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Original Article

# Clinical and Audiologic Characteristics of Tinnitus in Subjects Aged <65 and ≥65 Years

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**OBJECTIVE:** This study compared the characteristics of tinnitus, by audiologic tests and questionnaires, in older and younger subjects.

**MATERIALS and METHODS:** Medical records of 258 outpatients with tinnitus were retrospectively reviewed. Characteristics compared in subjects aged <65 and ≥65 years included patient history and the results of physical examinations, questionnaires, and audiologic tests.

**RESULTS:** Fifty-nine patients were aged 65 years and older (older group), and 199 were less than 65 years old (younger group). The prevalence of chronic tinnitus was significantly higher in the older group ($p<0.05$). Assessments of audiologic configuration showed that the rate of high frequency steeply sloping configuration was significantly higher ($p<0.05$). The rate of sensorineural hearing loss was significantly higher in the older group ($p<0.05$). On tinnitograms, loudness was significantly higher in the older group ($p<0.05$). Auditory brainstem responses analysis showed that V latency was longer in the older group ($p<0.05$). The older group showed lower responses at every frequency on distortion product otoacoustic emissions ($p<0.05$) and lower signal-to-noise ratio at every frequency on transient evoked otoacoustic emissions ($p<0.05$).

**CONCLUSION:** The clinical manifestations of tinnitus and audiological results differ between older and younger subjects with tinnitus.

**KEYWORDS:** Tinnitus, elderly, age, audiologic configuration

## INTRODUCTION

Tinnitus is an auditory phantom sensation, in which noise can be heard even in the absence of external sound stimuli. It has been estimated that one-third of the population experiences tinnitus at least once in his or her lifetime, with an overall prevalence of about 20%. The 1999-2004 United States National Health and Nutritional Examination Survey (NHANES) estimated that the prevalence of tinnitus was 25.3% [1], whereas the 2009-2011 Korea National Health and Nutrition Examination Surveys (KNHANES) estimated a prevalence of 19.7% [2]. Because the number of older persons in the population is increasing rapidly, and as younger people become increasingly exposed to industrial and recreational noise, the prevalence rate of tinnitus is expected to further increase [3].

Although tinnitus can occur at any age, its prevalence has been reported to be higher in older than in younger individuals. Tinnitus is the second most commonly reported ear problem, after hearing loss, but it is seldom recorded in clinical databases. Age-related cochlear degeneration in animals may be associated with hearing problems observed in patients with tinnitus. Tinnitus accompanying hearing loss caused by presbycusis has been described as presbytinnitus [4]. It is unclear, however, whether this tinnitus results from hearing loss due to aging, and further evaluations are warranted to rule out other causes. This study compared the characteristics of tinnitus, as determined by audiologic tests and questionnaires, in older and younger subjects.

## MATERIALS AND METHODS

### Subjects and study design

This retrospective study included 258 outpatients, from January 2016 to December 2016, who visited the outpatient clinic with the complaint of tinnitus and who completed a physical examination, medical history survey, questionnaire survey for measuring subjective discomfort due to tinnitus, and underwent full-scale audiometry. Patients with ear infection (e.g., otitis media, myringitis, mastoiditis), previous ear surgery, a history of trauma, uncertain history, or vague manifestations of tinnitus were excluded from the study. Acute tinnitus was defined as symptom duration less than 3 months and chronic tinnitus as symptom duration longer than 3 months. Patients with subacute tinnitus patients who experienced tinnitus from 3 weeks to 3 months were considered to have

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acute tinnitus. Patients with conductive hearing loss were excluded if they had any abnormality on impedance audiometry or physical examination. Patients were divided into two groups, a younger group (aged <65 years) and an older group (aged ≥65 years); the cutoff of 65 years was chosen because this is the threshold for senior citizens in Korea.

All patients underwent a detailed physical examination at their first visit, along with a history taking that included demographic characteristics, occupation, the laterality and duration of tinnitus, and accompanying symptoms. Each subject was administered three questionnaires: the Tinnitus Handicap Inventory (THI), the Beck Depression Inventory (BDI), and a Visual Analog Scale (VAS) of discomfort from tinnitus. Audiologic examinations included pure tone audiometry (PTA), tinnitogram, auditory brainstem responses (ABR), distortion product otoacoustic emissions (DPOAEs), and transient evoked otoacoustic emissions (TEOAEs). The study protocol was approved by the Institutional Review Board of Medical Center.

**Tinnitus Handicap Inventory (THI), Beck Depression Inventory (BDI), and Visual Analog Scale (VAS)**

The THI, which assesses the degree of subjective discomfort associated with tinnitus, includes three sub-scales, functional, emotional, and catastrophic, with a total of 25 questions. Each item was recorded as "no" (0 points), "sometimes" (2 points), and "yes" (4 points), with scores added to calculate the total score. The BDI, which is used to measure depression, consists of a total of 21 questions, each scored from 0-3 points, with a total of 0-63 points. The reliability and validity of these Korean versions has been established previously.[5, 6] Tinnitus-associated discomfort was scored from 0 to 10 on a VAS, and a face pain scale was used to enhance patient understanding.

**Pure tone audiometry (PTA)**

Pure tone audiometry examines air conduction and bone conduction at 125, 250, and 500 Hz, and at 1, 2, 3, 4, and 8 kHz. PTA scores were calculated using a six-part partition method, using the formula [(500 Hz+[2×1000 Hz]+[2×2000 Hz]+4000 Hz)/6]. Subjects were categorized into six audiologic configurations: high frequency gently sloping (HFGS), high frequency steeply sloping (HFSS), flat, low frequency ascending (LFA), mid-frequency U-curve (MFU), and mid-frequency reversed U-curve (MFRU). Patients who could not be classified into any of these configurations were regarded as "not categorized," and those who fit into two or more configurations were defined as the "overlap" group [7]. In subjects who complained of bilateral tinnitus, each ear was analyzed separately. Patients with asymmetric hearing disturbance, defined as a ≥30 dB difference between the two ears, were excluded. Subjects with C5-dip were defined as those with most severe hearing loss at 4 kHz and an auditory threshold more than 10dB HL lower at 8 kHz than 4 kHz [8].

**Tinnitogram**

All patients underwent tinnitography to evaluate the direction of tinnitus, pitch, and loudness. Residual inhibition (RI) and minimum masking level were also measured. On tinnitus pitch tests, patients' individual sound characteristics were categorized into four groups, according to Korean onomatopoeia of tinnitus [7]: (1) "Woong" (mechanical sound) [u:ŋ] at low frequency; (2) "Schae" (sound of a cicada) [s'oi:] at middle and high frequencies; (3) "Phee" [p'i:] at high frequency, including [ʧ i:, ʧ i:ŋ, ʧ ɛ:ŋ, ʧ ik]; and (4) "Weeing" [wi:ŋ] at full frequency range, including [we:ŋ, tsi:, wa:ŋ]. Subjects who did not fit into any of these categories were classified as "others.." Subjects who experienced tinnitus at two or more pitches were classified by their dominant sound.

**Auditory brainstem responses (ABR), distortion product otoacoustic emissions (DPOAEs), and transient evoked otoacoustic emissions (TEOAEs)**

ABR tests were performed to assess damage to the cochlea, outer hair cells, subcortical region of the brain, and the eighth cranial nerve. Six items on the ABR were measured: I latency, III latency, V latency, I-III IPL (interpeak latency), III-V IPL, and I-V IPL [9]. DPOAE and TEOAE were also performed to determine the function of outer hair cells [10]. DPOAEs were categorized based on responses to 1, 2, 3, 4, and 6 kHz, and response or non-response at each pitch was recorded. TEOAE was categorized by signal-to-noise ratio (SNR) at 1, 1.5, 2, 3, and 4 kHz, with normal defined as an SNR >3 dB [11]."

**Statistical Analysis**

Normality test was done by Shapiro-Wilk W test. Categorical variables were compared by chi-squared tests and continuous variables by Student's t-tests. Normality was tested using the Shapiro-Wilk W test. All statistical analyses were performed using SPSS 20.0 software, with a p value <0.05 considered statistically significant.

**RESULTS**

Of the 258 patients, 199 were aged <65 years (younger group), and 59 were aged ≥65 years (older group) (Table 1). The mean ages of subjects in the younger and older age groups were 48.60±12.419 years (range, 18-64 years) and 69.53±4.091 years (range, 65-81 years). There were no significant differences between the groups in sex, laterality, associated symptoms, and pitch (p>0.05). The rate of chronic tinnitus, which had persisted for at least 3 months prior to study participation, was significantly higher in the older than in the younger group (p<0.05). Higher percentages of the older than of the younger group were unemployed (retired) and housewives (p<0.05). The average THI, BDI, and VAS scores were lower in the older group, although sensitivity to tinnitus did not differ significantly in the two groups (p>0.05 each, Table 2).

Pure tone audiometry showed that more than 80% of subjects fell into three patterns-Flat, HFGS, and HFSS-regardless of age. Data from affected ears showed that HFSS was significantly more frequent, while Flat and HFGS were significantly less frequent, in the older than in the younger group (p<0.05, Table 3). Rates of C5-dip, indicative of noise-induced hearing loss, were similar in the two age groups (Table 3). The percentage of patients with sensorineural hearing loss and an average threshold shift >25 dB in PTA was significantly higher in the older group (p<0.05).

Tinnitogram analysis showed that loudness was significantly higher in the older group (p<0.05), whereas pitch did not differ significantly (p>0.05). ABR analysis showed that V latency was shorter in the younger group (p<0.05, Table 4). The older group showed lower responses at every frequency on DPOAE (p<0.05, Table 5) and lower SNR at every frequency on TEOAE (p<0.05, Table 6). We summarized the differences between the younger and older age groups (Table 7).

**Table 1.** Summary of subjects and preoperative testing

| | Younger age (<65 years) (n=199) Mean: 48.60±12.41 Min:18/Max: 64 | | Older age (≥65 years) (n=59) Mean: 69.53±4.091 Min: 65/Max: 81 | | |
|---|---|---|---|---|---|
| | N | (%) | N | (%) | p |
| Sex | | | | | |
| Male | 70 | (35.2) | 23 | (39.0) | |
| Female | 129 | (64.8) | 36 | (61.0) | 0.593 |
| Tinnitus localization | | | | | |
| Unilateral right | 43 | (21.3) | 13 | (22.0) | |
| Unilateral left | 88 | (44.2) | 28 | (47.5) | |
| Bilateral | 68 | (75.9) | 18 | (30.5) | 0.707 |
| Tinnitus duration | | | | | |
| Acute (<3 mo) | 108 | (54.3) | 20 | (33.9) | |
| Chronic (>3 mo) | 91 | (45.7) | 39 | (66.1) | 0.006* |
| Associated symptoms | | | | | |
| Hearing disturbance | 62 | (31.2) | 23 | (39.0) | 0.777 |
| Ear fullness | 35 | (17.6) | 5 | (8.5) | |
| Vertigo | 17 | (8.5) | 3 | (5.1) | |
| Autophonia | 5 | (2.5) | 0 | (0) | |
| None | 80 | (40.2) | 27 | (45.8) | |
| Tinnitus Pitch | | | | | |
| Weeing | 44 | (22.1) | 13 | (13.0) | |
| Phee | 78 | (39.2) | 18 | (37.2) | |
| Schae | 31 | (15.6) | 14 | (23.7) | |
| Woong | 27 | (13.6) | 7 | (10.2) | |
| Others | 19 | (9.5) | 6 | (13.6) | 0.470 |
| Current Occupation | | | | | |
| Unemployed & Housewife | 83 | (41.9) | 42 | (72.4) | |
| Employed | 116 | (58.1) | 17 | (27.6) | 0.000* |
| Industry | 12 | (6.1) | | | |
| Service and Sales | 26 | (13.1) | | | |
| Soldier | 7 | (3.5) | | | |
| Office work | 35 | (17.7) | | | |
| Student | 15 | (7.6) | | | |
| Others | 20 | (10.1) | | | |

* p<0.05

## DISCUSSION

As the number of senior citizens increases, so do rates of tinnitus and presbycusis [12]. The most common cause of tinnitus is hearing disturbance, and patients with tinnitus may present with other clinical manifestations, such as dizziness and ear fullness [13, 14].

**Table 2.** THI, VAS, and BDI scores in the younger and older patient groups

| | Younger age (<65 years) (n=199) | Older age (≥65 years) (n=59) | p |
|---|---|---|---|
| THI | 40.61±25.37 | 36.10±22.18 | 0.219 |
| VAS | 5.05±2.97 | 4.61±3.09 | 0.324 |
| BDI | 10.49±8.28 | 9.19±9.40 | 0.308 |

THI: Tinnitus Handicap Index; BDI: Beck Depression Index; VAS: Visual Analog Scale

**Table 3.** Number of ears with flat, HFGS, and HFSS configurations and C5-dip

| | Younger age (<65 years) | | Older age (≥65 years) | | |
|---|---|---|---|---|---|
| | N | (%) | N | (%) | p |
| Flat | 88 | (37.9) | 15 | (20.8) | |
| HFGS | 60 | (25.9) | 11 | (15.3) | 0.000* |
| HFSS | 84 | (36.2) | 46 | (63.9) | |
| C5 dip | | | | | |
| Yes | 28 | (10.5) | 5 | (6.5) | |
| No | 238 | (89.5) | 72 | (93.5) | 0.382 |

HFGS; high frequency gently sloping; HFSS; high frequency steeply sloping; C5 dip (4 kHz hearing loss) that showed most severe hearing loss at 4kHz and have more than 10 dB HL less threshold of auditory at 8 kHz than 4 kHz.

* p<0.05

**Table 4.** ABR results in the younger and older patient groups

| | Younger age (<65 years) | | Older age (≥65 years) | | |
|---|---|---|---|---|---|
| | Mean (ms) | SD | Mean (ms) | SD | p |
| I latency | 1.60 | 0.22 | 1.65 | 0.17 | 0.101 |
| III latency | 3.79 | 0.32 | 3.86 | 0.22 | 0.101 |
| V latency* | 5.74 | 0.29 | 5.86 | 0.32 | 0.003* |
| I-III IPL | 2.17 | 0.20 | 2.18 | 0.15 | 0.764 |
| III-V IPL | 1.92 | 0.19 | 1.94 | 0.20 | 0.410 |
| I-V IPL | 4.10 | 0.20 | 4.15 | 0.22 | 0.107 |

ABR: auditory brainstem responses; IPL: interpeak latency

* p<0.05

The incidence of chronic tinnitus was significantly higher in the older than in the younger group (p<0.05). Unlike younger patients, who tend to be evaluated soon after developing symptoms, older patients are more likely to be evaluated much later. In contrast to young patients, who recognize tinnitus as a disease and visit hospital promptly upon recognition of its onset, most elderly patients did not regard the symptoms of tinnitus seriously unless they caused serious discomfort, and they only visited hospital when the condition had developed into a chronic state.

Patient medical history should include occupation [15]. This study therefore evaluated patients' jobs when they first visited the hos-

**Table 5.** Percentages of DPOAE responsive ears in the younger and older patient groups

| Freq (kHz) | Younger age (<65 years) | Older age (≥65 years) | p |
|---|---|---|---|
| 1* | 73.8% | 50.6% | 0.000* |
| 2* | 68.9% | 48.1% | 0.001* |
| 3* | 56.2% | 29.9% | 0.000* |
| 4* | 50.6% | 23.4% | 0.000* |
| 6* | 36.0% | 18.2% | 0.003* |

DPOAe: distortion product otoacoustic emissions* p<0.05

**Table 6.** TEOAE SNRs in the younger and older patient groups

| | Younger age (<65 years) | | Older age (≥65 years) | | |
|---|---|---|---|---|---|
| Freq (kHz) | Mean (ms) | SD | Mean (ms) | SD | p |
| 1* | 8.95 | 7.94 | 4.42 | 6.23 | 0.000* |
| 1.5* | 12.94 | 8.05 | 6.24 | 7.76 | 0.000* |
| 2* | 11.71 | 8.27 | 6.33 | 6.73 | 0.000* |
| 3* | 9.13 | 8.27 | 4.34 | 6.78 | 0.000* |
| 4* | 6.81 | 7.88 | 4.31 | 6.30 | 0.044* |

SNR: signal-to-noise ratio
* p<0.05

**Table 7.** Summation of differences between the younger and older age groups

| | Younger age (<65 years) | Older age (≥65 years) | p |
|---|---|---|---|
| Tinnitus duration | Acute | Chronic | 0.006* |
| Current occupation | Employed | Unemployed & Housewife | 0.000* |
| Audiologic configuration | Flat, HFGS | HFSS | 0.000* |
| ABR (V latency) | Normal | Abnormal | 0.003* |
| DPOAE, TEOAE | Normal | Abnormal | <0.005* |

HFGS: high frequency gently sloping; HFSS: high frequency steeply sloping; ABR: auditory brainstem response; DPOAEs: distortion product otoacoustic emission; TEOAE: transient evoked otoacoustic emissions
* p<0.05

pital, with occupations categorized as industrial, service/sales, military, office work, student, and others. Of the subjects aged ≥65 years, 72.4% were unemployed (retired) or housewives, indicating that they were not directly exposed to noise at the time of hospital visit. However, their previous occupations were not recorded. Rates of C5 dip, which is related to noise-induced hearing loss, were similar in the two groups. C5 dip showed a threshold at 4 kHz, almost at the beginning of noise-induced hearing loss, and affects adjacent frequency areas as patients are continuously exposed to noise. In comparison, presbycusis shows a greater decrease in hearing threshold around 8 kHz. In some patients, noise-induced hearing loss shows a specific threshold shift around 4 kHz, whereas presbycusis shows a threshold shift around 8 kHz. In most patients, however, both noise-induced hearing loss and hearing loss due to aging (presbycusis) occur at high frequency, making them hard to differentiate [8]. Using the C5 dip standard, there was no significant difference between the two groups in rates of hearing loss due to noise exposure. Nevertheless, determining a patient's previous occupation may provide insight into the relationship between exposure to noise and tinnitus.

This study found that over 90% of the patients with tinnitus could be classified into three audiologic configurations: HFSS, HFGS, and flat type. Since previous studies yielded similar results, these three groups were compared, while excluding patients with other audiologic configurations [7, 16]. The higher rate of HFSS, indicating a threshold shift at high frequency, and the lower rate of HGFS in the older group were not unexpected.

Although previous research compared the psychological aspects of tinnitus in younger and older subjects [17], to our knowledge, no comparative studies performed to date have evaluated audiological configuration based on PTA data. Moreover, none had analyzed the details of noise-induced hearing loss, tinnitus pitch, and auditory tests such as ABR, TEOAE, and DPOAE and their correlation with occupational history.

Presbycusis is thought to be caused by degeneration of the stria vascularis of the inner ear [18]. If tinnitus is accompanied by a physiological transition caused by hearing loss, ABR is needed to evaluate the reaction of the cranial nerve, and DPOAE is needed to evaluate functions of outer hair cells. ABR can be used to assess electronic transitions in the auditory nerve and auditory tract. Newborn babies show a long V wave, which becomes similar to that in adults within approximately 18-24 months after birth. Women >50 years were found to have a shorter V wave latency than younger females [19], although other studies reported that age had little effect [20]. Our ABR results indicated that only V wave latency differed significantly in the two age groups, a difference that may be due to aging, not to tinnitus characteristics caused by aging.

Abnormal TEOAE results have been reported in 85% of tinnitus patients [21], and case-control studies comparing patients with and without tinnitus found that abnormalities on TEOAE and DPOAE were significantly more frequent in patients with than without tinnitus [10]. DPOAE has also been associated with hearing loss [22]. Because DPOAE reflects auditory status at mid and high frequencies, as well as being related to audiometric thresholds, it is useful in predicting hearing loss. The relationships between subjective tests, such as PTA and tinnitogram, and objective tests, such as ABR, TEOAE, and DPOAE, makes the latter necessary, in conjunction with subjective tests and questionnaires, when testing the severity of tinnitus and hearing ability in older aged patients. Also, despite there being no audiographic abnormalities, abnormalities could be found in ABR and OAE tests, making objective tests necessary for more precise evaluation.

Previous studies found no age-related differences in depression or subjective tinnitus severity accompanying hearing loss [17]. Our tinnitogram analysis found no differences in pitch, but the older group

showed higher average loudness. We also found that THI, VAS, and BDI were higher in younger than in older patients, but the differences were not statistically significant. Tinnitus in older aged patients likely accompanies high frequency hearing impairment caused by presbycusis, suggesting adaptation to tinnitus that occurred much earlier in time. Because chronic tinnitus is much harder to cure, it requires precise and active evaluation.

Analysis of the data showed that the hearing threshold was increased in the older group with tinnitus at all frequencies compared to the younger group with tinnitus, leading us to think that SNHL affected the outcomes. In addition, since all subjects in this study were patients with tinnitus, it is difficult to confirm the prevalence of tinnitus according to SNHL. Further research that would compare data between the groups with and without tinnitus according to age is needed.

This study had several limitations. First, its retrospective, cross-sectional design precluded inclusion of follow-up data from initial evaluation to recovery. Second, because previous occupation was not recorded, exposure to noise could not be evaluated. Third, the small numbers of patients with LFA, MFU, and MFRU prevented evaluation of these configurations as a function of age. Fourth, there were no control groups, consisting of age- and hearing-threshold-matched older and younger individuals without tinnitus; thus, the differences observed between the two groups of tinnitus patients may have been due to age alone.

## CONCUSION

The clinical manifestations of tinnitus and audiological results differ between older and younger subjects with tinnitus.

**Ethics Committee Approval:** This study was approved by our Institutional Ethical Committee (201701009).

**Informed Consent:** N/A.

**Peer-review:** Externally peer-reviewed.

**Author contributions:** Concept - S.H.D., S.G.Y.; Design - S.G.Y.; Supervision - S.G.Y.; Resource - S.H.D.; Materials - S.S.K., H.J.K.; Data Collection and/or Processing - S.H.D., H.J.K.; Analysis and/or Interpretation - S.H.D., J.H.Y.; Literature Search - S.H.D., J.H.Y., H.J.K.; Writing - S.H.D., S.H.K.; Critical Reviews - S.G.Y.

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## REFERENCES

1. Shargorodsky J, Curhan GC, Farwell WR. Prevalence and characteristics of tinnitus among US adults. Am J Med 2010; 123: 711-8. [CrossRef]
2. Park KH, Lee SH, Koo JW, Park HY, Lee KY, Choi YS, et al. Prevalence and associated factors of tinnitus: data from the Korean National Health and Nutrition Examination Survey 2009-2011. J Epidemiol 2014; 24: 417-26. [CrossRef]
3. Toh ST, Lu P, Ong M, Seet B. Prevalence of hearing disorders in Singapore military conscripts: a role for routine audiometry screening? Singapore Med J 2002; 43: 622-7.
4. Podoshin L, Ben-David J, Teszler CB. Pediatric and Geriatric Tinnitus. Int Tinnitus J 1997; 3: 101-3.
5. Kim JH, Lee SY, Kim CH, Lim SL, Shin JN, Chung WH, et al. Reliability and Validity of a Korean Adaptation of the Tinnitus Handicap Inventory. Korean J Otorhinolaryngol-Head Neck Surg 2002; 45: 328-34.
6. Song YM, Lee HK, Kim JW, Lee K. Reliability and Validity of the Korean Version of Beck Depression Inventory-II via the Internet: Results from a University Student Sample. J Korean Neuropsychiatr Assoc 2012; 51: 402-8. [CrossRef]
7. Kim SI, Kim MG, Kim SS, Byun JY, Park MS, Yeo SG. Evaluation of tinnitus patients by audiometric configuration. Am J Otolaryngol 2016; 37: 1-5. [CrossRef]
8. Jung KJ, An W, Park E, Chang J, Jung HH, Im GJ. Analysis of 4 kHz Notch Audiogram as a Sign of Noise Induced Hearing Loss. Korean J Otorhinolaryngol-Head and Neck Surg 2014; 57: 155. [CrossRef]
9. Kehrle HM, Granjeiro RC, Sampaio AL, Bezerra R, Almeida VF, Oliveira CA. Comparison of auditory brainstem response results in normal-hearing patients with and without tinnitus. Arch Otolaryngol Head Neck Surg 2008; 134: 647-51. [CrossRef]
10. Granjeiro RC, Kehrle HM, Bezerra RL, Almeida VF, Sampaio AL, Oliveira CA. Transient and distortion product evoked oto-acoustic emissions in normal hearing patients with and without tinnitus. Otolaryngol Head Neck Surg 2008; 138: 502-6. [CrossRef]
11. Shekhawat GS, Searchfield GD, Stinear CM. The relationship between tinnitus pitch and hearing sensitivity. Eur Arch Otorhinolaryngol 2014; 271: 41-8. [CrossRef]
12. Davis AC. Epidemiological profile of hearing impairments: the scale and nature of the problem with special reference to the elderly. Acta Otolaryngol Suppl 1990; 476: 23-31.
13. Barozzi S, Socci M, Ginocchio D, Filipponi E, Martinazzoli MG, Cesarani A. Benign paroxysmal positional vertigo and tinnitus. Int Tinnitus J 2013; 18: 16-9. [CrossRef]
14. Yang CW, Jung J, Kim SH, Byun JY, Park MS, Yeo SG. Comparison of clinical characteristics in patients with bilateral and unilateral tinnitus. Acta Otolaryngol 2015; 135: 1128-31.
15. Engdahl B, Krog NH, Kvestad E, Hoffman HJ, Tambs K. Occupation and the risk of bothersome tinnitus: results from a prospective cohort study (HUNT). BMJ Open 2012; 2: e000512. [CrossRef]
16. Gilles A, Goelen S, Van de Heyning P. Tinnitus: a cross-sectional study on the audiologic characteristics. Otol Neurotol 2014; 35: 401-6. [CrossRef]
17. Park SY, Han JJ, Hwang JH, Whang ES, Yeo SW, Park SN. Comparison of tinnitus and psychological aspects between the younger and older adult patients with tinnitus. Auris Nasus Larynx 2016; 44: 147-51. [CrossRef]
18. Spiess AC, Lang H, Schulte BA, Spicer SS, Schmiedt RA. Effects of gap junction uncoupling in the gerbil cochlea. Laryngoscope 2002; 112: 1635-41. [CrossRef]
19. Jerger J, Johnson K. Interactions of age, gender, and sensorineural hearing loss on ABR latency. Ear Hear 1988; 9: 168-76. [CrossRef]
20. Burkard RF, Sims D. The human auditory brainstem response to high click rates: aging effects. Am J Audiol 2001; 10: 53-61. [CrossRef]
21. Thabet EM. Evaluation of tinnitus patients with normal hearing sensitivity using TEOAEs and TEN test. Auris Nasus Larynx 2009; 36: 633-6. [CrossRef]
22. Gorga MP, Neely ST, Ohlrich B, Hoover B, Redner J, Peters J. From laboratory to clinic: a large scale study of distortion product otoacoustic emissions in ears with normal hearing and ears with hearing loss. Ear Hear 1997; 18: 440-55. [CrossRef]