

Assessment of effects of hearing aid fitting on the perceptual characteristics of tinnitus

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Background

Evidence of systematic relationships between the perceptual characteristics of tinnitus, like its pitch or loudness, and those of the absolute hearing threshold curves, like the presence and degree of hearing loss at certain frequencies, would probably help to understand how tinnitus is related to the configuration of hearing loss.

Objective

The objective of this study was to determine the effects of hearing aid fitting on the perceptual characteristics of tinnitus.

Participants and methods

The participants of the study were 50 adults (20–60 years old) with subjective tinnitus and different degrees of hearing loss. Otorhinolaryngological examination, tonal audiometry, and acoustic immittance testing were done. Participants answered Tinnitus Handicap Inventory (THI) Questionnaire at the time of the first fitting with their hearing aid and performed at 0, 3, 6, and 12 months postfitting.

Results

THI showed a significant decrease throughout the 12 months from 74.80 ± 15.98 at baseline to 61.84 ± 14.02 3 months later, then 38.35 ± 10.98 by the sixth month and 12.90 ± 4.26 by the end of 12 months. At the baseline, no slight or mild cases were detected, whereas moderate THI represented 16%, severe 28%, and catastrophic 56%. These rates changed 3 months later as catastrophic cases decreased almost to one-third of its rate at the baseline. By the sixth month, no catastrophic cases were detected and severe stages recorded trivial rates, whereas most of cases were categorized as mild or moderate. By the end of the study, the great majority of cases were slight (81.6%) and the remaining portion was mild, with no moderate, severe, or catastrophic cases recorded.

Conclusion

Analysis of the results has shown that the use of hearing aids are one of the number of therapeutic options offered to tinnitus patients and promote the improvement in the perceptual characteristics of tinnitus.

Keywords:

hearing aid fitting, hearing loss, Tinnitus Handicap Inventory, tinnitus

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Introduction

Tinnitus is the perception of sound within the human ear when no actual sound is present. Tinnitus is not a disease, but a symptom that can result from a wide range of causes [1]. Tinnitus can be perceived in one or both ears or in the head. It is usually described as a ringing noise [2].

Most of tinnitus sufferers have subjective tinnitus that cannot be heard by the examiner. This condition could be accompanied by serious psychological impacts like depression and anxiety, low concentration, and loss of control [3].

Clinical evaluation of the effects of tinnitus on a patient's ability to function and their sense of well-being is important to estimate tinnitus handicap in their

overall quality of life [4]. Self-report questionnaires elucidate the effect that the tinnitus has on the individual's daily life [4]. The Tinnitus Handicap Inventory (THI) was used as a brief, easy way to evaluate the disabling consequences of tinnitus [5]. It can be applied in an initial evaluation of handicap or later as well as a way to measure treatment outcome [5].

The influence of hearing loss on the degree of suffering caused by tinnitus remains uncertain [6]. Weisz *et al.* [7] and Searchfield *et al.* [8] have shown that severe

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tinnitus was associated with hearing loss at low and high frequencies. According to different reports 85–96% of patients with tinnitus are complaining of different degrees of hearing loss [9], and only 8–10% showed normal audiometry [10]. In some cases, the mere amplification of environmental noise relieves or significantly reduces tinnitus perception, providing immediate improvement; in other cases, such improvement is slower and more gradual to facilitate the neurophysiological process [11].

Sound enrichment is applied to facilitate the habituation of tinnitus perception by decreasing the difference between tinnitus-related neural activity and background neural activity [12]. For patients suffering from both tinnitus and hearing impairment, sound enrichment is provided by amplifying environmental sounds of low intensity through hearing aids [12]. Those sounds result in reduction of the attention focus on tinnitus, thus achieving the retraining process [13].

Hearing aids are an important tool of the audiological management of tinnitus [14–17] because hearing loss is the main risk factor for tinnitus [18]. However, the beneficial results from a change in reactions to tinnitus and an improvement in hearing function cannot be predicted [19].

Aim

The goal of the study is to determine the effects of hearing aid fitting on the perceptual characteristics of tinnitus.

Participants and methods

This study is an interventional prospective design that was conducted initially on 60 patients (before ending in 50 after 10 drops) with different degrees of hearing loss [conductive hearing loss (CHL), mixed hearing loss, and sensorineural hearing loss (SNHL)] and on those suffering from tinnitus in the age range from 22 to 61 years and of both sexes.

Inclusion criteria

All participants had type A curve tympanograms. All participants were complaining of different types of hearing loss: CHL, mixed, or SNHL. All patients were complaining of different degrees of tinnitus.

Exclusion criteria

Type B or C curve tympanogram patients; patients with bilateral within normal hearing threshold level peripherally; patients with hearing loss but not

complaining of tinnitus; patients fitted before with hearing aids, sound generators, or assistive listening devices; generalized anxiety patients; generalized depression patients, patients with central nervous system disorders (epilepsy, multiple sclerosis).

There were 10 patients who dropped out from the study. Three of them were assessed initially and 3 months postfitting and the remaining seven patients were assessed initially, at 3 and 6 months postfitting.

Participants included in this study were recruited from patients referred to the Audiology Clinics of Beni Suef University Hospital, Egypt and Maghrabi Hospital, Riyadh, Kingdom of Saudi Arabia audiological evaluation. The study took place in the period between January 2013 and July 2014. The study was approved by the Ethics Committee of the Ear, Nose, and Throat Department and informed consents were obtained from all participants.

All participants who participated in this study were subjected to: (i) full history taking, (ii) otological examination, (iii) audiological evaluation; all measures for the participants were performed using Grason-Stadler (GSI) 61 audiometer (GSI 33, Otometrics, Denmark) and stimuli were delivered through TDH-50 P Telephonics headphones (Denmark) and GSI loudspeakers for aided free-field audiometry. Pure tone audiometry in the frequency range 0.25–8 kHz were tested. Speech audiometry including speech recognition threshold using Arabic spondee words [20] and word discrimination score, using Arabic phonetically balanced words [21]. (iv) Immittanceometry was done using GSI 33 Grason-Stadler (USA), calibrated according to the ISO standards, using single-component, single-frequency tympanometry with a probe tone of 226 Hz. Testing of the acoustic reflex threshold was done for ipsilateral and contralateral elicited reflexes, using pure tones at 500, 1000, 2000, and 4000 Hz. (v) Through hearing aid fitting system HI-PRO (GN Otometrics A/S, Taastrup, Denmark).

Procedures

- (1) Participants were fitted for hearing aids and subsequently returned to repeat measurements of thresholds and tinnitus loudness and spectra at 3, 6, and 12 months after their initial visit.
- (2) THI was answered at initial 3, 6, and 12 months after proper hearing aid fitting.
- (3) Aided free-field audiometry was performed at 500, 1, 2, and 4 kHz at initial 3, 6, and 12 months after proper hearing aid fitting.

Statistical analysis

Data were analyzed using the software, statistical package for social sciences, version 18. Frequency distribution with its percentage and descriptive statistics with mean and SD were calculated. The data were summarized using descriptive statistics: mean, SD, minimal, and maximum values for quantitative variables and number and percentage for qualitative values. Statistical differences were tested using the χ^2 -test for qualitative variables, independent sample *t*-test for quantitative normally distributed variables, whereas nonparametric Mann–Whitney test for quantitative variables which are not normally distributed. Pearson's correlation were done to test for linear relations between variables. *P* values of less than or equal to 0.05 were considered statistically significant. *P* values of less than or equal to 0.01 were considered highly significant [22].

Results

This study included 50 patients suffering from different degrees of hearing loss [10 (20%) CHL, 35 (70%) SNHL, 5 (10%) mixed] associated with tinnitus. Their age ranged from 22 to 61 years with a mean of 40.66 ± 9.58 years. They were 23 (46%) women and 27 (54%) men.

Table 1 shows the mean hearing thresholds and the mean aided hearing thresholds of the studied group.

Table 1 Descriptive analysis of hearing thresholds and aided hearing thresholds of the studied group

Frequency (Hz)	Average hearing threshold (dB)	Mean	SD	Minimum	Maximum
Hearing thresholds					
250	36	42.2	10.6	30	55
500	44	45.7	9.2	35	55
1000	52	54.8	8.07	40	65
2000	48	49.01	8.07	40	70
4000	50	51.1	6.03	45	75
8000	56	57.08	7.87	55	80
Aided hearing thresholds					
250	15.04	13.3	10.5	10	25
500	22.94	14.02	11.7	15	25
1000	23.9	21.5	10.2	15	30
2000	22.07	20.9	9.06	15	30
4000	25.02	21.89	10.1	20	35
8000	25.7	23.8	9.5	20	35

Table 2 Impact of hearing loss type on Tinnitus Handicap Inventory score

Hearing loss	<i>N</i>	Mean of Tinnitus Handicap Inventory score	SD	Minimum of score	Maximum of score	<i>P</i> value
CHL	10	80.00	12.51	48.00	88.00	0.199
SNHL	35	72.17	16.92	38.00	94.00	
Mixed	5	82.80	11.71	70.00	100.00	

CHL, conductive hearing loss; SNHL, sensorineural hearing loss.

Table 2 shows that there were no statistically significant differences between CHL, SNHL, and mixed hearing loss regarding THI score.

Table 3 shows that there was no statistically significant difference between men and women regarding THI score ($P > 0.05$).

Table 4 shows that there was a moderate positive correlation between hearing threshold and each of THI baseline ($P < 0.05$).

Table 5 shows that there were moderate positive correlations between aided hearing thresholds and each of THI baseline, at 3, 6, and 12 months ($P < 0.05$).

Table 6 shows that by the baseline, no slight or mild cases were detected, whereas moderate THI represented 16%, severe 28%, and catastrophic 56%. These rates changed 3 months later as catastrophic cases decreased almost to one-third of its rate at the baseline. By the sixth month, no catastrophic cases were detected and severe stages recorded trivial rates, whereas most of cases were categorized as mild or moderate. By the end of the study, the great majority of cases were slight (81.6%) and the remaining portion was mild, with no moderate, severe, or catastrophic cases recorded.

Table 3 Impact of gender on Tinnitus Handicap Inventory score

Sex	N	Mean of Tinnitus Handicap Inventory score	SD	Minimum of score	Maximum of score	P value
Male	27	72.96	15.42	46.00	92.00	0.384
Female	23	76.96	16.71	38.00	100.00	

Table 7 shows that the Tinnitus Handicap Questionnaire score showed a significant decrease throughout the 12 months from 74.80±15.98 at baseline to 61.84±14.02 3 months later, then 38.35 ±10.98 by the sixth month, and hit a low of 12.90±4.26 by the end of 12 months ($P<0.05$).

Discussion

A continuous or interrupted reduction in auditory stimuli increases the sensitivity of subcortical neurons, resulting in plastic reorganization of the auditory cortex, with sustained awareness of tinnitus [23,24]. The previous studies suggest that feelings of intensity of tinnitus signal may be related to the annoyance caused by this condition [25].

In the current study, we studied different types of hearing loss. CHL (20%), SNHL (70%), and mixed (10%) were investigated. We found that there were no statistically significant differences between the type of hearing loss regarding the THI score as shown in Table 2. This was in accordance with Searchfield *et al.* [8], who assessed tinnitus severity by another questionnaire Tinnitus Severity Index Questionnaire. They stated that no correlation was found between the type of hearing loss and Tinnitus Severity Index score.

In our study, the participants were 27 (54%) men and 23 (46%) women. We found no statistically significant difference in the annoyance due to tinnitus among men and women noticed by the THI score (Table 3).

In agreement with our study, Erlandsson and Holgers [26] and Alhamzi *et al.* [27] found that no significant difference in the severity of tinnitus based on THI score according to gender difference.

In contradictory to our study, Stousser and Tyler [28] and Hiller and Goebel [29] found significant severity in terms of intensity and annoyance due to tinnitus in male patients, whereas Lockwood *et al.* [30] stated a slightly higher prevalence in women regarding annoyance to tinnitus in their study.

In the current study, we found that there was a moderate positive correlation between hearing threshold and

Table 4 Correlation between average of hearing thresholds (500, 1, 2, and 4 kHz) level and Tinnitus Handicap Inventory baseline

Tinnitus Handicap Inventory baseline	Hearing threshold
Correlation (<i>r</i>)	0.596
P value	<0.001*
N	50

$r<0.3$ 'mild correlation', 0.3–0.7 'moderate correlation', >0.7 'strong correlation'. * $P<0.05$, significant

Table 5 Correlation between average aided hearing thresholds and each of Tinnitus Handicap Inventory baseline, at 3, 6, and 12 months

	Aided hearing threshold
THI baseline	
Correlation (<i>r</i>)	0.670
P value	<0.001*
N	50
THI 3 months	
Correlation (<i>r</i>)	0.628
P value	<0.001*
N	50
THI 6 months	
Correlation (<i>r</i>)	0.468
P value	0.001*
N	50
THI 12 months	
Correlation (<i>r</i>)	0.318
P value	0.026*
N	50

THI, Tinnitus Handicap Inventory.

Table 6 Progress of Tinnitus Handicap Inventory grading over 12 months

	THI baseline [n (%)]	THI 3 months [n (%)]	THI 6 months [n (%)]	THI 12 months [n (%)]
Slight	0 (0.0)	0 (0.0)	0 (0.0)	40 (81.6)
Mild	0 (0.0)	3 (6.0)	21 (42.9)	9 (18.4)
Moderate	8 (16.0)	15 (30.0)	25 (51.0)	1 (0.0)
Severe	14 (28.0)	24 (48.0)	4 (6.1)	0 (0.0)
Catastrophic	28 (56.0)	8 (16.0)	0 (0.0)	0 (0.0)

THI, Tinnitus Handicap Inventory.

each of the THI score at baseline ($P<0.05$) as shown in Table 4. Axelsson and Ringdahl [31] concluded that tinnitus is more common and severe in patients with hearing loss. Also, Holgers *et al.* [32] noticed a moderate correlation between the severity of tinnitus and audiometric parameters.

Table 7 Progress of Tinnitus Handicap Inventory score over 12 months

	N	Mean of Tinnitus Handicap Inventory score	SD	Minimum of score	Maximum of score	P value
Baseline	50	74.80	15.98	38.00	100.00	<0.001*
3 months	50	61.84	14.02	32.00	88.00	
6 months	50	38.35	10.98	18.00	60.00	
12 months	50	12.90	4.26	4.00	22.00	

* $P < 0.05$, significant.

In divergence from our study, Weisz *et al.* [7] showed that increased hearing loss at high frequencies was associated with a lower severity of tinnitus.

Alhazmi *et al.* [27] found that nearly two-third of the patients in their study with tinnitus had some degree of hearing loss, whereas one-third had normal hearing. Also, they assessed the influence of tinnitus perception on the quality of life using THI and Tinnitus Functional Index questionnaires. They noticed no significant difference in the scores of both questionnaires when applied in tinnitus participants with normal hearing and those with hearing loss.

In the present study, we found that there was a moderate positive correlation between aided hearing threshold and each of the THI baseline, at 3, 6, and 12 months ($P < 0.05$) (Table 5). Shekhawat *et al.* [33] reported in their scoping review that hearing aids are considered a popular choice for tinnitus treatment.

Searchfield *et al.* [34] suggested that tinnitus perception can be explained by an adaptation level theory in which it is the potential product of the tinnitus signal, background noise, and psychological/cognitive factors. Hearing aids may have positive effects on tinnitus by improving quality of life related to hearing impairment by decreasing attention to tinnitus and increasing masking from ambient sound [35] and by compensating for deafferentation to reduce central gain [36].

In the current study as shown in Table 6, we reported that at the THI baseline no slight or mild cases were detected, whereas a moderate THI represented 16%, severe 28%, and catastrophic 56%. These rates changed 3 months later as catastrophic cases decreased almost to one-third of its rate at the baseline. By the sixth month, no catastrophic cases were detected and severe stages recorded trivial rates, whereas most of cases were categorized as mild or moderate. By the end of the study, the great majority of cases were slight (81.6%) and the remaining portion was mild, with no moderate, severe, or catastrophic cases recorded. Also, we found that the

THI score showed a striking reduction throughout the 12 months (Table 7).

This was in agreement with Surr *et al.* [14] who administered the THI before and 6 weeks after hearing aid fitting and demonstrated that 90% of their participants showed a significant decrease in THI scores.

Savastano [37] assessed the relation between THI score and the presence or absence of hearing loss in tinnitus sufferers. THI results demonstrated that, in most cases, a slight or mild grade groups in the THI was referred to individuals with hearing loss; normal hearing patients with tinnitus were more common in the moderate and catastrophic groups, which was statistically significant compared with the hearing loss group.

Cabral *et al.* [38] stated that the analysis of the results concerning tinnitus relation to patients by comparing scoring of the answers obtained from Tinnitus Handicap Questionnaire and Tinnitus Acceptance Questionnaire on tinnitus sensation before and after the use of hearing aids showed significant improvement with the use of hearing aids. The mean scores are significantly decreased after hearing aid fitting, indicating the efficacy of hearing aids in patients suffering from tinnitus, mainly in relation to their emotional and hearing aspects.

Conclusion

Analysis of the results has shown that the use of hearing aids is one of a number of therapeutic options offered to tinnitus patients and promotes the improvement in the perceptual characteristics of tinnitus. Providing hearing aids for tinnitus treatment will always have the potential consequence of decreasing tinnitus distress.

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Conflicts of interest

There are no conflicts of interest.

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