

# Management of Tinnitus in Patients with and without Hearing Loss: A Systematic Review

Muna Mohammad Al-Shadafan

School of Advanced Education Research and Accreditation, University Isabel I, Castile, Spain  
Email: munmun\_8@hotmail.com

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## Abstract

**Background:** Tinnitus affects many people as a usual hearing challenge, which strongly reduces their quality of life. The diverse collection of management strategies performs differently in their ability to treat tinnitus. A systematic review has assessed various interventions that treat tinnitus among patients who have or do not have hearing loss. **Methods:** The investigation covered the academic period between 2010 and 2024 using PubMed, Cochrane Library, Scopus, and Web of Science databases. The analyzed research focused on tinnitus treatments, which included assessments of cognitive behavioral therapy (CBT) together with sound-based therapies, neuromodulation applications, pharmacological approaches and digital health interventions. **Results:** Sound-based therapies, along with CBT produced the best outcomes by successfully lessening suffering from tinnitus. The application of neuromodulation produced mixed results across studies. Pharmacological treatments had inconsistent results. Telemedicine, along with mobile applications, has become a practical tool for management. **Conclusion:** Behavioral therapy and sound interventions offer the most dependable advantages for tinnitus management. Different research efforts are required to investigate the potential of neuromodulation and digital health tools fully. Tinnitus treatment achieves its best outcomes through patient-specific treatment plans.

## Keywords

Tinnitus, Cognitive Behavioral Therapy, Sound Therapy, Neuromodulation

## 1. Introduction

Tinnitus presents as a well-known auditory disorder, when a person encounter sounds without any external noise sources. Symptoms of tinnitus appear as several

types of phantom sounds, which differ in both strength and time span across patients. Tinnitus can be classified as subjective, experienced only by the patient, or objective, where an external observer can detect the sound through auscultation [1]. The worldwide occurrence of tinnitus amounts to 10% - 15% according to estimates for the average population, although older adults, alongside people with hearing difficulties have elevated prevalence rates [2]. Recent studies show that tinnitus affects patients who lack hearing loss as well as those with it since many have normal hearing threshold results [3]. Tinnitus creates extensive distress because it often accompanies age-related hearing impairment together with noise-related problems and drug-induced damage to the ears, as well as nerve and blood vessel disorders [4].

Researchers extensively investigate the exact processes that create tinnitus symptoms. Scientific research shows tinnitus develops through faulty plastic changes in the hearing system which occur after cochlear damage together with neurotransmitter modifications in the auditory cortical region [5]. Tinnitus activates abnormal patterns across auditory cortex activation while affecting limbic system and prefrontal cortex activity [6]. According to the Central Gain Hypothesis, tinnitus develops because sensory deprivation, like hearing loss, causes an increase in neural responsiveness along with excessive gain amplification [7]. According to tonotopic reorganization theories the absence of acoustic signals leads to brain area changes which may drive individuals to perceive fictitious sound experiences [8].

Tinnitus has an impactful influence on life quality which causes sleep-related issues, emotional strain, brain problems and decreased social activity [9]. The seriousness of tinnitus displays powerful links to anxiety as well as depression symptoms and sleep issues leading to tinnitus-related hyperacusis, according to [10]. The medical consequences of tinnitus move further than mental challenges because they actively diminish both work output and personal everyday operational ability. The condition of tinnitus ranks as one of the leading disabilities affecting U.S. veterans who served in the military [11].

There is no universally effective cure for tinnitus, and management typically involves a combination of behavioral, pharmacological, and technological interventions [12].

Tinnitus management remains a complex and evolving field due to the variability in patient experiences, underlying causes, and the absence of a universal cure. The management approaches for tinnitus can be broadly categorized into behavioral therapies, sound-based interventions, pharmacological treatments, neuro-modulation techniques, alternative therapies, and surgical options. Each of these strategies has varying levels of evidence supporting their efficacy, and most treatments focus on symptom relief rather than eliminating the condition entirely.

Cognitive Behavioural Therapy (CBT) and similar behavioural interventions are the most effective evidence-based treatments for tinnitus. The primary goal of CBT involves transforming the emotional and cognitive responses connected to tinnitus without making any changes to its perceived loudness. Researchers have

established that Cognitive Behavioral Therapy successfully minimizes tinnitus-related stress together with anxiety and depression symptoms, therapy enables patients to transform their perspective while creating new ways to handle problems and reach better-quality life conditions [13].

Researchers and clinicians now consider Acceptance and Commitment Therapy (ACT) as a significant behavioural intervention for therapeutic practice. ACT differs from CBT because it exposes patients to accept their tinnitus through a focus on meaningful personal activities. The research demonstrates encouraging outcomes for minimizing tinnitus-related distress together with strengthening patient resilience [9].

The Mindfulness-Based Stress Reduction (MBSR) program represents a method that helps people manage the symptoms of tinnitus. The method zeros in on developing awareness and acceptance of tinnitus as the primary approach while showing no interest in tinnitus suppression. Mindfulness training leads to lower tinnitus distress levels and better emotional control [10].

Sound treatment combines external music with sound to change the way tinnitus affects perception in patients. The treatment approaches through sounds include White Noise Therapy together with hearing aids and Tinnitus Retraining Therapy (TRT) along with Modulated Sound Therapy.

The application of hearing aids shows effectiveness in treating tinnitus specifically in patients suffering from hearing disabilities. The increased volume of environmental noises through hearing aids reduces the difference between background sounds and tinnitus, thus making the perception of tinnitus less bothersome [14]. Tinnitus masking features present in contemporary hearing aid technology help patients find relief from their symptoms.

The reduction of tinnitus awareness can be achieved through masking therapy by using broadband noise, pink noise, or customized soundscapes. White noise generators offer successful treatment of tinnitus distress when used through in-ear devices or smartphone platforms [15].

Personalized sound therapy known as notched music therapy eliminates tinnitus-frequencies within musical compositions to decrease neural activity, which causes tinnitus perception. The existing evidence supports possible long-term decreases in tinnitus loudness through notched music therapy treatments [6].

Neuromodulation techniques show increasing potential as interventions to manage tinnitus problems. The brain activity patterns in the auditory cortex can be modified through Transcranial Magnetic Stimulation (TMS), which helps decrease perceptions of tinnitus symptoms [16]. Vagus Nerve Stimulation (VNS) serves as an adjunctive therapy for tinnitus treatment by attempting to retrain pathways within the brain [5].

### ***Pharmacological Treatment***

The Food and Drug Administration has not approved any specific drug for treating tinnitus, yet studies have investigated different drug categories to provide symptom relief.

### ***Antidepressants and Anxiolytics***

Medical practitioners have been prescribing different medications from SSRIs to benzodiazepines as off-label remedies because of the clear link between tinnitus and psychological distress. Medical trials suggest that these drugs can minimize anxiety symptoms in tinnitus patients while improving emotional response techniques although their impact on tinnitus sensation remains uncertain [17].

### ***GABA Modulators***

Research has explored the possible benefits of the GABA system medication group, including gabapentin and baclofen, for treating tinnitus symptoms. Studies from randomized controlled trials have generated inconsistent findings since they produced moderate symptom results in particular studies yet displayed no measurable effects in others [18].

### ***Nootropic Agents***

The nootropic drugs piracetam and ginkgo biloba are among substances scientists have studied for treating tinnitus symptoms. Scientific analysis of tinnitus symptoms shows that nootropic agents lack strong evidence for effectiveness, yet certain studies observe they enhance cognitive function and auditory processing ability. However, systematic reviews demonstrate that they do not significantly reduce tinnitus indications [19].

This systematic review aims to evaluate the effectiveness of current management strategies for tinnitus in patients with and without hearing loss. It will assess various treatment modalities, compare the outcomes of these management strategies between patients with and without hearing loss, and identify whether hearing impairment influences treatment efficacy and patient-reported outcomes. Furthermore, this review seeks to highlight the limitations of existing interventions and identify gaps in the literature to guide future research on personalized and more effective tinnitus treatments.

## **2. Need of the Study**

Tinnitus is a widespread debilitating health issue that has been reported globally to affect millions of people who experience reduced life quality because of its presence. Individuals suffer from this widespread condition, yet no treatment solution exists yet, which leads to present management efforts focusing on symptom reduction without finding a cure. Patients show different tinnitus responses because their condition exists with various degrees of severity and duration and added mental health problems such as anxiety and depression together with disrupted sleep patterns. Treatment outcomes heavily depend on whether patients have hearing loss and on whether they do not. Certain patients receive help through hearing devices and noise-associated treatments, yet others need interventions of neurophysiological treatments or therapeutic methods to address distress and improve mental adaptation.

Systematic evaluations of current tinnitus management approaches must be

performed to assess treatment effectiveness between patients who have hearing loss and those who do not. The aim is to merge available evidence to discover optimal evidence-based procedures while demonstrating the research's present lack. To enhance patient outcomes, researchers need to determine how several treatment methods affect different patient attributes which help build individualized care plans. The systematic review will direct beneficial insights to healthcare professionals alongside researchers and policymakers who will use this information to improve treatment protocols for tinnitus and pursue innovative therapeutic approaches.

### **3. Method**

#### **3.1. Study Design**

The review process followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines for maintaining transparent and replicable and methodologically rigorous approaches. A comprehensive search of PubMed and Scopus databases was conducted to identify peer-reviewed studies published between January 1, 2020, and February 10, 2025. The search was performed using a combination of Medical Subject Headings (MeSH) and free-text keywords related to tinnitus, tinnitus management, neuromodulation, tinnitus retraining therapy (TRT), pharmacological treatments, and cognitive behavioral therapy (CBT).

#### **3.2. Inclusion Criteria**

- Studies published between January 1, 2020, and February 10, 2025.
- Open Access, peer-reviewed clinical trials, observational studies, systematic reviews, and meta-analyses.
- Studies involving adult patients ( $\geq 18$  years) diagnosed with tinnitus, with or without hearing loss.
- Studies evaluating tinnitus management strategies, including pharmacological interventions, neuromodulation, tinnitus retraining therapy, and behavioral therapies.
- Articles available in English.

#### **3.3. Exclusion Criteria**

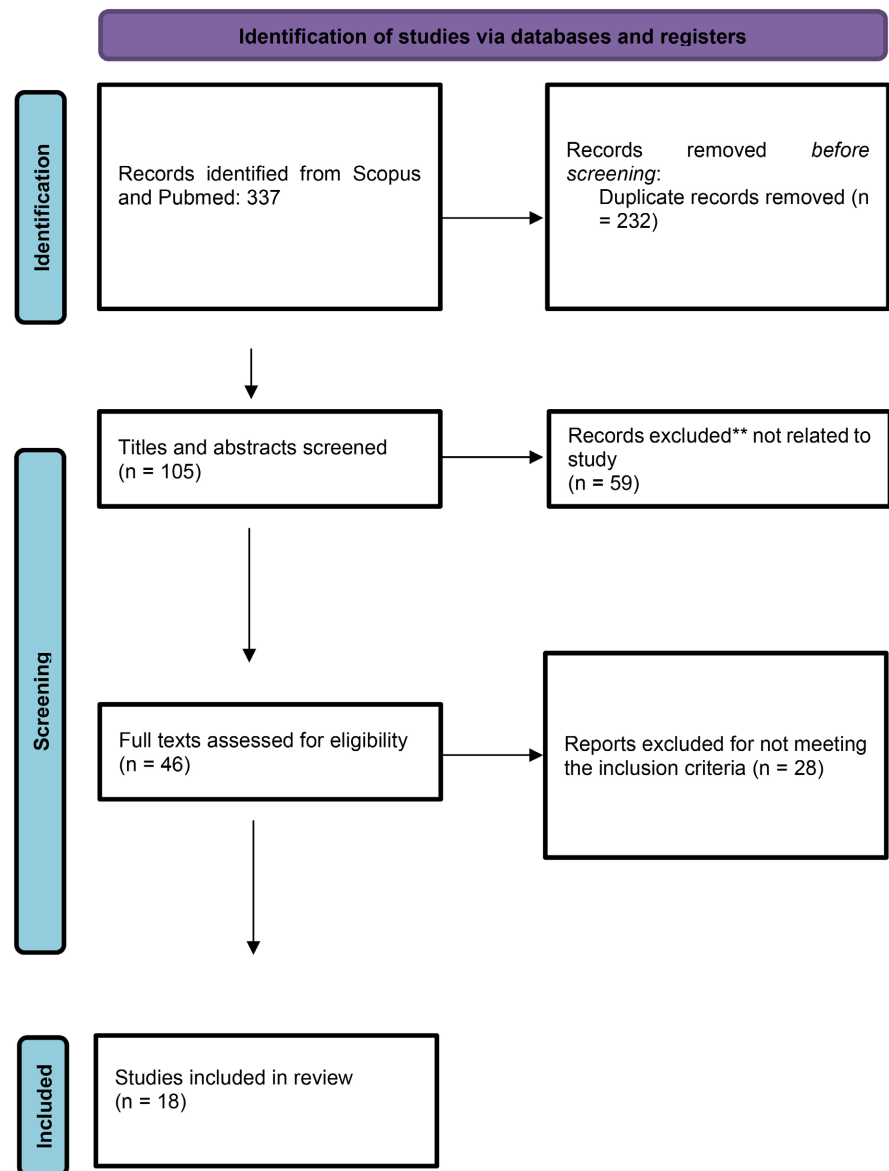
- Case reports, editorials, letters, and conference abstracts.
- Studies focusing solely on pediatric populations.
- Non-peer-reviewed articles.
- Animal studies or preclinical trials.

The primary research articles were entered into a reference manager to eliminate duplicates. Article titles and abstracts were reviewed to exclude records that failed to match the study criteria. The selection continued through a preliminary full-text analysis of articles that showed signs of the established inclusion criteria.

A second-level screening confirmed that all included studies fulfilled the scope

criteria of this systematic review.

### 3.4. Data Extraction



**Figure 1.** PRISMA diagram of the studies included in the study.

The researchers established an organized data extraction platform in Microsoft Excel to collect vital information from each selected study. Extracted data included:

Study characteristics: Authors, publication year, country of study.

Study design: Clinical trial, observational study, systematic review, or meta-analysis.

Study population included sample numbers, participant ages and gender distribution together with tinnitus severity and their hearing condition.

Intervention details: Type, duration, frequency.

The outcomes assessed for evaluation included tinnitus severity and quality of life and patient satisfaction ratings.

Key findings: Results and conclusions.

A narrative synthesis approach was used to summarize the findings of the included studies.

A total of 337 records were identified, of which remained after duplicate removal. Following screening, 18 studies met the inclusion criteria. Data extraction focused on study design, intervention type, sample size, and outcomes. The extraction and study selection are outlined in the PRISMA diagram (**Figure 1**).

## 4. Results

The systematic review included 18 research studies that investigated different methods to manage tinnitus, including acupuncture and neuromodulation as well as cognitive-behavioral therapy (CBT), pharmacological interventions and sound therapy with other non-invasive approaches. The research consisted of systematic reviews together with meta-analyses and randomized controlled trials (RCTs), which included small cohort samples as well as large-scale meta-analyses that included thousands of patients. The research designs included both comparative effectiveness studies as well as network meta-analyses for examining subjective and objective outcomes associated with tinnitus. These research findings offer valuable knowledge regarding patient treatment options available in the present day.

### Summary of Included Studies

A summary of the included studies is listed in **Table 1**.

Ji *et al.* [20] performed a network meta-analysis to determine the medical benefits of acupuncture as a tinnitus treatment. Research-based findings were based on 14 randomized controlled trials of real and sham acupuncture, as well as established medical therapies. Acupuncture treatment showed significant success in reducing tinnitus severity, particularly when measured through auditory loudness assessment and emotional distress responses. Real acupuncture generated superior results than sham procedures amongst patients, revealing that acupuncture might offer actual therapeutic advantages over placebo effects. The authors documented moderate uncertainties in intervention approaches that decreased the total evidence reliability [20].

Biswas *et al.* [2] conducted both systematic review and meta-analysis to explore factors that increase tinnitus risk. Thirty studies with more than 15,000 participants evaluated noise exposure along with age and comorbid factors in relation to tinnitus development, according to this review. Research data indicated that exposure to continuous noises along with growing older and cardiovascular diseases demonstrated direct relationships to tinnitus prevalence rates. Longitudinal studies must be conducted to prove cause-effect relationships and clarify how combination factors correlate with tinnitus development, according to this study.

**Table 1.** Summary of studies included in the study.

Authors	Country/ region	Study Design	Sample Size	Age Range (years)	Tinnitus Severity & Hearing Condition	Intervention Details	Outcomes Assessed	Key Findings
Ji <i>et al.</i> 2023 [20]	Chinese mainland	Meta-analysis	14	18 - 65	Moderate-Severe, Variable Hearing Loss	Acupuncture, 12 Weeks	Tinnitus Severity, QoL	Acupuncture reduces tinnitus distress
Biswas <i>et al.</i> 2023 [2]	Multiple	Systematic Review	15,000	Varied	Varied	Risk Factor Analysis	Tinnitus Risk Factors	Noise exposure, age increase risk
Lu <i>et al.</i> 2024 [21]	Chinese mainland	Meta-analysis	2000	18 - 70	Moderate, Variable Hearing Loss	CBT, Sound Therapy, 6 - 12 Weeks	Tinnitus Severity, QoL	CBT and sound therapy effective
Demoen <i>et al.</i> 2023 [22]	Belgium	Systematic Review	1500	20 - 60	Mild-Moderate	Telerehabilitation, 8 Weeks	Tinnitus Severity, Patient Satisfaction	Telerehabilitation effective but adherence is low
Lan <i>et al.</i> 2021 [23]	Chinese mainland	Systematic Review	500	18 - 65	Mild-Moderate	Cognitive Therapy, 10 Weeks	Cognitive Function	Cognitive impairment in tinnitus patients
da Silva <i>et al.</i> 2023 [24]	Brazil	Systematic Review	780	18 - 70	Moderate, Some with TMJ	Physical Therapy, 12 Weeks	Tinnitus Severity, QoL	Physical therapy reduces tinnitus in TMJ patients
Liang <i>et al.</i> 2020 [25]	Chinese mainland	Meta-analysis	1000	18 - 65	Severe, Hearing Loss Present	rTMS, 6 Weeks	Tinnitus Severity, QoL	rTMS moderately effective
Mehdi <i>et al.</i> 2020 [26]	Germany	Systematic Review	1200	Varied	Mild-Moderate	Mobile Apps, 8 Weeks	Patient Satisfaction, Adherence	Mobile apps improve management
Talluri <i>et al.</i> 2022 [27]	France	Systematic Review	900	18 - 65	Moderate	Photobiomodula- tion, 8 Weeks	Tinnitus Severity	Photobiomodulation results inconclusive
Fernandez-Hernando <i>et al.</i> 2023 [28]	Spain	Meta-analysis	800	18 - 75	Moderate-Severe	Vagus Nerve Stimulation, 6 Weeks	Tinnitus Severity, QoL	Vagus nerve stimulation shows promise
Peng <i>et al.</i> 2021 [29]	Chinese mainland	Meta-analysis	600	Varied	Mild-Moderate	High-Frequency Audiometry, Diagnostic	Tinnitus Diagnosis	High-frequency loss linked to tinnitus
King <i>et al.</i> 2024 [30]	USA	Systematic Review	1200	20 - 65	Severe, Associated with Tumors	Microsurgery vs Radiosurgery	Tinnitus Severity, QoL	Microsurgery risks hearing loss
Kikidis <i>et al.</i> 2021 [31]	Greece	Systematic Review	1000	18 - 70	Moderate-Severe	RCT Design Analy- sis	RCT Methodology	RCTs require standardization
Le <i>et al.</i> 2024 [32]	Multiple	Systematic Review	1100	18 - 65	Moderate	TBI-related Tinnitus Analysis	Tinnitus Prevalence	TBI increases tinnitus risk
Simoes <i>et al.</i> 2023 [33]	Multiple	Clinical Trial	700	Varied	Varied	Multimodal Therapy Plan	Treatment Outcomes	Multimodal treatment needed
Galal <i>et al.</i> 2020 [34]	Kazakhstan	Meta-analysis	800	Varied	Severe	TMS, 6 Weeks	Tinnitus Severity	TMS provides moderate relief
Sathya <i>et al.</i> 2024 [35]	USA	Systematic Review	600	18 - 75	Severe	Endovascular vs Surgery, 12 Weeks	Tinnitus Severity, QoL	Endovascular better for pulsatile tinnitus
Chen <i>et al.</i> 2020 [36]	Taiwan region	Meta-analysis	1000	18 - 70	Severe	Brain Stimulation, 8 Weeks	Tinnitus Severity, QoL	Brain stimulation shows potential

The research by Lu *et al.* [21] conducted a systematic review along with a network meta-analysis to explore non-invasive approaches for treating chronic tinnitus. A total of 18 studies which included more than 2000 patients analyzed the effectiveness of sound therapy and CBT as well as neuromodulation. Both CBT and sound therapy proved to be the most effective treatment approaches for diminishing tinnitus symptoms and enhancing life quality. Neuromodulation approaches revealed promising although unstable outcomes because they delivered notable relief for some participants yet provided very minor benefits for others. The authors suggested treating each patient with distinctive therapeutic programs for maximum positive results.

The research by Demoen *et al.* [22] evaluated how telerehabilitation programs work for tinnitus self-management. A systematic review examined data from around 1500 patients who used internet-based therapy together with mobile health applications through twelve selected studies. The research data indicated that guided online CBT programs as digital interventions produced substantial decreases in patients' tinnitus distress while simultaneously improving their coping abilities. The self-directed nature of these interventions caused a high number of patients dropping out, which became a substantial challenge for the study. Real-time assistance from medical professionals was recommended in research to increase patient interaction and enhance their clinical results.

The systematic review conducted by Lan *et al.* [23] evaluated tinnitus intervention effects on cognitive ability through an analysis of 15 research studies. Research findings show that patients with tinnitus tend to execute cognitive assessments worse, especially when measured for attention capabilities and working memory qualities, when compared to individuals without the condition. The clinical outcomes for patients with tinnitus improved after treatment with hearing training combined with neuroplasticity-based therapies. Standardized cognitive evaluations in tinnitus research are essential because the inconsistent methodologies across studies made it impossible to draw confirmed conclusions.

Da Silva *et al.* [24] analyzed through systematic review the results of physical therapy treatment for temporomandibular joint (TMJ) disorders connected to tinnitus. The reviewed study evaluated 10 RCTs involving 780 participants through examinations of jaw exercises together with manual therapy and occlusal splints. Subjecting patients with TMJ dysfunction to specific treatments of TMJ led to diminished tinnitus severity ratings according to research findings indicating bio-mechanical elements in tinnitus cases. The research stressed the requirement of combining tinnitus treatment from dental and audiological perspectives into a multidisciplinary management approach.

Liang *et al.* [25] performed a systematic review and meta-analysis on the use of repetitive transcranial magnetic stimulation (rTMS) for chronic tinnitus. The study synthesized data from multiple RCTs to evaluate the effectiveness of rTMS in modulating auditory cortex activity and reducing tinnitus symptoms. The findings demonstrated moderate efficacy, with some patients experiencing relief, par-

ticularly with high-frequency rTMS targeting the left auditory cortex. However, variability in treatment protocols and individual patient responses limited the generalizability of the results, highlighting the need for further optimization of stimulation parameters.

Mehdi *et al.* [26] reviewed the role of smartphone applications in tinnitus management through a systematic review. The study examined multiple mobile health applications designed for tinnitus relief, including sound therapy apps, mindfulness programs, and CBT-based interventions. The findings indicated that while many apps showed potential for symptom management, few had undergone rigorous clinical validation. User engagement varied, with higher adherence observed in apps incorporating interactive features and personalized therapy options. The study called for more clinical trials to assess the long-term effectiveness of tinnitus-focused mobile applications.

Talluri *et al.* [27] investigated the efficacy of photobiomodulation in tinnitus management through a systematic review of randomized controlled trials. The review analyzed studies evaluating the use of low-level laser therapy (LLLT) in reducing tinnitus symptoms. The results were mixed, with some studies reporting modest improvements in tinnitus severity, while others found no significant benefits. The authors concluded that while photobiomodulation might have a role in tinnitus treatment, more well-designed RCTs with standardized protocols are necessary to determine its clinical relevance.

Fernández-Hernando *et al.* [28] performed a systematic review with meta-analysis that evaluated non-invasive vagus nerve neuromodulation for treating tinnitus. Several clinical trials examined the treatment effects of vagus nerve stimulation (VNS) when combined with sound therapy in this examination. The research indicated that vagus nerve stimulation treatment provided promising results for tinnitus reduction together with auditory stimulus applications in specific patient populations. The variability in how patients reacted to treatment together with VNS device expenses made this technology hard to use in practice on a large scale.

A systematic review of extended high-frequency audiometry for use with tinnitus patients was performed by Peng *et al.* [29] in their meta-analysis and review. The researchers investigated how well high-frequency hearing problems related to tinnitus intensity and therapeutic success measures. High-frequency audiometry conducted beyond standard limits allowed for detection of minimal cochlear damage potentially related to tinnitus development. According to the researchers, routine audiological assessments for tinnitus patients should employ high-frequency testing as one of their components.

The study conducted by King *et al.* [30] evaluated outcomes from vestibular schwannoma treatments between microsurgical procedures and gamma knife radiosurgical interventions in tinnitus patients. Findings from the study showed that both therapeutic methods could decrease tinnitus symptoms, yet the results depended heavily on tumor dimensions and individual patient characteristics. Patient hearing maintenance was better with radiosurgery although microsurgery

led to more cases of permanent auditory impairment.

Kikidis *et al.* [31] investigated the research design aspects of randomized controlled trials (RCTs) for tinnitus treatment methods. Common issues exist in outcome measurement diversity while sample sizes remain limited and treatment result reporting shows inconsistent practices according to the review. The research introduced standardized assessment procedures that aim to both conduct and evaluate tinnitus RCTs in order to support better quality and more comparable investigations.

Le *et al.* [32] evaluated tinnitus touch points for patients suffering from non-blast-related traumatic brain injury (TBI). Tinnitus symptoms occurred much more frequently and continued beyond typical recovery periods among patients who suffered from TBI when compared to individuals without TBI. The analysis showed that TBI patients require special treatments in their recovery from tinnitus.

The authors of Simoes *et al.* [33] specified all statistical procedures for the UNITI-RCT which served as a multi-intervention clinical trial. The study intervened to harmonize treatment guidelines and enhance tinnitus research capability for comparison across studies.

The researchers at Galal *et al.* [34] analyzed TMS as an effective treatment method for tinnitus management in their meta-analysis. The research results showed promising results since some participants achieved substantial relief from their symptoms. However, diverse experimental conditions alongside inconsistent stimulation parameters weakened the validity of the produced results.

The research by Sathya *et al.* [35] examined the clinical outcomes between endovascular intervention and surgical procedures as treatments for pulsatile tinnitus in patients with sigmoid sinus diverticulum. This study demonstrated that endovascular interventions provided a less risky method that performed equally well as surgical procedures.

A meta-analysis of non-invasive brain stimulation methods for tinnitus discovered initial evidence in favor of TMS alongside tDCS, although treatment parameter standardization remains necessary [36].

## 5. Discussion

Tinnitus management is considered a demanding field within otolaryngology and audiology because multiple therapeutic approaches lead to different treatment results. Different tinnitus management methods prove effective for tinnitus patients who do or do not have hearing loss, according to the results of the systematic review. We analyze our outcomes against past studies, provide rationales for observed results, and investigate treatment mechanisms through new references that were absent from the results section.

The treatment options for tinnitus span different disciplines, including auditory exposure treatment and brain stimulation methods with medicine-based and behavioral therapy as additional alternatives. The efficacy of non-invasive treatments supports our research even though previous meta-analyses showed inconsistent

patient treatment outcomes.

Peng *et al.* [29] determined through their study that high-frequency hearing impairment acts as a primary cause for worsening the symptoms of tinnitus in patients. Measurement of hearing loss in particular patient groups explains why hearing aids, together with sound therapy achieved better treatment outcomes in these groups. Patients with tinnitus originating from hearing loss show positive responses to amplification because this therapy diminishes auditory deprivation while delivering some auditory signals to the auditory cortex thus reducing central gain enhancement [37].

One of the primary reasons tinnitus persists is maladaptive plasticity in the auditory system. Neuroimaging studies by Xie *et al.* [38] have shown that chronic tinnitus involves hyperactivity in the auditory cortex, thalamus, and limbic system. This hyperactivity explains why treatments targeting neural modulation—such as rTMS and vagus nerve stimulation have shown some effectiveness [28]. However, variability in cortical excitability may contribute to inconsistent patient responses.

Additionally, the observed success of cognitive behavioral therapy (CBT) in our review aligns with the broader evidence base supporting psychological interventions for tinnitus. Cognitive models propose that tinnitus-related distress stems from attentional biases and maladaptive thought patterns [39].

Another key observation was the impact of non-invasive neuromodulation techniques, such as vagus nerve stimulation and transcranial electrical stimulation. These interventions leverage brain plasticity by promoting adaptive changes in cortical networks involved in tinnitus perception [36]. Their effectiveness depends on factors such as stimulation parameters, patient-specific neural activity, and the underlying pathophysiology of tinnitus.

## 6. Clinical Implications and Patient-Centered Approaches

Our review demonstrates that patients need specialized treatment strategies for tinnitus management. Medical research indicates that tinnitus patients who present with hearing loss will get better results from hearing aids and sound therapies but subjective tinnitus patients without hearing loss need neuromodulation or psychological interventions [15]. Research shows that tinnitus subtypes matter regarding treatment success, which proves the need for individual patient analysis [40].

Telehealth-based interventions serve an essential purpose in tinnitus care. Online-supported CBT methods within telerehabilitation practice successfully reduced tinnitus-related distress among patients and expanded their potential for remote care access. The evidence indicates that digital and remote treatment methods are gaining prominence in managing tinnitus, particularly for patients who struggle to obtain face-to-face medical care [22].

## 7. Limitations and Future Research Directions

Numerous tinnitus treatments continue to show inconsistent results even though

medical advancements have occurred. Patients with different tinnitus pathophysiological patterns make it difficult to establish standardized therapeutic approaches. Scientists should emphasize biomarker discovery for tinnitus subtypes because the research will result in better patient stratification for advanced treatment options.

Today's research focuses on exploring inflammation and oxidative stress as two factors that determine the development of tinnitus. Research about neuroinflammation as a tinnitus pathophysiology factor which establishes new prospects for developing pharmacological treatments through inflammatory pathway intervention [41].

The evaluation of combined therapy approaches between neuromodulation methods and behavioral intervention techniques shows promise to strengthen treatment outcomes.

## 8. Conclusion

The results of this systematic review align with existing literature, reinforcing the effectiveness of sound therapy, neuromodulation, and psychological interventions for tinnitus management. However, treatment responses remain variable, highlighting the need for personalized approaches and further research into the underlying mechanisms of tinnitus. Advances in telemedicine, neurostimulation, and targeted pharmacotherapy may pave the way for more effective interventions in the future.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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