



Original Article

Tinnitus Retraining Therapy in Unilateral Tinnitus Patients with Single Side Deafness

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OBJECTIVE: The purpose of this study was to evaluate the audiologic and clinical characteristics of the tinnitus in single-sided deafness (SSD) patients and to determine whether tinnitus retraining therapy (TRT) is beneficial to those patients who suffer from tinnitus with SSD.

MATERIALS and METHODS: Thirty-six tinnitus patients with unilateral sensorineural profound hearing loss were included in the SSD group, and 46 tinnitus patients with normal hearing were included in the normal hearing group (NH group). Tinnitus evaluation consisted of the Tinnitus Handicap Inventory (THI), and visual analog scales (VAS) were obtained at the initial interview and 6 months after TRT. The therapeutic response was analyzed and compared between the two groups.

RESULTS: The subjective intensity of tinnitus and objective loudness were greater in the SSD group. According to the THI scores prior to TRT, the SSD group showed significantly higher values, except in the emotional subscale. The THI score was significantly improved after TRT in both groups. The total THI score and all the subscale scores were significantly reduced. The VAS average scores were reduced from 6.5 to 5.1 in the SSD group, without statistical significance, whereas in the NH group, the VAS average scores significantly decreased from 5.8 to 4.5 after TRT.

CONCLUSION: TRT was effective in SSD patients with subjective tinnitus.

KEYWORDS: Tinnitus, single-sided deafness, tinnitus retraining therapy

INTRODUCTION

Permanent acquired unilateral severe hearing loss or single-sided deafness (SSD) is estimated to affect 12-27 individuals in a population of 100,000. The majority of hearing losses are idiopathic or sudden, with other etiologies of SSD, such as acoustic neuroma and Meniere's disease^[1]. Tinnitus is considered a sequel of hearing loss and most patients with unilateral hearing loss suffer from some tinnitus. The prevalence of tinnitus reaches 68%-100% in severe hearing disturbance patients, and the treatment of tinnitus is hard in these patients^[2].

For patients with SSD and tinnitus, a bone-anchored hearing aid (BAHA) and the conventional contralateral routing of signals systems do not treat their tinnitus symptoms well because they cannot overcome the auditory defect of the deaf ear^[3]. Recently, cochlear implantation (CI) has been used in severe unilateral tinnitus patients with unilateral deafness. There is an 81%-95% improvement in tinnitus by CI in patients with SSD and uncontrolled tinnitus in the affected ear^[4]. However, all participants do not experience the beneficial effects of CI, and an increase in tinnitus after CI has been reported. Furthermore, CI for SSD has not got the Food and Drug Administration approval^[5].

Tinnitus retraining therapy (TRT) is a tinnitus treatment method based on the neurophysiological model for tinnitus. It has been performed since the 1990s, with therapeutic results achieved in approximately 70% of tinnitus patients without remarkable side effects. Furthermore, TRT is known to be effective for any type of tinnitus without regard to etiology^[6]. Despite the wide use of TRT, there have been no published studies yet that have reported the effects of TRT in SSD patients.

The purpose of this study was to evaluate the audiologic and clinical characteristics of tinnitus in SSD and to evaluate whether TRT provides a benefit to those patients who suffer from tinnitus with SSD.

MATERIALS and METHODS

Patients with unilateral tinnitus who presented to our outpatient clinic during a 3 year period from January 2010 to June 2013 and patients who had received complete TRT for at least 6 months were included in this study. The study protocol was approved by the Institutional Review Board of the Medical Center.

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Patients were classified into two groups. In the first group, SSD patients with unilateral sensorineural severe to profound hearing loss (pure tone average threshold at 0.5, 1, 2, and 4 kHz greater than 70 dB) and tinnitus at the ipsilateral side were selected. The patients had normal hearing (average hearing threshold at 0.5, 1, 2, and 4 kHz lower than 25 dB) and no tinnitus in the contralateral ear [3]. A comparable second group comprising the normal hearing group (NH group) comprised patients with unilateral tinnitus and normal hearing in both ears. Patients whose tinnitus was bilateral or patients who were unable to determine the side were excluded. Subjects with objective tinnitus, evidence of middle ear pathology, or retrocochlear disease were also excluded.

The patients' full medical histories were taken and a physical examination of each patient's ear, nose and throat was checked. Audiometric assessment in all cases included pure tone audiogram (Grason-Stadler GSI 61 Clinical; Nicolet Biomedical, Madison, USA), tympanogram (Grason-Stadler GSI 33 middle-ear analyzer; Viasys, Conshohocken, PA), tinnitogram (including loudness and pitch, residual inhibition, and minimum masking levels), uncomfortable loudness level, otoacoustic emissions (Otoport Screener; Otodynamics, Hatfield, Hertfordshire, UK), auditory brainstem response (GSI AUDIOScreener; Grason-Stadler, Minneapolis, MN, USA), computed tomography (Lightspeed 16; General Electric Medical Systems, Milwaukee, WI, USA), and magnetic resonance imaging (Signa Horizon; General Electric Medical Systems, Milwaukee, WI, USA) to rule out retrocochlear lesion.

Pure tone and narrow band noise were used according to the range of loudness and frequency. For pure tone, sounds generated in the audiometer were used. For the frequencies, the following 11 kinds of frequencies were used: 125, 250, 500, 750, 1,000, 1,500, 2,000, 3,000, 4,000, 6,000, and 8,000 Hz. The loudness of tinnitus had a range from 0 to 110 dB, which was adjustable at intervals of 1 dB. The most similar frequency was found by asking the patients about the frequency that was most similar to their tinnitus, and then moving the dissimilar side to the similar side scale-by-scale. In the beginning, when it was not possible to find a similar tone through the pure tone test, the test was conducted with narrowband noise. If no similar tone was found even through the narrowband noise, white noise and a voice signal noise were used to figure out the kinds of sounds. With the pitch match test, the frequencies of tinnitus were found, and the loudness of tinnitus was measured by repetitions ascending and descending the frequencies by 5 dB intervals from the hearing threshold values at a time for 2-3 s. The dB level of an external sound was that judged by a given individual to be equivalent to the loudness of their tinnitus.

Patients were explained that the minimum masking levels is a test to look for the minimum stimulation tone when tinnitus in the ears is not heard and the narrow band noise in the frequency of tinnitus obtained from the tinnitus pitch matching test is used as the tinnitus masking sound. The length of stimulation tone was 2-3 s. By increasing the narrow band noise by 5 dB in terms of hearing threshold, the minimum value of the masking sound when tinnitus is not heard is obtained.

Tinnitus evaluation consisted of the Korean version of the Tinnitus Handicap Inventory (THI), and visual analog scales (VAS) on annoyance were obtained at the initial interview and 6 months after TRT. THI consisted of 25 questions assessing the impact of tinnitus on the

patient's quality of life. The completed inventory was scored from 0 to 100. The inventory has three subscales: functional, emotional, and catastrophic response. A patient whose scores improved by ≥ 7 points in THI was defined as a successful treatment, and the success rates were compared between groups [7].

The TRT treatment was individually delivered following the principles outlined by Jastreboff and Hazell [8]. TRT was composed of directive counseling and sound therapy. The directive counseling was conducted one-on-one by a single specialist for 1 h. Patients attended counseling appointments with the specialist every 2 months and completed questionnaires. Second, sound therapy has an intention of decreasing the sound difference between tinnitus and the environment, causing a lessened perception of tinnitus. Patients with normal hearing on the unaffected side were fitted with wearable sound generators (silent Star, Viennatonne, Audifon-Resound), whereas patients with hearing loss on the unaffected side were fitted with hearing aids. They were fitted with a sound generator or hearing aids on the unaffected side for at least 8 h a day. Jastreboff's classification was not applicable because all patients had SSD.

Statistical Analysis

A paired t-test was conducted to evaluate the differences between the THI and VAS scores treatment either before or after. A two-tailed t-test and chi-square test were used to compare the baseline parameters and the mean differences after treatment. All the statistical analyses were performed using Statistical Package for the Social Sciences version 18.0 software (SPSS Inc.; Chicago, IL, USA), and statistical significance was defined as $p < 0.05$.

RESULTS

In 82 participants (37 males and 45 females), 36 belonged to the SSD group and 46 were in the NH group. The 36 SSD patients included 14 males and 22 females. The mean age of the SSD patients was 53.7 (± 10.6) years. The 46 subjects from the NH group included 23 males and 23 females. The mean age of the NH group was 52.3 (± 11.1) years. Baseline characteristics (age, sex, duration of tinnitus, and side of tinnitus) showed no significant difference between the two groups (Table 1).

On comparing the characteristics of tinnitus, 89% of the SSD group complained of continuous tinnitus, while 63% of NH group complained of continuous tinnitus. The subjective intensity of tinnitus and objective loudness were greater in the SSD group, and the differences were statistically significant (Table 2).

According to the THI scores prior to TRT, the SSD group showed significantly higher values, except in the emotional subscale. For the

Table 1. Comparison of the clinical characteristics

	SSD group	NH group	P
No of subjects	36	46	
Age (Mean \pm SD)	53.7 \pm 10.6	52.3 \pm 11.1	0.55
Sex (M:F)	14:22	23:23	0.31
Duration of tinnitus (mo)	46.5 \pm 58.9	43.8 \pm 35.5	0.51
Location (Rt: Lt)	17:19	23:23	0.80

SSD: single-sided deafness; NH: normal hearing

VAS score, prior treatment, the SSD group scored 6.5 ± 5.7 , while the NH group scored 5.8 ± 1.9 , without statistical significance (Table 3).

Significant improvement after TRT in the THI scores was found in both groups, whereby the total THI score and all the subscale scores were significantly reduced. In the SSD group, total THI decreased from 68.1 to 26.4, functional from 30.3 to 9.2, emotional from 24.6 to 10.6, and the catastrophic scale from 13.1 to 6.5. In the NH group, the total THI decreased from 53.5 to 30.6, functional from 23.1 to 12.7, emotional from 21.2 to 12.2, and the catastrophic scale from 9.2 to 5.8, respectively (Figure 1a, 2).

Visual analog scales average scores reduced from 6.5 to 5.1 in the SSD group, without statistical significance; whereas in the NH group, the

Table 2. Baseline characteristics of tinnitus

	SSD group	NH group	P
Nature (intermittent:continuous)	4:32	17:29	0.008*
Intensity (VAS)	6.6 ± 2.1	5.7 ± 2.0	0.05*
Type (tone:NBN)	14:22	35:11	0.001*
Pitch (low:high)	20:16	21:25	0.45
Loudness (dB HL)	58.9 ± 27.3	40.0 ± 19.4	0.01*
MML (dB HL)	82.1 ± 13.8	55.9 ± 14.1	<0.01*

SSD: single-sided deafness; NH: normal hearing; NBN: narrow band noise; MML: minimum masking level

*p<0.05

Table 3. Initial characteristics of the questionnaires

	SSD group	NH group	P
Pretreatment THI (total)	68.1 ± 25.7	53.5 ± 23.2	0.009*
Functional	30.3 ± 10.8	23.1 ± 11.2	0.004*
Emotional	24.7 ± 10.8	21.3 ± 8.9	0.12
Catastrophic	13.1 ± 5.6	9.2 ± 5.4	0.002*
Pretreatment VAS	6.5 ± 5.7	5.8 ± 1.9	0.44

SSD: single-sided deafness; NH: normal hearing

*p<0.05

VAS average scores decreased significantly from 5.8 to 4.5 after TRT (Figure 1b). Successful treatment rate had no significant difference between groups, i.e., 83% in the SSD group and 74% in the NH group.

DISCUSSION

Tinnitus is the hearing of sound in the absence of external sound stimulation. Even though an absolute treatment for tinnitus remains difficult, various treatment modalities have been developed to reduce the symptoms. Because TRT is free of contraindications and side effects, it is a reasonable rehabilitation approach [9].

Several studies have reported that TRT is a useful treatment for tinnitus: general tinnitus was reduced after 3 months and a significant improvement in the VAS scores and THI scores was reported at 6 months after the beginning of TRT [10]. Since the treatment is aimed to work above the tinnitus source, the cause of tinnitus is irrelevant and TRT could be effective for all types of tinnitus [6]. TRT could be successfully used for any type of tinnitus; for example, continuous, intermittent unilateral, or bilateral, [11]. In addition to primary tinnitus, TRT is also proven to be effective for tinnitus in somatosounds as well as for Meniere disease [12]. Stobik et al. [13] found that there was a significant correlation between tinnitus-related distress and hearing loss severity. Nevertheless, the loss of hearing is often only a secondary diagnosis, as tinnitus is regarded as a more uncomfortable symptom.

Normal hearing is only present in 9.9% of the ears affected by tinnitus, and only 7.5% of tinnitus patients are given a hearing aid, although 53% report that there is spontaneous hearing loss in the ear affected by tinnitus [14]. No statistically significant difference in pitch was seen between the NH group and hearing loss group. However, a statistically significant difference was evident between NH and hearing loss groups with regard to loudness. On the THI questionnaire, patients with the NH group showed a mild handicap, whereas those in the hearing loss group showed a moderate handicap [15]. Patients with hearing loss have a high severity of tinnitus compared to patients with normal hearing, and the distress associated with sleeping increased with the tinnitus severity [16]. A recent study reported that the severity of tinnitus was significantly higher in tinnitus patients with hearing loss, as compared with tinnitus patients with normal hearing, and THI showed similar results between the two groups [17].

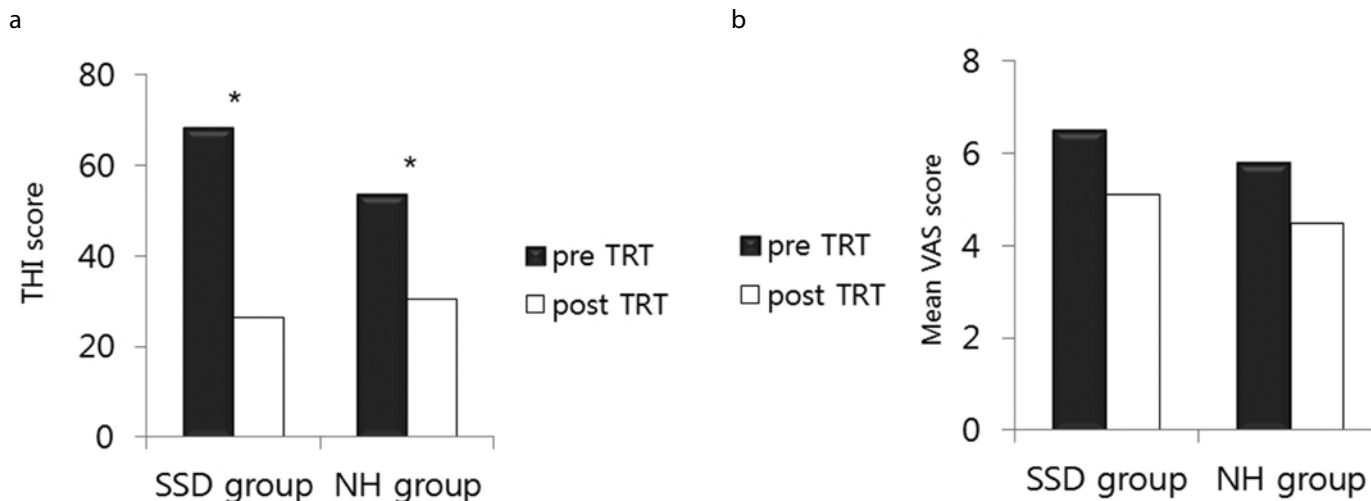


Figure 1. a, b. Changes of total THI score (a), and mean VAS score (b) of tinnitus before and after TRT

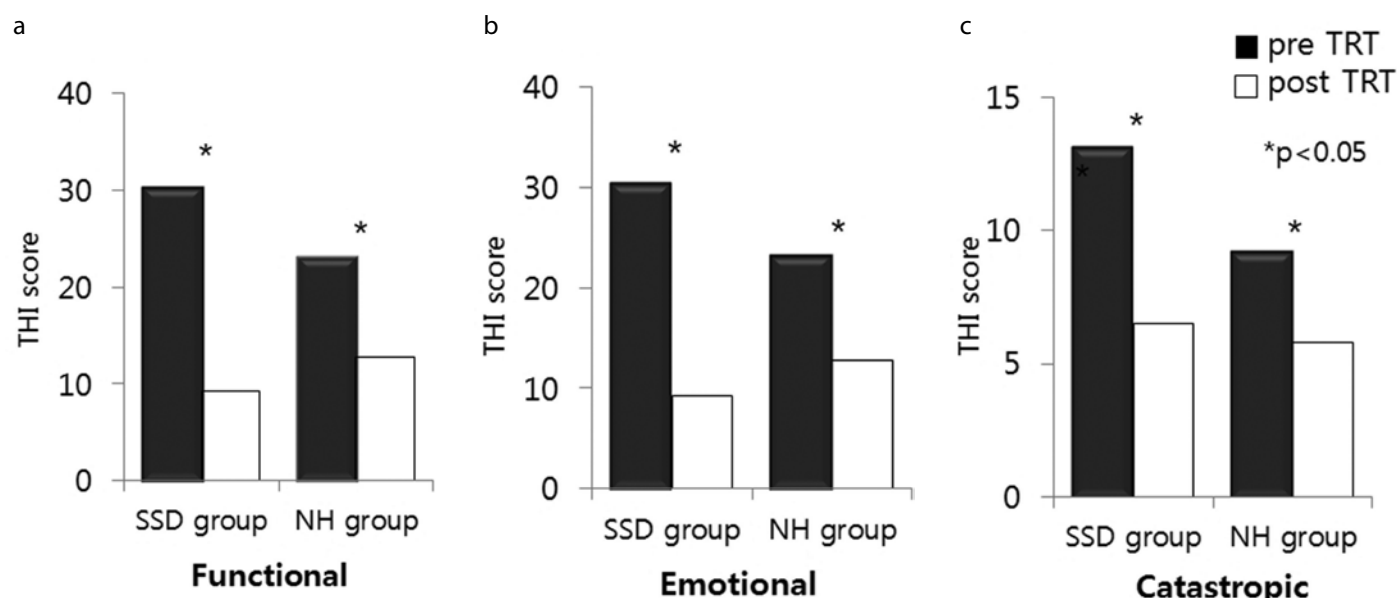


Figure 1. a-c. Changes of THI subscale of tinnitus before and after TRT. (a) functional, (b) emotional, (c) catastrophic

In this study, there was no difference in the intensity of tinnitus between the groups. However, there was a significant difference in terms of the nature, type, and loudness between the two groups. We also found that tinnitus with SSD had a greater impact on the life of affected individuals.

The current study indicated that TRT is an effective method for tinnitus treatment in SSD patients, and was improved in 83% of subjects. This effect was not significantly different when compared to the NH group. Although the underlying mechanism responsible for the observed results is not clear, this finding would support the neurophysiological model of tinnitus. It was difficult for patients with SSD to have hearing and comprehension in the presence of noise. SSD results in a greater disability than subjects with both hearing defects evaluated by using the speech, spatial, and qualities of the Hearing Scale questionnaire (SSQ) [18].

A sound generator or hearing aids amplify background noise so that they provide partial masking while reducing the prominence or loudness of tinnitus. They could be a useful tool for habituation to the perception of the tinnitus. In this way, the tinnitus slowly lessens being annoying and this decreases listening stress and fatigue, and thereby the ability to deal with tinnitus is improved.

Whenever possible, hearing aids should be fitted in both ears since this allows the understanding of verbal messages and better spatial localization. These two elements are known to be important to activate the whole acoustic nervous system. However, there was no point in wearing a sound generator or hearing aid on the deaf side, so we recommended wearing the instrument on the contralateral side according to the hearing levels in this study.

The lack of input from the damaged sensory apparatus can induce tinnitus as the brain attempts to interpret missing sensory data for sensorineural hearing loss. The volume and the frequency of the noise can be aggravated according to the physical condition. This can increase social problems and aggravate the hardship of speech un-

derstanding. BAHA showed an advantage according to the patient's transcranial attenuation of patients. Another study reported that the localization of sound was not improved, but the head shadow effect was reduced in patients using BAHA [19].

Although standard treatment is not available in SSD patients with tinnitus, the effect of CI on unilateral tinnitus resulting from SSD have been studied. Several recent studies suggest important benefits of cochlear implant regarding tinnitus [4]. However, cochlear implants have limitations, such as high cost and invasive surgery; and furthermore, there is not much evidence from studies on CI in patients with SSD. Since the patients with SSD had severe to profound hearing loss, HAs were not advantageous to the sound. Residual hearing may be sufficient to decrease the strength of the tinnitus signal and a normal hearing in the contralateral ear is sufficient to understand the counseling that is a crucial part of TRT. Even though cochlear impaired function is considered to be the origin of tinnitus, the conscious cortex and subcortical level play an important role for emotional reaction and tinnitus perception. The connections between the limbic system and auditory pathways are in charge of the emotional response and the autonomous nervous system reactions of anxiety, sleep disorders, and depression that are common in tinnitus patients [20]. As TRT is aimed at removing negative associations of the tinnitus signal and regulating the nonauditory pathways affecting the limbic and autonomic nervous system in a significant way, it could be considered as a viable treatment option for tinnitus arising from SSD. In conclusion, the overall TRT success rate was 83% in the SSD group and 74% in the NH group, and there was no significant group wise difference. TRT was thus demonstrated as effective in SSD patients with subjective tinnitus.

Ethics Committee Approval: The study protocol was approved by the Institutional Review Board of Medical Center.

Informed Consent: Written informed consent was obtained from all participants.

Peer-review: Externally peer-reviewed.

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REFERENCES

1. Baguley DM, Williamson CA, Moffat DA. Treating tinnitus in patients with otologic conditions. In: Tyler RS, editor. Tinnitus treatment. New York: Thieme. 2006; 41-50.
2. Miyamoto RT, Bichey BG. Cochlear implantation for tinnitus suppression. *Otolaryngol Clin North Am* 2003; 36: 345-52. [\[CrossRef\]](#)
3. Távora-Vieira D, Marino R, Krishnaswamy J, Kuthbutheen J, Rajan GP. Cochlear implantation for unilateral deafness with and without tinnitus: a case series. *Laryngoscope* 2013; 123: 1251-5. [\[CrossRef\]](#)
4. Arndt S, Aschendorff A, Laszig R, Beck R, Schild C, Kroeger S, et al. Comparison of pseudobinaural hearing to real binaural hearing rehabilitation after cochlear implantation in patients with unilateral deafness and tinnitus. *Otol Neurotol* 2011; 32: 39-47. [\[CrossRef\]](#)
5. Vermeire K, Van de Heyning P. Binaural hearing after cochlear implantation in subjects with unilateral sensorineural deafness and tinnitus. *Audiol Neurotol* 2009; 14: 163-71. [\[CrossRef\]](#)
6. Jastreboff PJ, Jastreboff MM. Tinnitus retraining therapy: a different view on tinnitus. *ORL J Otorhinolaryngol Relat Spec* 2006; 68: 23-9. [\[CrossRef\]](#)
7. JH Kim, SY Lee, CH Kim, SL Lim, Juno Shin, WH Chung, et al. Reliability and validity of a Korean adaptation of the tinnitus handicap inventory. *Korean J Otolaryngol* 2002; 45: 328-34.
8. Jastreboff PJ, Hazell JW. A neurophysiological approach to tinnitus: clinical implications. *Br J Audiol* 1993; 27: 7-17. [\[CrossRef\]](#)
9. Baracca GN, Forti S, Crocetti A, Fagnani E, Scotti A, Del Bo L, et al. Results of TRT after eighteen months: our experience. *Int J Audiol* 2007; 46: 217-22. [\[CrossRef\]](#)
10. Hatanaka A, Ariizumi Y, Kitamura K. Pros and cons of tinnitus retraining therapy. *Acta Otolaryngol* 2008; 128: 365-8. [\[CrossRef\]](#)
11. Jastreboff PJ. Tinnitus retraining therapy. In *Textbook of tinnitus*. Springer New York. 2011: 575-96. [\[CrossRef\]](#)
12. Herraiz C, Plaza F, De los Santos G. Tinnitus retraining therapy in Meniere disease. *Acta Otorrinolaringol Esp* 2006; 57: 96-100.
13. Stobik C, Weber RK, Münte TF, Walter M, Frommer J. Evidence of psychosomatic influences in compensated and decompensated tinnitus. *Int J Audiol* 2005; 44: 370-8. [\[CrossRef\]](#)
14. Pilgramm M, Rychlik R, Leibisch H, Siedentop H, Goebel G, Korchhoff D. Tinnitus in the Federal Republic of Germany: a representative epidemiological study. In: Hazell, J.W. (Ed.). *Proc 6th Int Tinnitus Semin*, Cambridge UK 1999; 64-7.
15. Prestes R, Daniela G. Impact of tinnitus on quality of life, loudness and pitch match, and high-frequency audiometry. *Int Tinnitus J* 2009; 15: 134-8.
16. Axelsson A, Ringdahl A. Tinnitus—a study of its prevalence and characteristics. *Br J Audiol* 1989; 23: 53-62. [\[CrossRef\]](#)
17. Yenigün A, Doğan R, Aksoy F, Akyüz S, Dabak H. Assessment of tinnitus with tinnitus severity index, tinnitus handicap inventory and distortion product otoacoustic emissions in patients with normal hearing and hearing loss. *Kulak Burun Bogaz Ihtis Derg* 2014; 24: 11-6. [\[CrossRef\]](#)
18. Noble W, Gatehouse S. Interaural asymmetry of hearing loss, speech, spatial and qualities of hearing scale (SSQ) disabilities, and handicap. *Int J Audiol* 2004; 43: 100-14. [\[CrossRef\]](#)
19. Hol MK, Bosman AJ, Snik AF, Mylanus EA, Cremers CW. Bone-anchored hearing aids in unilateral inner ear deafness: an evaluation of audiometric and patient outcome measurements. *Otol Neurotol* 2005; 26: 999-1006. [\[CrossRef\]](#)
20. Herraiz C, Hernandez FJ, Plaza G, De Los Santos G. Long-term clinical trial of tinnitus retraining therapy. *Otolaryngol Head Neck Surg* 2005; 133: 774-9. [\[CrossRef\]](#)