies, showcasing the variability and adaptability of this therapeutic approach. For instance, in the study by Isik et al. [19], carrier tones with frequencies of 200 Hz for the left ear and 209.3 Hz for the right ear were used, therefore resulting in the generation of binaural beats with a frequency of 9.3 Hz, which aligns with the alpha pattern. In the study conducted by Menziletoglu et al. [25], a 432 Hz sound (considered the "perfect frequency") was compared with binaural alpha beats. This time, compared to the previously presented study, the authors used carrier tones of 220 Hz and 210 Hz, respectively. Galvez et al. [30] used lower carrier tones than other authors, namely 154 Hz for the left ear and 168 Hz for the right ear.

3.8. Intervention Time

One crucial aspect to consider when using binaural beats as a complementary therapy is the duration of patient exposure. In some studies, the therapy is administered for relatively short periods; for instance, Isik et al. [19] applied the therapy for 10 min. Conversely, other research advocates for longer exposure times. For example, Padmanabhan et al. [20] recommended 30 min for an optimal therapeutic effect. This variability in exposure duration underscores the need for further investigation into the optimal duration of binaural beat therapy sessions to maximize the therapeutic benefits while ensuring patient comfort and compliance. The most extended duration of binaural beat therapy application observed among the studies included in this review was 60 min, as documented in the studies conducted by Wiwatwongwana D. et al. [26] and Opartpunyasarn P. et al. [23]

The rationale behind this extended period of therapy is attributed to its concurrent use during medical procedures, such as cataract surgery and fiberoptic bronchoscopy, in which patients require sustained support and relaxation.

3.9. Pure Binaural Beats or Masking with Sound

An important aspect of applying binaural beats is masking them with certain sounds from nature or music rather than presenting them as two pure tones. Masking with other sounds creates a pleasant sensation for the patient, who can listen to relaxing sounds, including sounds of the rain, the ocean, or even their favorite music.

In the analyzed studies, authors such as Isik et al. [19] preferred the use of pure beats and obtained satisfactory results in terms of the patients' anxiety symptoms, while authors such as Opartpunyasarn P. et al. [23] used binaural beats in addition to sounds of a waterfall, birds chirping, and forest sounds. The authors of this study also concluded that binaural beats have a more pronounced anxiolytic effect than the control condition.

4. Discussions

Researchers support the use of this therapy to reduce and alleviate anxiety symptoms, but these effects are primarily demonstrated in the short term. The studies included in this review support the modification of patients' perceptions of anxiety symptoms, as demonstrated in the meta-analysis conducted by Garcia-Argibay et al. [38] where, in addition to the effect on anxiety, the effects of binaural beats on patients' cognition, pain perception, and moods were also evaluated. Most of the studies included in this paper assessed the effect of binaural beats on the reduction in anxiety generated by a medical procedure such as dental removal [19] or cataract surgery [26]. The intervention was mainly made before the procedure, but some authors used it even post-procedure. Further research is needed to see whether this therapy can have long-term effects.

Based on our research, we identified studies that provide evidence suggesting that the effects of binaural beats are not superior to those of music therapy. This review included three studies that did not report a significant change in anxiety levels when comparing the effects of binaural beats and music, whether the music was selected by the patients [31] or was 432 Hz music chosen by the authors [24]. This outcome may be influenced by the greater inclination of individuals to listen to music rather than use binaural beats, as music is a ubiquitous part of human life and more commonly utilized. As noted by Salamon et al. [39], music therapy can help alleviate stress and promote relaxation. Additionally, some patients may be more hesitant to engage with binaural beats than music, particularly when they can choose the music themselves.

Regarding the binaural beat pattern used to reduce anxiety symptoms, it can be seen that the alpha pattern is the most often used by authors. Although this model is found in most studies, some authors have obtained favorable results using other models, such as the delta pattern. These patterns are responsible for modifying the state of consciousness, as Lane et al. [40] stated in their study; therefore, patients can focus more on the music embedded with binaural beats than focusing on the negative part of their situation at that moment in time. An integral aspect that substantiates and enhances this argument is the conclusion drawn by Tani et al. [41]; their study indicates that binaural beats contribute to heightened patient comfort during medical procedures. Additionally, these beats foster a pleasant environment, boosting patient confidence, encouraging the willingness to return for future medical procedures, and improving compliance.

Another pivotal consideration in the implementation of binaural beat therapy is the careful selection of carrier tones employed to create frequency disparity. The choice of carrier tones plays a significant role in determining the effectiveness and specificity of the binaural beat therapy. Interestingly, this diversity in carrier tone selection persists even when the underlying frequency patterns remain consistent across studies or diverge in their objectives. Furthermore, this underscores the nuanced nature of binaural beat therapy, where researchers tailor the choice of carrier tones to suit their specific therapeutic goals and

target populations. Wahbeh et al. [42] concluded that the most efficient type of frequencies for the carrier tones are the ones between 200 Hz and 900 Hz. In the case of this review, we found a significant discrepancy in carrier tones, but on average, most of the authors preferred carrier tones close to 200 Hz.

The exposure time used for binaural beat therapy exhibits considerable variation across studies. Many authors report a preferred duration of 10 min, although there are instances where therapy is extended to 30 min. Currently, no standardized protocol clearly defines the optimal exposure time for each individual binaural pattern or specific pathology. Further research is needed to establish evidence-based guidelines that can tailor the duration of exposure to maximize therapeutic benefits for different conditions and individual patient needs.

As non-pharmaceutical methods, binaural therapy for stress and anxiety could have large population usability, considering different psychologically demanding workplaces or secondary anxiety and depression manifestations in auto-immune or neurological disorders [43]. As previously discussed in this review, anxiety and depression can emerge as significant complications for patients suffering from various diseases. One of the most common complications following a stroke is post-stroke depression [44,45]. Binaural beats have the potential to assist both patients and caregivers in managing the challenges associated with neurological pathologies regardless of the specific characteristics of the condition. These auditory stimuli may help reduce stress and anxiety levels, thereby creating a more supportive environment for coping with neurological disorders. Furthermore, binaural beats may enhance patients' motivation and desire for rehabilitation. The therapeutic effects of binaural beats, which include promoting relaxation and reducing negative emotional states, can make patients more receptive to rehabilitation efforts and more committed to their recovery processes [46]. This increased motivation is crucial, as effective rehabilitation often requires sustained effort and a positive attitude.

Incorporating binaural beats into rehabilitation protocols may also benefit caregivers, who frequently experience high levels of stress and burnout. By providing a non-invasive means of achieving relaxation and emotional stability, binaural beats can improve caregivers' well-being, enhancing their ability to provide efficient care. This holistic approach, addressing both the physical and psychological aspects of recovery, is essential for improving overall patient outcomes and ensuring a higher quality of life during and after rehabilitation. Therefore, using binaural beats holds promise for enhancing the efficacy of treatment strategies for neurological conditions [47].

Binaural beat therapy is considered cost-effective for multiple reasons [31]. First, the production of binaural beat audio tracks is relatively inexpensive, only necessitating basic audio editing software and a sound source. Once produced, these tracks can be digitally distributed at minimal cost, often offered for free or at a very low price on various platforms. Second, the equipment required to experience binaural beats is limited to a pair of stereo headphones, which are generally affordable and widely accessible. Binaural beats can be used at home without the need for frequent sessions with a professional, unlike traditional therapies, which can help eliminate ongoing costs associated with therapist visits. Access to high-quality binaural beat recordings is available through many apps and online resources without subscription fees, further reducing the financial barrier to entry. Binaural beats offer an economically accessible option for many people due to their low production and distribution costs, along with the ability to self-administer the therapy.

After reviewing the studies that met the inclusion criteria, it is clear that most authors reported positive outcomes regarding the effect of BB on anxiety symptoms. Specifically, the authors noted reductions in blood pressure (BP) and heart rate (HR) [25,26], which are physiological indicators of anxiety that are particularly prevalent in patients preparing for surgery. Furthermore, BB seems to influence a decrease in scores recorded in the final assessments of anxiety and depression, indicating increased relaxation among patients, potentially enhancing their quality of life. The authors preferred to use low frequencies, including alpha, beta, and delta waves, which can cause alterations in brain wave patterns

observed using EEG [48]. An example of this effect is demonstrated in the study by Galvez et al. [30]. Patients who were stimulated with a beta band model showed a decrease in theta band power according to the EEG. The papers included in this review mostly focused on anxiety as a secondary disorder caused by another illness or stress. To develop a treatment that can be universally applied, further research into the long-term impacts is required.

Concerning the assessment of depression, only one study [29] meeting the inclusion criteria was identified in the databases. The authors of this study concluded that exposure to binaural beats helped to reduce depression levels, as measured using the PHQ-9 scale. Similar to the effects of binaural beats on anxiety studies, the authors used alpha waves. Notably, the effects identified in this study persisted over a longer duration of binaural beat exposure, specifically 4 and 8 weeks, compared to the previously presented studies where the authors only used binaural beats for shorter sessions.

This study has the advantage of promoting the use of BB for treating specific conditions like anxiety and depression. It can be a starting point for future studies to explore its potential as an additional therapy in other medical fields. However, this review has some limitations. There is a significant variation in the research, with anxiety being studied in different diseases, each affecting patients' quality of life differently. This means that patients may experience and describe anxiety in various ways. Additionally, there is a low number of studies in this area, and the review only includes studies written in English, potentially excluding significant research published in other languages.

5. Conclusions

Binaural beats present a cost-effective and user-friendly method for alleviating the symptoms of anxiety and depression. However, thorough research is necessary to establish a standardized protocol that includes the correct patterns, carrier frequencies, and exposure times for each type of pathology. As an emerging technology, binaural beats can enhance patient compliance with conventional medical therapies and increase their willingness to undergo proposed treatments by incorporating music, which is widely appreciated and accessible.

Moreover, binaural beat therapy can be administered at home, making it a convenient option that can help reduce the financial burden on the global medical system. This accessibility allows patients to engage in therapeutic activities without frequent hospital visits, thereby saving costs and resources for patients and healthcare providers. Additionally, the low incidence of adverse effects associated with binaural beats, compared to medication or standard therapies, makes it a safer alternative for managing mental health symptoms. This minimal risk profile further supports its potential as a supplementary treatment in clinical practice, providing a non-invasive and economically feasible option for enhancing patient care and well-being.

Further studies are necessary to establish standardized protocols for using binaural beats across a broader range of pathologies, such as neurologic disorders. This would enhance binaural beats' efficacy and reliability as a therapeutic tool, potentially expanding their use in clinical settings and improving patient outcomes across diverse medical conditions.

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