

Customized Music Therapy Combined With the Counseling and Follow-Up System: Stratified Results for Tinnitus Efficacy

Tianyi Ni, MM*, Yuehong Liu, MD*, Hongbo Xie, MD, Siyi Yang, MD, Yulu Wang, MM, Yun Jiang, MM, and Zhao Han, MD 

OTO Open
2024, Vol. 8(3):e173
© 2024 The Author(s). OTO Open published by Wiley Periodicals LLC on behalf of American Academy of Otolaryngology-Head and Neck Surgery Foundation.
DOI: 10.1002/oto.173
<http://oto-open.org>

WILEY

Abstract

Objective. Chronic subjective tinnitus is a worldwide intractable problem. In our previous studies, customized music therapy combined with a follow-up system can reduce tinnitus perception and improve anxiety/depression. This study aims to explore which characteristics of tinnitus patients are more likely to benefit from our therapy.

Study Design. This study included 1031 patients with chronic subjective tinnitus, all of whom completed customized music therapy with the follow-up system. Population demographics, tinnitus characteristics, and tinnitus-related scales at pretherapy and posttherapy were collected.

Setting. Huadong Hospital affiliated Fudan University, Department of Otorhinolaryngology-Head & Neck Surgery from 2018 to 2022.

Methods. A paired *t* test and the one-way analysis of variance were utilized to the overall efficacy and stratified difference based on tinnitus duration/age/tinnitus frequency.

Results. There were significant statistical differences in the Tinnitus Handicap Inventory (THI), Tinnitus Loudness Visual Analog Scale (VAS), and Hospital Anxiety and Depression Scale (HADS)-A/D scores between pretherapy and 3 months posttherapy. THI and HADS (A/D) scores decreased the most in the 1-year duration tinnitus group. The most significant decrease in THI and VAS scores was observed in the 31- to 50-year-old tinnitus group. Patients with high-frequency tinnitus and extended high-frequency tinnitus had greater decreases generally than those with low-frequency tinnitus though no significance.

Conclusion. Group with severe and prolonged tinnitus, shorter duration of tinnitus onset, and 31 to 50 years old benefit more from our therapy. Therefore, standardized personalized music and consulting and follow-up systems while promoting early treatment can reduce tinnitus and its comorbidities.

Keywords

chronic tinnitus, consulting, customized music, follow-up, stratified analysis, treatment

Received March 20, 2024; accepted April 14, 2024.

Tinnitus is one of the most common intractable disorders of hearing, which can be defined as the conscious perception of sound in the absence of an external acoustic source.¹ According to the European Tinnitus Guideline,² tinnitus of >6 months is considered chronic, whereas in China this duration is set at 1 year.³ Chronic subjective tinnitus sometimes turn into bothersome tinnitus, which affects life and is hard to treat clinically.⁴

The mechanism of chronic subjective tinnitus is unclear, and there is a lack of a primary etiology. At present, it is considered as the result of central remodeling after damage to the peripheral auditory system, that is, compensatory responses after deafferentation in areas such as the brainstem and subcortex.⁵ During the transition to bothersome tinnitus, abnormal discharges in the auditory neural center cause disturbances in the limbic emotional system, the autonomic nervous system, and the sleep-wake system,^{6,7} making it difficult for conventional treatments (drugs, etc) to be effective. Some forms of sound therapy can suppress or eliminate tinnitus for a long time.⁸ Music therapy combined with counseling is an important part of tinnitus treatment. Compared with the only counseling control and the counseling and placebo sound therapy control, counseling

Department of Otorhinolaryngology-Head and Neck Surgery, Huadong Hospital Affiliated Fudan University, Shanghai, China

*These co-first authors contributed equally to this article.

Corresponding Author:

Zhao Han, MD, Huadong Hospital of Fudan University, No. 221 West Yan'an Road, Jing An District, Shanghai 200040, China.
Email: sfhanzao@163.com

and conventional sound therapy increase treatment efficiency.⁹ There is no evidence that music therapy is relevant for single tinnitus quality, such as tonal-like tinnitus. By adjusting tinnitus pitch in fluctuating tinnitus, music therapy is applicable to multiple tinnitus qualities in clinical practice.

We have previously demonstrated considerable efficacy using customized music therapy combined with a complete follow-up system and found that baseline Tinnitus Handicap Inventory (THI), Visual Analog Scale (VAS), and Hospital Anxiety and Depression Scale (HADS)-A/D scores were significant influences on tinnitus efficacy.¹⁰ However, the reported efficacy in 14 tinnitus participants who completed the 6-month sound therapy via smartphone application was not significant.¹¹ In our clinical work, we have found that tinnitus patients with different characteristics, such as age, gender, and duration of tinnitus, have different treatment outcomes. It is, therefore, important to explore which characteristics of tinnitus patients are more likely to benefit from customized music therapy combined with the consulting and follow-up system and to find the explanation.

Materials and Methods

Patients

This study included patients with tinnitus as the main complaint who presented to the otolaryngology department from January 2018 to October 2022. The Ethics Committee of Huadong Hospital Affiliated to Fudan University approved this study. All patients had signed consents before therapy. Inclusion criteria included (1) subjective tinnitus, (2) age ≥ 14 years, (3) duration of tinnitus ≥ 1 year, (4) tinnitus frequency range of 125 to 16k Hz, (5) absence of organic ear pathology, (6) noise-like tinnitus, tonal-like tinnitus, cricket-like tinnitus, unknown tinnitus, and (7) ability to complete the music therapy and follow up registrations on time independently or with assistance. Exclusion criteria: (1) objective tinnitus, (2) presence of systemic diseases that can cause tinnitus (eg, diabetes mellitus, hypertension, hyperthyroidism, or hypothyroidism), (3) organic lesions of the ear (eg, otitis media, otosclerosis, cerumen impaction), (4) undergoing other treatments for tinnitus, (5) failure to register complete information about the characteristics of the tinnitus or inaccurate registration (except for the frequency), (6) poor cooperation with the examination or inability to communicate the obstacles in a normal way, (7) psychiatric disorders that are currently undergoing treatment, and (8) pregnancy.

Tinnitus Valuation

The initial diagnosis of tinnitus is made by an otologist in an outpatient otolaryngology clinic, based on a history, physical examination, and audiological examination, and includes patients with a diagnosis of "chronic subjective tinnitus." Demographic characteristics (eg, age, gender) and tinnitus characteristics (eg, loudness, frequency) were recorded. The frequency of tinnitus was measured by frequency matching on the Bozi Tinnitus Sound Therapy platform. The

THI, Tinnitus Loudness VAS, and HADS were used to indicate the severity of tinnitus and concomitant anxiety and depressive states.¹² The THI is the patient's subjective evaluation of tinnitus perception and indicates the impact of tinnitus on quality of life. A total of 25 entries were scored on 3 levels of functionality, severity, and emotionality to categorize the tinnitus group into 5 grades, with grades 1 to 5 being slight (THI of 0-16), mild (THI of 18-36), moderate (THI of 38-56), severe (THI of 58-76), and catastrophic (THI of 78-100), respectively.¹³ Higher scores or ratings represent a subjective belief that tinnitus is more disruptive to the patient's life. The VAS is the patient's subjective assessment of tinnitus loudness and ranges from 0 to 10, with tinnitus loudness being positively correlated with the score.¹⁴ The HADS consists of 2 subscales, the HADS-A (Anxiety score) and the HADS-D (Depression score), with 7 scoring items each and an overall score range of 0 to 21. Higher scores indicate more severe anxiety or depression, with scores of 8 to 10 suggesting possible anxiety or depression, and scores of 11 to 21 corresponding to significant anxiety or depression.¹⁵ The change in THI before and after treatment was used as the main evaluation criterion for efficacy. The differences in the effects of therapy among the affected groups in each stratum were explored through the stratification of tinnitus duration, age, and frequency.

Cognitive Behavioral Counseling Before Music Therapy

To improve patient compliance, each patient was provided with approximately 60 minutes of counseling prior to customizing music therapy. The main content is to introduce the core mechanism of tinnitus, with the concept of reversible central remodeling of the auditory system. Then we introduce how tinnitus affects the limbic emotional system, autonomic nervous system, and consciousness system. All the above mechanisms are explained in layman's terms to make it easier for patients to understand.

Music Production and Therapy

The process is based on the Tinnitus Assistant App, which utilizes software containing a simulated tinnitus-related brain (provided by Sound Ocean Company and approved by the US Food and Drug Administration), inverted phase editing program to customize music that is in the opposite phase of the tinnitus sound, with the same frequency and loudness, based on the principle of wave superposition. Music therapy should be performed in a relatively quiet environment. Recommended headphones should be used to avoid acoustic damage during therapy. Set the music volume to the same level as the tinnitus loudness. Try to focus on the music and not on the tinnitus during the therapy session. Three music therapy sessions per day, each greater than 30 minutes in duration, for a total of greater than 2 h/day, are recommended. For patients with fluctuating tinnitus, the music can be customized and adjusted several times.

Follow-Up and Statistical Methods

Patients included in the single-arm study underwent 3 months of music therapy and complete follow-up, with the App reminding them to complete the music on time and recording the duration of the therapy. When the App's automatic reminders were ineffective, dedicated customer service would urge them to do so again. In the process of completing the music therapy, patients could ask and communicate with the customer service at any time, and the customer service would also monitor the patient's use and provide timely feedback. At 0, 1, 2, and 3 months after treatment, patients were required to complete the THI, VAS, and HADS-A/D questionnaires. A paired *t* test was utilized to evaluate the efficacy of treatment in all patients in terms of tinnitus severity and concomitant symptoms, while the 1-way analysis of variance and least significant difference comparisons were used to show the stratified analysis of music therapy efficacy based on tinnitus duration/age/tinnitus frequency.

Results

Patients Characteristics

A total of 1031 patients were included in our study, all of whom were outpatients diagnosed as chronic subjective tinnitus. The pretherapy characteristics were displayed in **Table 1**. The average age was 42.88 ± 12.43 years old. We used 10 years as an age group to cluster all patients. There were 510 females and 521 males. The mean duration of tinnitus was 3.93 ± 7.58 years. According to tinnitus frequency, all the patients were divided into low-frequency (LF, ≤ 2 kHz), high-frequency (HF, 2 k–8 kHz), extended high-frequency tinnitus (EHF, >8 kHz), and unavailable frequency tinnitus group, respectively, accounting for 17.4%, 23.1%, 37.5%, and 22.0% of all the patients enrolled. For unavailable frequency tinnitus, we choose normal daily life sounds or electronic sounds other than pure tones to match, such as ringing, buzzing, and insect sounds. Base on the tinnitus severity scale (THI), the patients were divided into 5 groups: slight, mild, moderate, severe, and catastrophic, respectively, accounted for 5.3%, 18.7%, 29.9%, 23.1%, and 23.0% of all the patients enrolled. Confirmed or suspected anxiety/depression was present in 76.0% of all tinnitus patients. There were more tinnitus patients with anxiety alone than those with depression alone (70.0% for anxiety, and 41.8% for depression).

Stratified Analysis of Music Therapy Efficacy Based on Baseline THI Scale

Our primary basis for evaluating the efficacy of music therapy was mainly the change in tinnitus severity after

Table 1. Description of Baseline Characteristics of Patients With Chronic Subjective Tinnitus

Pretherapy characteristics	n = 1022
Age, y	42.88 ± 12.43
<31	182 (17.7%)
31-40	271 (26.3%)
41-50	287 (27.8%)
51-60	217 (21.1%)
>60	74 (7.1%)
Gender (%)	
Female	510 (49.5)
Male	521 (50.5)
Tinnitus duration, y	3.93 ± 7.58
1	614 (59.6%)
1-3	192 (18.6%)
>3 years duration tinnitus frequency, %	225 (21.8%)
LF (20-2000 Hz)	179 (17.4%)
HF (2001-8000Hz)	238 (23.1%)
EHF (8001-16,000 Hz)	387 (37.5%)
Unavailable	227 (22.0%)
Tinnitus severity levels	
Slight (0-16)	55 (5.3%)
Mild (18-36)	193 (18.7%)
Moderate (38-56)	308 (29.9%)
Severe (58-76)	238 (23.1%)
Catastrophic (78-100)	237 (23.0%)
HADS-A ≥ 8	722 (70.0%)
HADS-D ≥ 8	431 (41.8%)

HADS-A(D) ≥ 8 , confirmed or suspicious anxiety (depression).

Abbreviations: A, anxiety; D, depression; EHF, extended high frequency; HADS, Hospital Anxiety and Depression Scale; HF, high frequency; LF, low frequency.

treatment. As shown in **Figure 1**, the values of THI ($t = 21.3$, $P < .01$), VAS ($t = 18.5$, $P < .01$), HADS-A ($t = 17.5$, $P < .01$), and HADS-D ($t = 9.8$, $P < .01$) score were significantly decreased after 3 months posttherapy. **Table 2** showed that the THI scores of the slight, mild, moderate, severe, and catastrophic group decreased by -3 , 3 , 11 , 19 , and 28 points, respectively, after 3 months of music therapy. According to the THI grading stratification before and after therapy, patients in the catastrophic group had the greatest decline in THI scores.

Stratified Analysis of Music Therapy Efficacy Based on Tinnitus Duration/Age/Tinnitus Frequency

There was a stratified analysis of changes in THI, VAS, and HADS-A/D scores after 3 months of music therapy based on tinnitus duration (see **Figure 2**). After therapy, THI scores decreased by about 15 points in 1 and 1 to 3 years duration tinnitus groups, which was higher than that of over 3 years duration tinnitus group (a decrease of 11 points). However, only significance was shown between 1 year and over 3 years duration tinnitus group ($P = .01$). In terms of VAS, the decrease in scores was

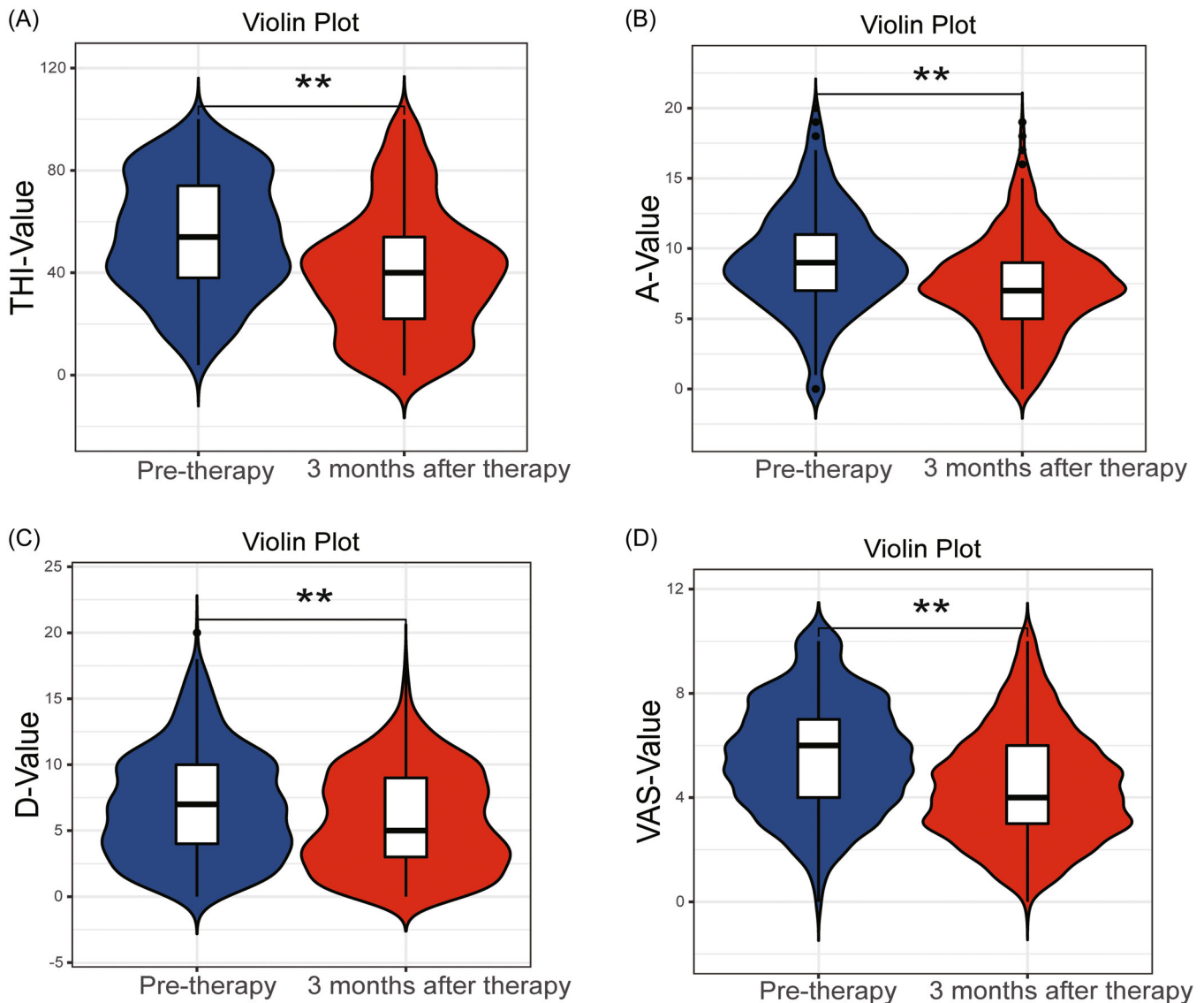


Figure 1. Significant statistical differences in Tinnitus Handicap Inventory (THI)/Visual Analog Scale (VAS)/Hospital Anxiety and Depression Scale (HADS)(A/D) score between pretherapy and 3 months posttherapy. (A) Depicts the differences in THI, (B) Depicts the differences in HADS-A, (C) Depicts the differences in HADS-D, and (D) Depicts the differences in VAS. **Statistical significance at $P < .05$.

Table 2. Stratified Analysis Based on Baseline THI Scale

Severity scale	THI (pretherapy)	THI (3 months after therapy)	Δ THI
Slight	11	14	-3
Mild	28	25	3
Moderate	47	36	11
Severe	67	48	19
Catastrophic	86	58	28
Overall	55	41	14

Abbreviation: THI, Tinnitus Handicap Inventory.

observed in 1 to 3 years (1.3 points) and 1-year (1.2 points) duration tinnitus group, followed by over 3 years duration tinnitus group (0.9 points decrease). There were significant changes observed between 1 year ($P = .031$),

1 to 3 years ($P = .017$), and over 3 years duration tinnitus group, but no significance between 1 and 1 to 3 years duration tinnitus group. After treatment, HADS-A scores decreased by 2.2 points in 1-year duration tinnitus group, which was higher than that of 1 to 3 years and over 3 years duration tinnitus group (a decrease of 1.5 points). Only significance was shown between 1-year and over 3 years duration tinnitus group ($P = .005$). Meanwhile, HADS-D scores decreased by 1.25, 1, and 0.75 points in 1, 1 to 3, and over 3 years duration tinnitus group, respectively. There were no significant changes in HADS-D between the 3 groups.

Stratified by age, the changes in THI, VAS, and HADS-A/D scores after 3 months of music therapy were shown. Thirty-one to 40 age tinnitus group showed the greatest decrease in THI scores (17 points), followed by 41 to 50 age tinnitus group (15 points), and <31 age tinnitus group

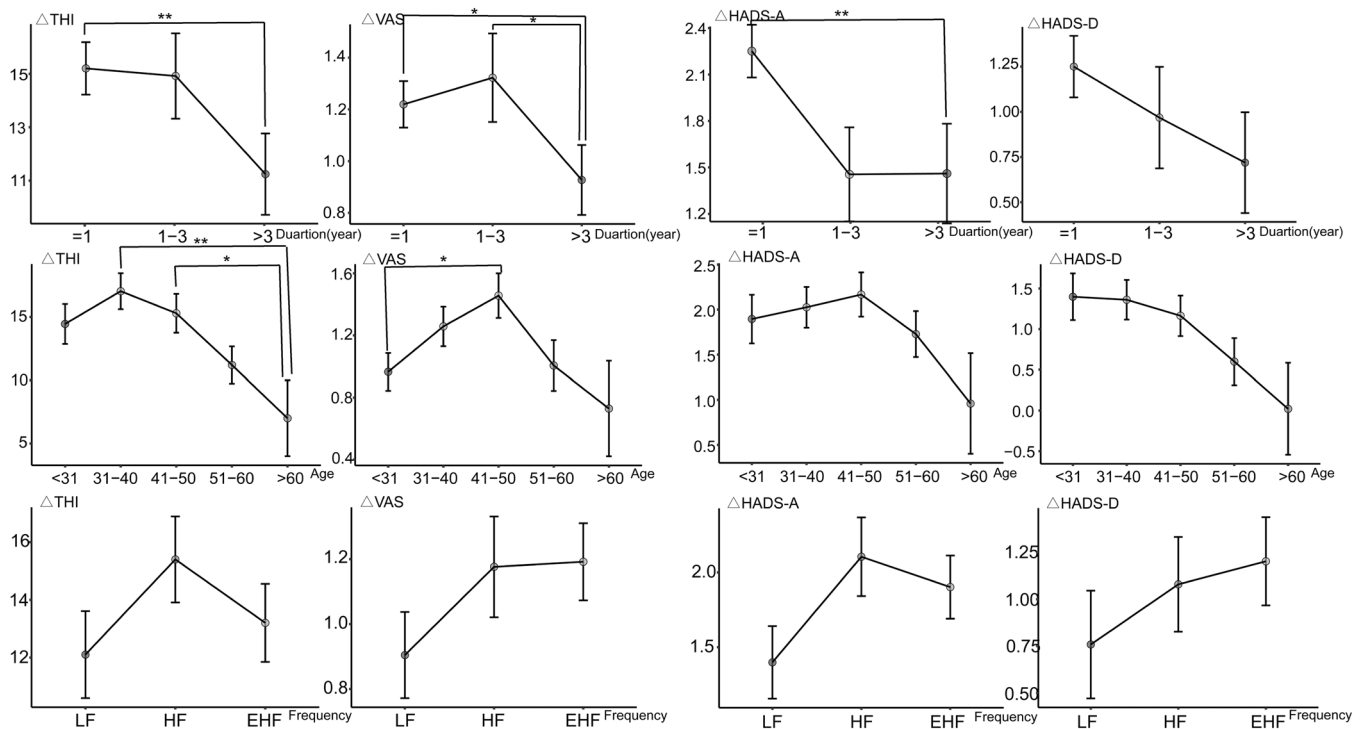


Figure 2. The overall average Tinnitus Handicap Inventory (THI)/Visual Analog Scale (VAS)/Hospital Anxiety and Depression Scale (HADS) (A/D) score changes based on characteristics of the patient. The upper/middle/lower panels show stratified analysis based on tinnitus duration/age/tinnitus frequency, respectively. The error bars represent ± 1 standard deviation. **Statistical significance at $P \leq .05$; *Statistical significance at $P \leq .01$.

(14 points), 51 to 60 age tinnitus group (12 points), and >60 age tinnitus group (7 points). There were significant changes shown between 31 and 40 age ($P = .006$), 41 to 50 age ($P = .019$), and >60 age tinnitus group, but no significance between 1 and 1 to 3 years duration tinnitus group. In terms of VAS, 41 to 50 age tinnitus group showed the highest post-therapy decrease in score (1.4 points), which was higher than 31 to 40 age tinnitus group (1.2 points), followed by <31 and 51 to 60 age tinnitus group (1.0 points). Only significance was shown between <31 age and 41 to 50 age tinnitus group ($P = .029$). Referring to HADS-A, it decreased by 2.2, 2.0, 1.8, 1.6, and 1.0 points in 41 to 50, 31 to 40, <31 , 51 to 60, and >60 age tinnitus groups, respectively. For HADS-D, the degree of decline was inversely proportional to age, with the older the age, the less the decline in score. There were no significant changes in VAS and HADS-D between the 3 groups.

The stratified analysis of THI, VAS, and HADS-A/D scores after music therapy based on tinnitus frequency was also indicated, with HF tinnitus group experiencing the greatest decrease in THI scores after music therapy (15 points), compared to 13 and 12 in the EHF tinnitus and LF tinnitus groups, respectively. VAS scores decreased by 1.2 points in HF and EHF tinnitus group, which was higher than that of LF tinnitus group (0.9 points). HADS-A scores decreased the most in HF tinnitus group (2.0 points), compared with 1.8 points in EHF tinnitus group and 1.3 points in the LF tinnitus group. In addition, the decrease in HADS-D values

increased with increasing frequency. There were no significant changes in any of the scores of the 4 questionnaires between the 3 groups.

Discussion

Tinnitus is a common but intractable problem in otorhinolaryngology department. Especially when it is accompanied by emotional problems such as anxiety, depression, and sleep disorders,¹⁶ it can easily be transformed into disabling bothersome tinnitus.⁷ The mechanism of chronic subjective tinnitus is still unclear, leading to diverse treatment options, including cognitive, neuromodulation, sound therapy, and so on.² The Heidelberg music therapy model and tailor-made notched music therapy are the most widely used sound therapies in the past.^{17,18} The customized music therapy used in our project is made by inverse-phase editing procedure where the tinnitus frequency loci or tinnitus sounds described/selected by the patient were the same with the frequency and intensity of the music but with an opposite phase. Based on the superposition property of waves, the superposition of the music and the tinnitus sound eliminate the latter. The effectiveness of the music is also judged by observing changes in brain area excitability. While if the patient is free of tinnitus, the music can stimulate the patient's brain in the opposite direction, reducing the sensitivity of the tinnitus sound and achieving the purpose of rehabilitation. In addition, the music therapy used in our study was based on a complete follow-up

system. Regular phone follow-ups are available to ensure therapy time, and the App allows for documentation of treatment progress and results. The follow-up system can shorten the therapy time and reduce patients' stress and anxiety. Our previous study showed that it was difficult to cure tinnitus out of the hospital with acoustic therapy alone, but if combined with an effective follow-up system, the outcome will be greatly improved.¹⁹ The importance of a follow-up system was also demonstrated in our previous large-sample study.¹⁰

Our study showed that the more severe the tinnitus pretreatment, the better the efficacy we got, and there was a statistically significant difference between pre- and posttherapy, in which the patients in the catastrophic group had a THI decrease of up to 28 points. This was similar to the results of previous studies,²⁰ with only a difference in the average decline value, which is related to the enrolled population. This may fully demonstrate that music therapy has a definite effect and is worthy of promotion in clinical practice.

If stratified by age, we included a cohort of patients with an equal distribution of patients in each age group between 30 and 60 years, and relatively few patients younger than 30 and older than 60 years. According to the mechanism of tinnitus production, patients older than 60 years were more likely to have tinnitus due to age-related hearing loss and decline in compensatory brain plasticity.^{21–24} The failure of this condition to manifest in our inclusion population may be related to the untimely access to medical care by elderly patients or due to the inability to use smartphones to access the internet for music. In our study, tinnitus patients aged 31 to 50 showed better decreases in THI, VAS, and HADS-A with the least decrease in the >60 age tinnitus group. While HADS-D decreased more in the younger age group. Overall, it appeared that the >60 age tinnitus group had the poorest outcome, perhaps because this patient population still have internet access barriers that limit the effectiveness of the music therapy and follow-up system. It may also be related to the inability of elderly patients to accurately localize tinnitus frequencies, leading to bias in customized music production, or the fact that hearing loss in elderly patients tends to be predominantly full-frequency, with multiple tinnitus loci or heterogeneity of tinnitus loci. The 31 to 50 age tinnitus group showed relatively better results in anxiety improvement, which is probably related to anxiety generated by work stress, and therefore, for this age group, more measures should be focused on reducing stress and avoiding late-night sleep.

Referring to the therapy effects based on tinnitus duration, we found that the shorter the initial duration, the more significant the efficacy of music therapy, and the 1-year duration tinnitus group is significantly higher than that of over 3 years duration tinnitus group. This may be related to the central plasticity with auditory network and cognitive function.²⁵ When the remodeling process has just begun, less effort is required to reverse the process. With longer time, the more pronounced the central remodeling becomes. By means

of magnetic resonance imaging, Wang et al found that after sound therapy, not only was partially restored the functional connectivity between the left parahippocampal gyrus and the cingulate cortex, but also the activity in the right Heschl's gyrus.²⁶ All these changes were toward normal levels, suggesting that the process of gradual centralization of chronic tinnitus during the decompensated phase is reversible.

According to the classification of tinnitus frequency, we divided it into LF, HF and EHF tinnitus group. Thus, we completed the delineation of tinnitus frequency sites. Teismann et al used a short-term tailor-made notched music training to treat 2 groups with different tinnitus frequencies, in which the results showed that patients with tinnitus frequencies ≤ 8 kHz showed significant improvement in subjective tinnitus loudness and tinnitus-associated auditory evoked potentials, whereas patients with tinnitus frequencies > 8 kHz showed no significant improvement.¹⁷ In our results, no significant statistical difference was shown in these changes, but HF and EHF tinnitus group had better results as seen in **Figure 2**. In terms of THI and HADS-A scores, HF tinnitus group decreased more than EHF tinnitus group, which is also not completely consistent with Teismann's findings. We attribute this difference to the heterogeneity of study sample sizes and classification methods. On the other hand, 22.0% of our patients had unavailable tinnitus frequency, which means the patient did not match the specific tinnitus frequency. The situation was due to the heterogeneity of tinnitus or the patient's subjective belief that the tinnitus could not match any pure tone frequency. In addition, we cannot ensure all frequency matches were done precisely, which would also cause differences in efficacy. Through a randomized controlled trial, Jin et al found broadband sound stimulation still has a certain effect on alleviating tinnitus.²⁷ Han et al studied the tinnitus frequency matching group was significantly more effective in music therapy than the tinnitus frequency nonmatching group by running another controlled trial.²⁸ Therefore, we recommend that broadband music can be used, especially for patients whose tinnitus frequency is difficult to match. Nevertheless, it is worth thinking about how to formulate more efficient music of general applicability.

There are some limitations in our study. First, we did not stratify the effect of hearing loss on efficacy of music therapy, nor did we consider the relationship between frequency of hearing loss and frequency of tinnitus, which will be analyzed in another study. Second, due to the limitations of clinical research, we designed a 1-arm efficacy study without a control group, so its reliability needs to be deeply investigated.

Conclusion

Our study is the largest sample-sized study of music therapy for tinnitus in China, which aims to explore which tinnitus patient groups are more beneficial to customized music therapy. Early treatment, precise

frequency matching, and attention to anxiety relief are expected to optimize the efficacy of therapy. We believe that standardized and universal personalized music will help more tinnitus patients in the future.

Acknowledgments

Special thanks to the Otolaryngology residents of the Huadong Hospital Affiliated Fudan University who supported the field-work of this study. The authors acknowledge the reviewers of this manuscript.

Author contributions

Tiany Ni, methodology and data collection writing—original draft; **Yuehong Liu**, methodology and data collection, writing—original draft; **Hongbo Xie**, formal analysis and data curation; **Siyi Yang**, formal analysis and data curation; **Yulu Wang**, formal analysis and data curation; **Yun Jiang**, formal analysis and data curation; **Zhao Han**, conceptualization; writing—review and editing; All authors have read and agreed to the final version of the manuscript.

Disclosures


Competing interests: There is no potential conflict of interest was reported by the authors.

Funding source: This work was supported by the Shanghai Municipal Commission of Science and Technology Fund (NO.20Y11902300) by the China government. The funders had no role in study design, data collection, data analysis, data interpretation, or writing of the report.

Data Availability Statement

Part of the data analyzed during this study is included in the published article. Full data sets generated and analyzed during the study are available from the first author or the corresponding author on reasonable request.

ORCID iD

Zhao Han  <http://orcid.org/0000-0002-5753-6952>

References

- Sereda M, Xia J, Scutt P, Hilton MP, El Refaie A, Hoare DJ. Ginkgo biloba for tinnitus. *Cochrane Database Syst Rev.* 2022; 11(11):013514.
- Cima RFF, Mazurek B, Haider H, et al. A multidisciplinary European guideline for tinnitus: diagnostics, assessment, and treatment. *HNO.* 2019;67(suppl 1):10-42.
- Yu L, Yang S, Wang Q, Li M. [Diagnosis and treatment of tinnitus]. *Lin Chung Er Bi Yan Hou Tou Jing Wai Ke Za Zhi.* 2022;36(5):325-334.
- Sherlock LP, Brungart DS. Functional impact of bothersome tinnitus on cognitive test performance. *Int J Audiol.* 2021;60(12):1000-1008.
- Knipper M, Zimmermann U, Müller M. Molecular aspects of tinnitus. *Hear Res.* 2010;266(1-2):60-69.
- Ghodratitoostani I, Zana Y, Delbem ACB, Sani SS, Ekhtiari H, Sanchez TG. Theoretical tinnitus framework: a neurofunctional model. *Front Neurosci.* 2016;10:370.
- Sun H, Feng G, Yu H, et al. Risk factors of decompensated tinnitus and the interaction effect of anxiety and poor sleep on decompensated tinnitus: a multicenter study. *Acta Otolaryngol.* 2021;141(12):1049-1054.
- Henry JA. Sound therapy to reduce auditory gain for hyperacusis and tinnitus. *Am J Audiol.* 2022;31(4):1067-1077.
- Formby C, Yang X, Scherer RW. Contributions of counseling and sound generator use in tinnitus retraining therapy: treatment response dynamics assessed in a secondary analysis of a randomized trial. *J Speech Lang Hear Res.* 2022; 65(2):816-828.
- Liu Y, Yang S, Wang Y, et al. Efficacy and factors influencing outcomes of customized music therapy combined with a follow-up system in chronic tinnitus patients. *J Otolaryngol Head Neck Surg.* 2023;52(1):29.
- Husain FT, Khan RA, Tai Y, Shahsavarani S. Evaluating the efficacy of a smartphone app for tinnitus relief using behavioral and brain imaging measures. *Am J Audiol.* 2022; 31(3):633-645.
- Hoff M, Kähäri K. A Swedish cross-cultural adaptation and validation of the Tinnitus Functional Index. *Int J Audiol.* 2017;56(4):277-285.
- Frumkin MR, Kallogjeri D, Piccirillo JF, et al. Development and preliminary evaluation of the tinnitus severity short form. *Am J Audiol.* 2021;30(2):404-415.
- Aazh H, Moore BCJ. Tinnitus loudness and the severity of insomnia: a mediation analysis. *Int J Audiol.* 2019;58(4): 208-212.
- Crocetti A, Forti S, Ambrosetti U, Bo LD. Questionnaires to evaluate anxiety and depressive levels in tinnitus patients. *Otolaryngol Head Neck Surg.* 2009;140(3):403-405.
- Hall DA, Xiong B, Li W, Wang Y, Zhang X, Zhao F. Why is tinnitus a problem? a large-scale qualitative evaluation of problems reported by tinnitus patients in mainland China. *Int J Audiol.* 2023;22:1-10.
- Teismann H, Okamoto H, Pantev C. Short and intense tailor-made notched music training against tinnitus: the tinnitus frequency matters. *PLoS One.* 2011;6(9):e24685.
- Krick CM, Grapp M, Daneshvar-Talebi J, Reith W, Plinkert PK, Bolay HV. Cortical reorganization in recent-onset tinnitus patients by the Heidelberg Model of Music Therapy. *Front Neurosci.* 2015;9:49.
- Wei HHZ, Qin L. Sound therapy for patients with tinnitus out of hospital and the influencing factors. *J Nurs Sci.* 2017;32(2):89-91.
- Cuesta M, Garzón C, Cobo P. Efficacy of sound therapy for tinnitus using an enriched acoustic environment with hearing-loss matched broadband noise. *Brain Sci.* 2022;12(1):82.
- Koops EA, Renken RJ, Lanting CP, van Dijk P. Cortical tonotopic map changes in humans are larger in hearing loss than in additional tinnitus. *J Neurosci.* 2020;40(16):3178-3185.
- Vanneste S, De Ridder D. Deafferentation-based pathophysiological differences in phantom sound: tinnitus with and without hearing loss. *Neuroimage.* 2016;129:80-94.
- Jafari Z, Kolb BE, Mohajerani MH. Age-related hearing loss and tinnitus, dementia risk, and auditory amplification outcomes. *Ageing Res Rev.* 2019;56:100963.

24. Waechter S. Association between hearing status and tinnitus distress. *Acta Otolaryngol.* 2021;141(4):381-385.
25. Cai Y, Chen S, Chen Y, et al. Altered resting-state EEG microstate in idiopathic sudden sensorineural hearing loss patients with tinnitus. *Front Neurosci.* 2019;13:443.
26. Han L, Pengfei Z, Chunli L, et al. The effects of sound therapy in tinnitus are characterized by altered limbic and auditory networks. *Brain Commun.* 2020;2(2):fcaa131.
27. Jin IK, Choi SJ, Ku M. Notched and nonnotched stimuli are equally effective at the mixing-point level in sound therapy for tinnitus relief. *J Am Acad Audiol.* 2021; 32(7):420-425.
28. Wang J, Ding J, Song J, Hu L, Cong N, Han Z. A prospective study of the effect of tinnitus sound matching degree on the efficacy of customized sound therapy in patients with chronic tinnitus. *ORL.* 2022;84(3):229-237.