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RESEARCH ARTICLE

The effect of hearing amplification on tinnitus improvement

Sara Bahaghighat[1], Saeid Farahani[1*], Reza Hoseinabadi[1], Shohreh Jalaie[2]

[1]- Department of Audiology, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran

[2]- Biostatistics, School of Rehabilitation, Tehran University of Medical Sciences, Tehran, Iran

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Abstract

Background and Aim: Using hearing aids is one of the most important management methods for patients with hearing loss and tinnitus. Many studies have been conducted to assess the effect of hearing aids on tinnitus using different tools, but there is no consensus on their usefulness and effect in relieving tinnitus. The present study aimed to investigate the effect of hearing amplification on tinnitus using the tinnitus handicap inventory (THI) and tinnitus psychoacoustic measurements.

Methods: A total of 10 patients (5 male and 5 female), aged 39 to 70 years old with mild to severe sensorineural hearing loss (amplifiable hearing loss) and chronic tinnitus entered the study. The Persian version of the THI was completed for the patients and tinnitus psychoacoustic measurements, the visual analogue scale (VAS) loudness, and the annoyance VAS were performed. The patients used hearing aids for six weeks, and measurements were repeated after the intervention.

Results: Comparing the total mean score of all of the study variables before and after the intervention showed significant reductions ($p<0.05$). Based on tinnitus pitch matching, no significant difference was observed in mean score changes in the THI between low-pitch and high-pitch groups.

Conclusion: Improvement was observed in tinnitus annoyance after using hearing aids for 6 weeks. Tinnitus pitch is not a good criterion for determining tinnitus treatment prognosis.

Keywords: Tinnitus handicap inventory; psychoacoustic measurement; visual analogue scale

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Introduction

Tinnitus is a sound perception in the absence of any external source with 10-15% prevalence in the general population [1]. As a result of the auditory input deprivation, spontaneous and synchronous neural activity increase in ascending auditory pathways. Evidence shows that dorsal cochlear nucleus (DCN) is the source of tinnitus generation. Tinnitus shows several forms of plasticity [2].

Tinnitus is mostly accompanied by hearing loss, so hearing aids are very important in managing tinnitus among patients with hearing loss and tinnitus [1,3-5].

Psychoacoustic measurements and self-assessment questionnaire including the tinnitus handicap inventory (THI) are the main subjective tools for evaluation of tinnitus effects on daily life and for documenting tinnitus

* **Corresponding author:** Department of Audiology, School of Rehabilitation, Tehran University of Medical Sciences, Piche-Shemiran, Enghelab Ave., Tehran, 1148965141, Iran. Tel: 009821-77530636, E-mail: s_farahani@tums.ac.ir

treatment results [6-8].
Different studies are conducted for evaluating the effect of hearing aids on tinnitus, but there is no consensus among researchers to the benefits of hearing aids in patients with tinnitus [9-12]. As cultural differences affect patients' attitude towards hearing aid usage and auditory rehabilitation has important role on reducing tinnitus difficulties, it is advisable to conduct a study in the Iranian population. The present study aimed to investigate the effect of hearing amplification on tinnitus, using the THI and psychoacoustic evaluations [13].

Methods

The current study included 14 subjects (7 males and 7 females) with mild to severe sensory neural hearing loss (amplifiable hearing loss) and chronic tinnitus in the age range of 30 to 70 years old. Inclusion criteria were chronic subjective tinnitus (at least for six months), no previous hearing aid use or other tinnitus treatments, no use of tranquilizers, anti-depressants, anti-anxiety, anti-seizures and ototoxic medications, not suffering from Meniere's disease, high blood pressure, thyroid problems, hyperlipidemia, hyperglycemia, tumors and mild, moderate or severe score in the THI [14,15]. Exclusion criteria consisted of missing patients in the follow-up. Four patients were excluded from the study as they did not participate in the follow-up.
Written consent was obtained from all patients who fulfilled inclusion criteria. This study was approved by the Ethics Committee of Tehran University of Medical Sciences. After taking the patients' histories, they were examined by otoscopy (by Riester, Germany) and tympanometry (Danplex tymp 87, Denmark). Then they completed the Persian version of THI. The THI includes 25 questions with functional, emotional and deficit evaluation subparts [16,17]. Then air conduction (AC) and bone conduction (BC) audiometry on half octave band intervals for 250 to 8000 Hz and speech audiometry by AC40 audiometer (Interacoustic, Denmark) were performed.
Psychoacoustic evaluations including pitch matching, loudness matching, minimum masking level (MML) and residual inhibition (RI) were performed by the AC40 audiometer. The procedure of pitch matching was as follows: contra lateral ear was used for asymmetric tinnitus or unilateral tinnitus but if tinnitus was equal in both ears or was heard in the midline of the head and hearing loss in both ears was symmetric, right ear was selected as the reference. At first 1000 Hz pure tone was used; two pure tone at 10 dB SL were presented for comparison and changed in half octave intervals, based on patient's report, to find the frequency that matched the best with the patient's tinnitus. This evaluation was repeated six times, as pitch matching varied a lot. Then the acquired pitch was compared to a noise in that frequency range by the patient when he/her was asked to judge which narrow band noise (NBN) was more similar to his/her tinnitus. If pure tone was selected by the patient, the pitch matching was stopped and if NBN was chosen by the patient, wide band noise (WBN) was used and the patient had to compare NBN with WBN and tell which sound is more similar to his/her tinnitus. For loudness matching, based on the selected sound, the same reference ear and pitch matched sound (pure tone, NBN or WBN) were used. The stimulus was presented at below threshold level and then it was increased in 1 dB steps till the patient reported equal level for his/her tinnitus. To be sure, evaluation was repeated three times and the average value was reported [6].
To evaluate minimum masking level, WBN (binaural stimulation in case of two sided tinnitus and monaural stimulation in case of one sided tinnitus) was presented below threshold ipsilateral and the level was increased in 1 dB steps. At first the patient had to point when he/she heard the noise, so the noise threshold was determined. Then noise level was increased by 1 dB steps till patient reported that tinnitus was masked by noise. This was the masking threshold. This phase was repeated six times and their average threshold was recorded. Finally, the difference between noise threshold and the noise masking level was reported as the minimum masking level (MML) by dB SL. For

measuring residual inhibition, WBN was presented binaurally at 10 dB above tinnitus masking level for 60 minutes and then it was suddenly stopped and the patient was asked to describe any changes in tinnitus, such as tinnitus reduction, tinnitus suppression, no changes, tinnitus worsening [6,18,19]. The visual analogue scale (VAS) for tinnitus loudness and bothersome was conducted, eventually [20,21].

After consulting with the patient and providing necessary information, ear mold was obtained and suitable hearing aid was prescribed based on degree and type of hearing loss. In the first session, first fitting was done and after two weeks of adaptation, fine tuning was performed based on hearing loss pattern and degree as well as patient's satisfaction. The hearing aid was asked to be worn for eight hours a day for six weeks and data logging was activated to make sure the patient follows this request [8,18,22]. Then, the patient was asked to visit for tinnitus evaluation including psychoacoustic assessments, THI and VAS, without using the hearing aid at the evaluation day, to prevent tinnitus suppression. THI, VAS for loudness and bothersome, loudness matching, and MML were compared before and after the intervention. To evaluate the effects of tinnitus pitch on the treatment prognosis, pitch was categorized into lower than 6000 Hz (low pitch) and higher than 6000 Hz (high pitch) and THI mean score was compared between these two groups [23,24]. To test normal distribution of the data, the Kolmogorov–Smirnov test was used and paired t-test was applied for data with normal distribution, and Wilcoxon test was used for comparison of data without normal distribution. For comparing THI score change and pitch matching, Mann-Whitney non-parametric test was used.

Results

The present study included 5 females and 5 males with mean (SD) age of 54.4 (8.76) years (age range: 39-70 years). Mean (SD) pure tune audiometry (PTA) for the right ear and the left ear were calculated as 40.33 (14.46) and 42.83 (22.03), respectively. 9 patients had binaural and one had monaural tinnitus. Five patients had tinnitus with high pitch (above 6000 Hz) and the remaining 5 patients had tinnitus with low pitch (below 6000 Hz). In detail, 5 patients had 8000 Hz tinnitus and the other 5 had 500, 1000, 1500, 3000 and 4000 Hz tinnitus. Of all, 4 patients received monaural hearing aids due to their economic status and 6 patients' binaural hearing aids. Based on the THI, patients had mild to severe handicap before the intervention, but there was no severe handicap after the intervention and 8 patients showed at least one level improvement after receiving the intervention. Table 1 shows a significant change in the results of before and after the intervention ($p<0.05$) which indicates a significant reduction in all parameters after six weeks of using hearing aids. THI mean score changes were not significant between the two groups ($p=0.69$) which shows that pitch has no effects on tinnitus improvement (Fig. 1).

Discussion

Tinnitus has always been a challenging issue for ENT specialists and requires specific attention because of its debilitating effects on people's life. As tinnitus is usually accompanied by some degree of hearing loss, using methods that can compensate sensory deprivation such as hearing aids can improve tinnitus. As THI is a criterion for determining tinnitus handicap, its effects on quality of life and it's distress, THI score reduction is indicative of improvement [17,25]. Hearing aids can promote speech recognition, relieve stress and anxiety, and improve communication and therefore quality of life. In addition, hearing aids can mask tinnitus by amplifying background noise and therefore patient may pay less attention to the tinnitus and this can reduce tinnitus by breaking the plasticity that has happened due to sensory deprivation [26,27]. The results were in agreement with the study of Berberian et al. that used hearing aid with sound generator. THI score showed significant reduction after intervention [26]. dos Santos et al. used two groups of patients, one using only hearing aids and the other using hearing aids and sound generator. About 78% of

Table 1. Mean and standard deviation of loudness matching, minimum masking level, loudness visual analogue scale, annoyance visual analogue scale, tinnitus handicap inventory before and after intervention

Variable	Pre-intervention	Post-intervention	p
Loudness matching	8.50±3.84	5.60±2.63	*0.001
Minimum masking level	11.10±3.76	7.80±2.82	*0.001
Loudness VAS	7.30±1.83	4.30±2.16	*0.007
Annoyance VAS	7.10±2.92	4.10±2.34	**0.011
THI	45.60±10.95	24.00±15.46	*<0.001

VAS; visual analogue scale, THI; tinnitus handicap inventory
*Pair sample t-test
**Wilcoxon signed- rank test

the patients using hearing aids showed more than 20 score reduction in the THI after the intervention. Therefore, patients' handicap classification changed from moderate to mild [27]. Rocha and Mondelli conducted a study on two groups (G1 with normal hearing and tinnitus using only sound generators and G2 with hearing loss and tinnitus using hearing aids and sound generator and received consultation) in three phases (before the intervention, three months and six months after the intervention). The THI mean score was 66.4 before the intervention (severe handicap) that reduced to 18.66 three months after the usage of hearing aids (mild handicap). This means more than 20 scores reduction, in all patients of both groups, after receiving the intervention [10]. The study of Araujo Tde and Iório was conducted on two groups (intervention and control groups) in three phases (before the intervention, one month and three months after the intervention). Hearing aids were prescribed for the intervention group. The mean score of THI was 45 before the intervention (moderate handicap), 21.33 one month after using hearing aids (mild handicap) and 9.17 (slight handicap) three months after the intervention. The THI score was significantly different between one and three months after the use of hearing aids [9]. On the other hand, in the study of Cribari et al., there was no improvement in the THI score after hearing aids usage. This study was conducted on 53 subjects (20 males and 32 females) with the mean age of 72.5 years with hearing loss who experienced no tinnitus reduction after wearing the hearing aids. Tinnitus bothersome was evaluated by the THI and life satisfaction was assessed by the quality of life questionnaire. The study showed that in spite of tinnitus bothersome, quality of life satisfaction was enhanced [11]. Andersson et al. showed no hearing aids benefit in patients with tinnitus using the THI. They studied the tinnitus-related anxiety by the Abbreviated Profile of Hearing Aid Benefit (APHAB), on 85 patients suffering from hearing loss and tinnitus whom received hearing aids one year prior to the study. The THI mean score was 27.5. Tinnitus-related anxiety showed less hearing aids benefit in the aversiveness of sound in the THI and hearing in noise in APHAB. The THI showed less benefits and more problems [28].

The present study showed decrease in loudness and MML. Loudness matching and MML were reported useful for evaluation of treatment effects [29]. Clinically, the most important tinnitus characteristic is its loudness and loudness matching is a valid assessment tool in most patients [6,18]. Loudness reduction can be an indicative of treatment benefits [6]. The MML is a common evaluation tool in many tinnitus

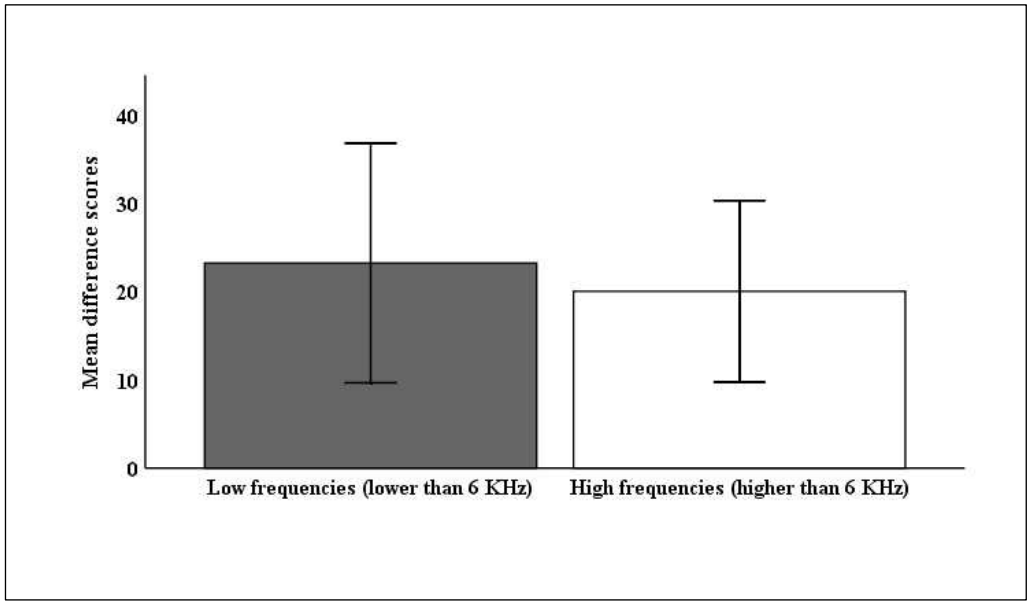

Fig. 1. Mean (standard deviation) difference scores of tinnitus handicap inventory according to pitch matching.

clinics with treatment benefits. The MML can provide information about prognosis of masking treatment. Patients who show good tinnitus masking, usually show more treatment effects. It is reported that dB difference between the MML and loudness matching can be a predictive of treatment benefits. If the MML score is less than loudness, treatment will probably be effective [6,18]. The loudness reduction after wearing hearing aids are predictable, as hearing aids has a positive effect on developing secondary plasticity and direct opposition with tinnitus by reducing neural spontaneous activity and central gain [30,31]. The MML improvement is attributable to the adaptation [32]. Rocha and Mondelli showed that the mean score of loudness was 1.33 dB SL in the right ear and 7.66 dB SL in the left ear before the intervention, but they did not report any loudness after the intervention [10]. Araujo Tde and Iório results were in agreement with the present study. The loudness mean score difference in both ears were significant one and three months after wearing hearing aids (p=0.002) [9]. dos Santos et al. studied effectiveness of combination therapy and hearing aid alone. Mean score of loudness before treatment in the hearing aids group, and loudness difference before and after the intervention were not significantly different and there was no loudness reduction after three months of using hearing aids. This result was not in line with the present study. In the group with combination therapy, mean score of loudness was significantly different before and after the intervention, but the MML results were in agreement with the present study. Mean score difference of the MML was 9.22 dB SL that was statistically significant [30]. In the present study, patients were divided into two groups with tinnitus pitch less than 6000 Hz (5 subjects) and those with more than 6000 Hz (5 subjects). Mean THI score showed no significant difference after receiving the intervention. Therefore, pitch matching had no effect on tinnitus improvement after wearing hearing aids. Many studies report that tinnitus pitch is effective in tinnitus improvement following hearing aids intervention and pitch is a suitable criterion for predicting hearing aid masking effects [33]. A positive treatment prognosis is suggested when tinnitus pitch is in the hearing aid response limit [9]. Araujo Tde and Iório studied 25 subjects with hearing loss and tinnitus (16 females and 9 males) with the mean age of 52.2 years.

Subjects used hearing aids and sound generators. To evaluate tinnitus pitch effects, 250 and 500 Hz, 1000 and 2000 and 3000 Hz, and finally 4000 and 6000 and 8000 Hz were considered as groups one, two and three, respectively. Free field aided audiometry was performed for these three frequency groups. The results showed that PTA had significant difference between three frequency groups before and after hearing aids intervention and it was suggested that when tinnitus pitch is within the hearing aids amplification limits, there is a more reduction in tinnitus bothersome [9]. Schaette et al. studied 15 subjects equipped with hearing aids and chronic tinnitus which 11 subjects had hearing aids and remaining 4 subjects had maskers. Patients were divided based on their tinnitus into two groups of pitch less than 6000 Hz (low pitch group) and pitch above 6000 Hz (high pitch). Improvement was evaluated by loudness VAS and tinnitus questionnaires at one, two, three and six months after these prosthesis and consultation in these two groups. VAS and tinnitus questionnaires results showed significant differences between before and after the treatment in the low pitch group. Therefore, pitch can affect sound therapy results when a prosthesis with limited frequency range (such as hearing aid) is used [23].

In the present study, loudness VAS and aversiveness were reduced. VAS is a widely used tool for evaluation of chronic pain, loudness assessment, and tinnitus aversiveness. The advantage of this method is easy performance and being understandable for patients [24]. Self-assessment tools (loudness VAS and bothersome) are designed as subjective methods for evaluating daily experienced tinnitus intensity. Their advantage in subjective problems such as tinnitus is reflecting personal experience. These are valid and reliable tools for evaluation of treatment-related changes in patients with chronic tinnitus [20]. The results of the present study were in agreement with findings of Berberian et al. They studied 15 subjects with hearing loss and tinnitus by bothersome VAS before and after using hearing aid. The comparison showed significant bothersome reduction following the use of hearing aid [26]. Rocha and Mondelli studied bothersome VAS in three stages: before the intervention, then three and six months after wearing hearing aids and reported bothersome VAS improvement within three and six months after using hearing aid [10]. Araujo Tde and Iório studied bothersome VAS in patients with and without tinnitus before the use of hearing aids, and three and six months after wearing hearing aids. The mean VAS score in patients with tinnitus showed significant reduction three and six months after wearing hearing aid that is in agreement with the present study [9]. Lee et al. showed bothersome VAS reduction after using hearing aids and sound generator within first three months of intervention which was continued for 24 months [34]. Schaette et al. showed that loudness VAS mean score after 6 months had significant reduction in the low pitch group but it showed significant increment in the high pitch group [23].

Conclusion

All study parameters showed significant reduction within six weeks after the use of hearing aids indicating tinnitus improvement. As there were no differences between degree of tinnitus improvement based on tinnitus pitch by THI score, it seems that pitch is not a suitable criterion for predicting treatment prognosis. Because THI, psychoacoustic evaluations of tinnitus and VAS assess different aspects of tinnitus, they cannot be used interchangeably. Therefore, it is necessary to use a test battery approach for accurate and precise evaluation. Finally, comparison of study results shows that nationality does not associate with amplification effects on tinnitus. However, it appears that Iranians are reluctant to use hearing aids due to cultural and economic reasons even when they have hearing loss accompanied by tinnitus and they prefer unilateral hearing aids over binaural.

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Conflict of interest

The authors declared no conflicts of interest.

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