INTERNATIONAL JOURNAL OF AUDIOLOGY
2024, VOL. 63, NO. 5, 373–380
https://doi.org/10.1080/14992027.2022.2160383

ORIGINAL ARTICLE

OPEN ACCESS

A comparison of interaural asymmetry, audiogram slope, and psychometric measures of tinnitus, hyperacusis, anxiety and depression for patients with unilateral and bilateral tinnitus

Hashir Aazh[a,b,c], Don McFerran[d], Ali A. Danesh[b], Christine Louw[e] and Brian C. J. Moore[f]

[a]Audiology Department, Royal Surrey NHS Foundation Trust, Guildford, UK; [b]Department of Communication Sciences & Disorders, Florida Atlantic University, Boca Raton, FL, USA; [c]Hashir International Specialist Clinics & Research Institute for Misophonia, Tinnitus and Hyperacusis, London, UK; [d]British Tinnitus Association, Sheffield, UK; [e]Department of Speech-Language Pathology and Audiology, University of Pretoria, Pretoria, South Africa; [f]Cambridge Hearing Group, Department of Psychology, University of Cambridge, Cambridge, UK

ABSTRACT

Objective: To evaluate differences in tinnitus impact, hyperacusis and hearing threshold level (HTL) between patients with unilateral and bilateral tinnitus. For patients with unilateral tinnitus, to compare audiological variables for the tinnitus ear and the non-tinnitus ear. To assess whether the presence of unilateral tinnitus increases the likelihood of interaural hearing asymmetry (relative to bilateral tinnitus) that warrants referral for an MRI scan.

Design: Retrospective cross-sectional.

Study Sample: Data regarding HTLs and responses to self-report questionnaires were collected from the records of 311 patients attending a tinnitus clinic.

Results: 38.5% had unilateral tinnitus and the ears with tinnitus had higher HTLs and greater HTL slopes than the ears without tinnitus. There was no significant difference in tinnitus impact and hyperacusis between patients with unilateral and bilateral tinnitus. 40% of patients with unilateral tinnitus and 13% of patients with bilateral tinnitus had a between-ear difference in HTL $\geq$15 dB at two adjacent frequencies (2AF15 asymmetry). Unilateral tinnitus increased the risk of 2AF15 asymmetry by a factor of 4.4.

Conclusions: Unilateral tinnitus increases the risk of having interaural asymmetry in HTLs that warrants referral for an MRI scan.

ARTICLE HISTORY
Received 29 May 2022
Revised 6 December 2022
Accepted 11 December 2022

KEYWORDS
Tinnitus; hyperacusis; hearing loss; psychometrics; audiology

Introduction

Tinnitus is defined as the perception of sound in the absence of an acoustic stimulus external to the individual. It can be perceived in one ear (unilateral tinnitus) or in both ears (bilateral), or sometimes within the head. Although most studies suggest that there is no difference in anxiety and depression symptoms between patients with unilateral and bilateral tinnitus (Cho et al. 2022; Yang et al. 2015; Alhazmi et al. 2016), there are conflicting reports in the literature regarding differences in tinnitus distress among them. Some studies suggest that unilateral tinnitus is more distressing than bilateral tinnitus (Genitsaridi et al. 2021; Alhazmi et al. 2016; Song et al. 2018). Other studies suggest no difference in tinnitus distress between unilateral and bilateral groups (Cho et al. 2022) or even the opposite pattern, that tinnitus distress is worse for patients with bilateral tinnitus (Yang et al. 2015).

It is not clear if hyperacusis symptoms differ for patients with unilateral and bilateral tinnitus. Hyperacusis is an intolerance of certain everyday sounds, which are perceived as too loud or uncomfortable and which cause significant distress and impairment in the individual's day-to-day activities (Aazh et al. 2022a). Cho et al. (2022) reported that 30% of patients with unilateral tinnitus compared to 15% of patients with bilateral tinnitus presented with symptoms of hyperacusis, based on a clinical interview. In contrast, Yang et al. (2015) reported that symptoms of hyperacusis, also assessed based on a clinical interview, were present for 4.8% of patients with unilateral tinnitus compared to 12.7% of patients with bilateral tinnitus, but the difference was not statistically significant. Genitsaridi et al. (2021) reported no statistically significant difference in scores for the Hyperacusis Questionnaire (HQ) (Khalfa et al. 2002) between patients with bilateral and unilateral tinnitus.

There is also controversy about differences in age between those with unilateral and bilateral tinnitus. Genitsaridi et al. (2021) reported that patients with unilateral tinnitus were older than those with bilateral tinnitus. In contrast, Yang et al. (2015) reported that patients with bilateral tinnitus were older than those with unilateral tinnitus and others reported no age effect (Cho et al. 2022; Alhazmi et al. 2016).

Although it seems that average hearing threshold levels (HTLs) are not significantly different between patients with

CONTACT Hashir Aazh info@hashirtinnitusclinic.com Audiology Department, Royal Surrey NHS Foundation Trust, Guildford, UK; Department of Communication Sciences & Disorders, Florida Atlantic University, Boca Raton, FL, USA; Hashir International Specialist Clinics & Research Institute for Misophonia, Tinnitus and Hyperacusis, London, UK

unilateral and bilateral tinnitus (Yang et al. 2015; Alhazmi et al. 2016), unilateral tinnitus may be associated with disorders of the auditory system that are associated with asymmetrical hearing loss, such as vestibular schwannoma or Ménière's disease (Henry et al. 2010; Ridder 2005; Choi et al. 2015). In some clinical guidelines, prompt pure tone audiometry is recommended for patients with unilateral tinnitus in order to assess whether the hearing loss is asymmetrical (National Institute for Health and Care Excellence 2018; National Institute for Health and Care Excellence 2020). If the between-ear difference is ≥15 dB according to the National Institute for Health and Care Excellence (2018) or ≥20 dB according to the British Academy of Audiology (2016) at two or more adjacent frequencies, referral of patients for Magnetic Resonance Imaging (MRI) is recommended. These guidelines contain a more nuanced recommendation to "consider" MRI for symmetrical hearing and unilateral tinnitus (National Institute for Health and Care Excellence 2020; British Academy of Audiology 2016).

Tsai et al. (2012) and Genitsaridi et al. (2021) reported that asymmetrical hearing loss at two adjacent frequencies predicts unilateral tinnitus. However, it is not clear how much unilateral versus bilateral tinnitus affects the risk of having an asymmetry in HTL ≥15 dB or ≥20 dB for at least two adjacent frequencies. This is important, as clinicians sometimes need to prioritise diagnostic tests for their patients, and audiometry is often completed after unilateral/bilateral tinnitus has been diagnosed. In addition, sometimes tinnitus patients may not be seen by audiologists or ENT doctors (some patients may be referred to psychologists or other healthcare professionals). Hence, hearing thresholds may not always be measured if a patient presents with tinnitus.

The pathologies that give rise to unilateral tinnitus may also be associated with an abnormal slope of the audiogram. For example, Ménière's disease is often associated with a low-frequency hearing loss, while exposure to intense sounds may result in a hearing loss restricted to frequencies above 3 kHz (Moore 2020). In this paper we test the hypothesis that unilateral tinnitus is associated with a steeper slope of the audiogram, regardless of whether the slope is positive or negative.

If unilateral tinnitus is associated with asymmetric hearing loss, it seems likely that the tinnitus would tend to be heard at the ear with greater hearing loss. Hence, for patients with unilateral tinnitus, we also compared audiological variables for the tinnitus ear and the non-tinnitus ear.

In summary, the aims of this study were (1) for patients with unilateral tinnitus, to compare audiological variables for the tinnitus ear and the non-tinnitus ear, (2) to compare audiological measures and psychometric measures of tinnitus, hyperacusis, anxiety and depression between patients with unilateral and bilateral tinnitus, and (3) to assess whether the presence of unilateral tinnitus increases the likelihood of interaural hearing asymmetry (relative to bilateral tinnitus) that warrants referral for an MRI scan.

Methods

Ethical approval

The study was registered and approved as a clinical audit by the Quality Governance Department at the Royal Surrey NHS Foundation Trust (RSFT). Patient consent was waived as this was a retrospective analysis of the available clinical data. Analysis of the data was approved by the South West-Cornwall and Plymouth Research Ethics Committee and the Research and Development department at the RSFT (Project ID: 182924).

Study design and patients

This was a retrospective cross-sectional study analysing routine clinical data available at the Audiology Department, RSFT, Guildford, UK. Data were included for 311 consecutive patients who were referred to the Tinnitus and Hyperacusis Therapy Specialist Clinic (THTSC) at the RSFT for tinnitus alone or tinnitus combined with hyperacusis in the years 2019–2020. Demographic data for the patients, their pure tone audiograms and the outcomes of their self-report questionnaires were imported from their records held at the Audiology Department. All measures were taken prior to the start of any treatment, at each patient's first visit to the clinic.

Pure tone audiogram

All audiometric equipment had been calibrated within the past year. Audiometry was conducted by qualified audiologists in sound-treated rooms using Aurical Audiometers (Natus Medical, Denmark) and TDH39 headphones. HTLs were measured using the procedure recommended by the British Society of Audiology (2018), but with some modifications proposed by Aazh and Moore (2017b) to minimise any discomfort. The starting presentation level at 0.25, 0.5, 2, 3, 4, 6, and 8 kHz was equal to the HTL at the adjacent frequency (e.g. if the threshold at 1 kHz was 20 dB HL, the starting level for measuring the HTL at 2 kHz was 20 dB HL, instead of 50 dB HL as recommended by the British Society of Audiology (2018)). The severity of hearing loss was categorised based on the values of the pure-tone average (PTA) across the frequencies 0.25, 0.5, 1, 2, and 4 kHz, as recommended by the British Society of Audiology (2018): Mild (20–40 dB HL), Moderate (41–70 dB HL), Severe (71–95 dB HL) and Profound (over 95 dB HL).

The absolute value of the difference in HTLs between 1 and 8 kHz divided by the number of octaves between 1 and 8 kHz, referred to here as HTL slope, was calculated separately for the right and left ears. We did this to test the hypothesis that unilateral tinnitus would be associated with a steeper slope of the audiogram, regardless of whether the slope was positive or negative.

To explore asymmetries in HTLs across ears, three variables were calculated:

1. Absolute value of the between-ear difference in PTA (across the frequencies 0.25, 0.5, 1, 2, and 4 kHz). If this value was ≥5 dB, then it was labelled as "asymmetrical PTA" (The number of patients with larger asymmetry in our study population was limited, so we used a 5-dB between ear difference to get a reasonable number classified as asymmetric PTA).
2. Absolute value of the between-ear difference at high frequencies (HF) (average of HTLs at 4 and 8 kHz). If this value was ≥20 dB, then it was labelled as "asymmetrical HF."
3. Absolute value of the between-ear difference for all pairs of adjacent frequencies for frequencies of 0.5, 1, 2, 4, and 8 kHz. If the difference for at least two adjacent frequencies was ≥20 dB, then it was labelled as "asymmetrical 2AF20." This is consistent with the BAA criteria for referring for MRI (British Academy of Audiology 2016). If the difference was ≥15 dB, then it was labelled as "asymmetrical 2AF15."

This is consistent with the NICE guideline for referring for MRI (National Institute for Health and Care Excellence 2020).

Self-report questionnaires

The following questionnaires were administered:

1. Tinnitus Impact Questionnaire (TIQ) (Aazh et al. 2022b)
   The TIQ is a 7-item questionnaire assessing the impact of tinnitus on day-to-day activities, sleep, and mood over a 2-week period. Cronbach's alpha for the TIQ is 0.89 (Aazh et al. 2022b). The overall score ranges from 0 to 21. A score below 5 indicates no impact of tinnitus, a score of 5 or 6 indicates mild impact, a score of 7 or 8 indicates moderate impact, and a score of 9 or more indicates a severe impact.
2. Hyperacusis Impact Questionnaire (HIQ) (Aazh et al. 2022a)
   The HIQ has eight items assessing the impact of hyperacusis on the patient's life over a 2-week period. Cronbach's alpha for the HIQ is 0.93. The overall score ranges from 0 to 24. Scores above 11 indicate a clinically significant impact of hyperacusis (Aazh et al. 2022a).
3. Visual Analogue Scale (VAS) (Maxwell 1978)
   The VAS score for loudness of tinnitus (hereafter Tinnitus Loudness) was assessed by asking the patient to rate the loudness of tinnitus during their waking hours over the last month. The patient was instructed that 0 corresponds to no tinnitus being heard and 10 is the loudest sound that they could imagine. The VAS score for annoyance induced by the tinnitus (hereafter Tinnitus Annoyance) was assessed by asking the patient to rate their subjective perception of annoyance on average during the last month (0 corresponds to no annoyance and 10 is the most annoying thing imaginable). The VAS score for the impact of tinnitus on their life (hereafter Tinnitus Life Impact) was assessed by asking the patient to rate the effect of tinnitus on their life during the last month (0 corresponds to no effect and 10 is the most extreme effect).
4. Sound Sensitivity Symptoms Questionnaire (SSSQ) (Aazh et al. 2022a)
   The SSSQ is a five-item questionnaire asking about the experience of a number of sound sensitivity symptoms, including loudness hyperacusis, pain or discomfort hyperacusis, annoyance hyperacusis/misophonia, and fear hyperacusis, over a 2-week period (Tyler et al. 2014). Cronbach's alpha for the SSSQ is 0.87 (Aazh et al. 2022a). The overall score ranges from 0 to 15. Scores of 5 or more indicate symptoms of sound tolerance problems (Aazh et al. 2022a).
5. Screening for Anxiety and Depression in Tinnitus (SAD-T) (Aazh et al. 2022a)
   The SAD-T contains four items that match those for the physical health questionnaire (PHQ-4; Kroenke et al. 2009). Two items relate to the experience of anxiety and two relate to the experience of depression. Cronbach's alpha for the SAD-T is 0.91 (Aazh et al. 2022a). The overall score ranges from 0 to 12. Scores of 4 or more indicate symptoms of anxiety and/or depression. This was calculated but not reported during a study on the acceptability and relevance of psychological questionnaires in the assessment of patients with tinnitus and/or hyperacusis (Aazh and Moore 2017c).

Statistical analysis

The data were anonymized prior to statistical analysis. Means and standard deviations (SDs) for the characteristics of the patients and scores for the self-report questionnaires, were calculated. Paired t-tests were used to compare audiological variables between ears with tinnitus and ears without tinnitus among patients with unilateral tinnitus.

Welch's *t*-tests (Delacre, Lakens, and Leys 2017) were used to compare age, audiological variables, and the scores for the questionnaires between patients with unilateral and bilateral tinnitus, and Chi-squared (χ^2) tests were used to compare the incidence of asymmetrical hearing loss and gender between patients with unilateral and bilateral tinnitus. Cohen's *d* was calculated to assess effect sizes (ES) based on mean comparison for unequal variances (Lakens 2013; Delacre, Lakens, and Leys 2017). Spearman correlation was used to assess the relationship between the measures of the asymmetry of hearing (i.e. asymmetrical PTA, asymmetrical HF, asymmetrical 2AF20, asymmetrical 2AF15) and the scores for the self-report questionnaires.

We assessed if unilateral tinnitus predicts asymmetrical PTA, asymmetrical HF, asymmetrical 2AF20, or asymmetrical 2AF15, using multinomial logistic regression models. The models assess the relative risk ratio (RRR) of having asymmetrical PTA, asymmetrical HF, asymmetrical 2AF20, or asymmetrical 2AF15 based on the presence/absence of unilateral tinnitus. The RRR is defined as the ratio of the risk of an outcome in one group (with unilateral tinnitus in this case) to the risk of an outcome in another group (with bilateral tinnitus). The values of the RRR and their 95% confidence intervals (CIs) were calculated adjusted for age and gender. Age and gender are known characteristics that might influence hearing and tinnitus (Aazh, Lammaing, and Moore 2017; Davis 1989). Analyses were restricted to patients with complete data for all variables required for a particular analysis. The number of patients included in each analysis (*n*) is reported. STATA (version 13) (StataCorp 2013) was used for statistical analyses.

Results

Characteristics of the study population

Of 311 patients, 61.5% ($n = 191$) had bilateral tinnitus or tinnitus heard within the head, 16.5% ($n = 52$) had tinnitus in the right ears and 22% ($n = 68$) had tinnitus in their left ears.

Only 175/311 patients had available audiograms. Patients with no available audiogram might have had hearing tests carried out at other centres prior to being referred to the THTSC for tinnitus management, in which cases it was deemed unnecessary to repeat their hearing test during their first visit. There was no significant difference in age between patients with and without audiograms ($p = 0.85$). The percentage of females was 51% for those with audiograms and 64% for patients without audiograms, and this difference was significant ($\chi^2 = 5.35$, $p = 0.021$). About 61% and 62% of patients with and without audiograms, respectively, had bilateral tinnitus and the difference in percentage was not significant ($\chi^2 = 0.065$, $p = 0.79$). Overall, the characteristics of the patients were similar for those with and without available audiograms.

Fifty-six percent of the patients were female (175/311). The mean age was 54 years ($SD = 16$ years), range 17–95 years. The mean PTA was 18 dB HL ($SD = 11$ dB) for the better ears and 25 dB HL ($SD = 18$ dB) for the worse ears (based on 175 patients with available audiograms).

The HTL slope averaged across ears was 8.7 dB/oct ($SD = 5.7$). The mean between-ears difference in PTA (0.25–4 kHz) was 7 dB HL ($SD = 13$ dB), and the mean between-ears difference at high frequencies (4 and 8 kHz) was 10.6 dB HL ($SD = 14$ dB). Asymmetry was present in the PTA for 19% of the population, at HF for 15%, for 2AF20 for 19%, and for 2AF15 for 23%.

The mean TIQ, HIQ, SSSQ and SAD-T scores for the study population were 6.9 ($SD = 5.5$; $n = 289$), 4.4 ($SD = 5.6$; $n = 242$), 2.3 ($SD = 2.8$; $n = 255$) and 3.5 ($SD = 3.4$; $n = 299$), respectively. The scores for the self-report questionnaires (TIQ, HIQ, SSSQ, SAD-T and VAS for Tinnitus Loudness, Annoyance, and Effect on Life) were not correlated with measures of the asymmetry of hearing loss (i.e. asymmetrical PTA, asymmetrical HF, asymmetrical 2AF20, asymmetrical 2AF15) ($p > 0.1$, for all Spearman correlations).

Differences in PTA and HTL slope between the ears with and without tinnitus among patients with unilateral tinnitus

The mean PTA for the right ears was 24 dB HL ($SD = 15$) for patients with tinnitus in the right ear ($n = 30$) and 17 dB HL ($SD = 11.5$) for patients with tinnitus in the left ear ($n = 39$), and the difference was significant ($p = 0.028$). The mean PTA for the left ears was 22 dB HL ($SD = 14$) for patients with tinnitus in the right ear and 27.5 dB HL ($SD = 20$) for patients with tinnitus in the left ear, but this difference was not significant ($p = 0.32$).

In another analysis, the PTA among 69 patients with unilateral tinnitus (for whom audiograms were also available) was compared for the ears with tinnitus and the ears without tinnitus. The mean PTA was 43 dB HL ($SD = 26$) for the ears with tinnitus and 34 dB HL ($SD = 25$) for the ears without tinnitus, and this difference was significant ($p = 0.0009$). In other words, the tinnitus tended to be heard in the ear with the greater hearing loss.

The mean HTL slope for the right ear was 10 dB/oct ($SD = 6.0$) for patients with tinnitus in the right ear and 7.7 dB/oct ($SD = 6.0$) for patients with tinnitus in the left ear, but this difference was not significant ($p = 0.094$). The mean HTL slope for the left ear was 8.0 dB/oct ($SD = 6.0$) for patients with tinnitus in the right ear and 9.3 dB/oct ($SD = 6.7$) for patients with tinnitus in the left ear, but the difference was not significant ($p = 0.4$). When the ears with unilateral tinnitus (regardless of right or left) were compared with the ears without tinnitus, the mean HTL slope was 9.7 dB/oct ($SD = 6.3$) for the ears with tinnitus and 8.0 dB/oct ($SD = 5.8$) for the ears without tinnitus, and this difference was significant ($p = 0.019$). In other words, the slope was on average greater for the ears with tinnitus. For 59 out of 69 patients with unilateral tinnitus the slope was greater for the tinnitus ear in the downward direction (greater loss at 8 than at 1 kHz), but for 7 patients, the audiogram for the tinnitus ear had an upward slope, with less hearing loss at 8 than at 1 kHz, and for 3 patients there was no difference in HTL between 8 and 1 kHz.

Comparison of audiological and self-report measures between patients with unilateral and bilateral tinnitus

The percentage of females was 57.5% for patients with unilateral tinnitus and 55.5% for patients with bilateral tinnitus, and the difference was not significant ($\chi^2 = 0.12$, $p = 0.73$). Table 1 shows that the between-ear differences in HTLs at 0.25, 0.5, 1, 2, and 4 kHz were significantly larger for patients with unilateral as opposed to bilateral tinnitus, with the largest ES of 0.53 at 4 kHz. Between-ear differences in HTLs at 8 kHz did not differ significantly for patients with unilateral and bilateral tinnitus. Table 2 shows the audiological variables and the scores for the self-report questionnaires and age for patients with unilateral and bilateral tinnitus. The only significant differences in any of the variables between patients with unilateral and bilateral tinnitus were for the across-ear asymmetry of PTA and asymmetry at HFs and the score for the HIQ. Although the mean HIQ score was only slightly higher (worse) for patients with bilateral tinnitus, the difference just reached statistical significance. Further analysis showed that among 242 patients with available HIQ scores, 12% percent of those with unilateral tinnitus and 17% of those with bilateral tinnitus had hyperacusis (i.e. HIQ score > 11), but this difference was not significant ($\chi^2 = 1.34$, $p = 0.24$). Based on TIQ scores ($n = 289$), for patients with unilateral tinnitus, 47% had no tinnitus impact, 16% had mild impact, 10% had moderate impact and 27% had severe tinnitus impact. These percentages were not significantly different from those for patients with bilateral tinnitus: 40% had no tinnitus impact, 11% had mild impact, 14% had moderate impact and 35% had severe tinnitus impact ($\chi^2 = 4.08$, $p = 0.25$). Based on SSSQ scores ($n = 255$), 18.4% of patients with unilateral tinnitus and 20.4% of patients with bilateral tinnitus had sound intolerance symptoms, and this difference was not significant ($\chi^2 = 0.15$, $p = 0.69$). Based on SAD-T scores ($n = 299$), 43% of patients with unilateral tinnitus and 37% of patients with bilateral tinnitus had symptoms of anxiety and/or depression, and this difference was not significant ($\chi^2 = 1.15$, $p = 0.28$).

Unilateral tinnitus and the likelihood of interaural hearing asymmetry

Patients with unilateral tinnitus had on average a larger between-ear difference in PTA and in average HTLs at 4 and 8 kHz than those with bilateral tinnitus. Among 175 patients with available audiograms, 35.3% with unilateral tinnitus and 8.4% with bilateral tinnitus had an asymmetrical PTA, and this difference was significant ($\chi^2 = 19.6$, $p < 0.0001$). 26% of patients with unilateral tinnitus and 8.5% of patients with bilateral tinnitus had asymmetrical HF, and this difference was significant ($\chi^2 = 9.9$, $p = 0.002$). Asymmetrical 2AF15 was found for 40% of patients with unilateral tinnitus and 13% of patients with bilateral tinnitus, and this difference was significant ($\chi^2 = 16.42$, $p < 0.001$). Asymmetrical 2AF20 was found for 32% of patients with unilateral tinnitus and 10% of patients with bilateral tinnitus, and this difference was significant ($\chi^2 = 13.2$, $p < 0.001$).

The presence of unilateral tinnitus compared to bilateral tinnitus was used in multinomial logistic regression analyses to assess if unilateral tinnitus predicts asymmetrical PTA, asymmetrical HF, asymmetrical 2AF20, and asymmetrical 2AF15. Data for 175 patients were included in these models, which were adjusted for age and gender. The presence of unilateral tinnitus increased the risk (the RRR) of having (1) asymmetrical PTA by a factor of 6.1 (95% CI: 2.6–14.4, $p < 0.0001$), (2) asymmetrical HF by a factor of 3.8 (95% CI: 1. 6–9.1, $p = 0.003$), (3) 2AF20 by a factor of 4.3 (95% CI: 1.9–9.7, $p < 0.001$), and (4) 2AF15 by a factor of 4.4 (95% CI: 2.1–9.3, $p < 0.001$).

Discussion

The results showed that most patients (61.5%) seeking help for tinnitus present with bilateral tinnitus. This could be because

Table 1. Results of independent-samples Welch's *t*-tests comparing absolute values of the between-ear differences in hearing threshold levels (HTLs) at 0.25, 0.5, 1, 2, 4, and 8 kHz for participants with unilateral and bilateral tinnitus.

	Unilateral tinnitus Mean (*SD*)	Bilateral tinnitus Mean (*SD*)	Difference: mean and 95% CI	*p* Value	ES and 95% CI
0.25 kHz	9.8 (15) *n* = 68	5.6 (9.3) *n* = 107	4.3 (0.3–8.3)	**0.036**	0.36 (0.054–0.67)
0.5 kHz	10.7 (17) *n* = 69	6.1 (10) *n* = 107	4.6 (0.1–9.2)	**0.044**	0.35 (0.04–0.65)
1 kHz	12.8 (21) *n* = 69	6.8 (11) *n* = 107	6.0 (0.7–11.3)	**0.026**	0.39 (0.087–0.7)
2 kHz	12.2 (19) *n* = 69	6.8 (10) *n* = 107	5.4 (0.4–10.3)	**0.035**	0.37 (0.065–0.68)
4 kHz	15.1 (20) *n* = 69	7.5 (9.3) *n* = 106	7.5 (2.5–12.6)	**0.004**	0.53 (0.21–0.83)
8 kHz	16.9 (21) *n* = 69	11.4 (12) *n* = 106	5.5 (0–11.0)	0.051	0.34 (0.036–0.65)

Significant *p* values are indicated in bold font. The sixth column shows ES values with 95% CIs based on Cohen's *d*.

Table 2. Results of independent-samples Welch's *t*-tests comparing the pure tone average (PTA) averaged across ears, between-ears difference in PTA (0.25–4 kHz), between-ears difference in high frequency hearing threshold level (HF HTL) (4 and 8 kHz), HTL slope (absolute value of the differences in HTLs between 8 and 1 kHz) for each ear and averaged across ears, scores for the TIQ (Tinnitus Impact Questionnaire), HIQ (Hyperacusis Impact Questionnaire), SAD-T (Screening for Anxiety and Depression-Tinnitus), VAS (Visual Analogue Scale) for Tinnitus Loudness, Tinnitus Annoyance and Effect of Tinnitus on Life, and age for patients with unilateral and bilateral tinnitus.

	Unilateral tinnitus Mean (*SD*)	Bilateral tinnitus Mean (*SD*)	Difference: mean and 95% CI	*p* Value	ES and 95% CI
PTA across ears	22.8 (15) *n* = 68	21 (12) *n* = 107	1.7 (−2.6 to 6.0)	0.44	0.12 (−0.18 to 0.43)
PTA of better ears (dB HL)	17.0 (12) *n* = 69	18.7 (11) *n* = 107	−1.6 (−5 to 2.0)	0.38	−0.13 (−0.44 to 0.16)
PTA of worse ears (dB HL)	28.4 (21) *n* = 68	23.5 (15) *n* = 107	4.8 (−1.0 to 10.7)	0.1	0.27 (−0.03 to 0.58)
Between-ears difference in PTA (dB)	11 (17) *n* = 68	4.8 (8.9) *n* = 107	6.2 (1.8 to 10.7)	**0.006**	0.49 (0.18 to 0.8)
Between-ears difference at HF (dB)	14.5 (19.9) *n* = 69	8.1 (8.3) *n* = 106	6.4 (1.4 to 11.5)	**0.013**	0.45 (0.14 to 0.76)
HTL slope averaged across ears (dB/oct)	8.8 (5.3) *n* = 69	8.4 (6.3) *n* = 106	1.1 (−4.0 to 6.4)	0.67	0.064 (−0.24 to 0.37)
TIQ score (0–21)	6.6 (5.6) *n* = 113	7 (5.5) *n* = 176	−0.5 (−1.8 to 0.8)	0.44	−0.09 (−0.33 to 0.14)
HIQ score (0–24)	3.5 (4.9) *n* = 95	4.9 (5.9) *n* = 147	−1.4 (−2.8 to −0.0)	**0.049**	−0.25 (−0.51 to 0.01)
SSSQ score (0–15)	2.2 (2.7) *n* = 98	2.4 (3.1) *n* = 157	−0.16 (−0.87 to 0.55)	0.66	−0.05 (−0.31 to 0.19)
SAD–T score (0–12)	3.6 (3.4) *n* = 114	3.4 (3.4) *n* = 185	0.12 (−0.7 to 0.92)	0.76	0.03 (−0.19 to 0.27)
VAS Tinnitus Loudness (0–10)	6.5 (1.8) *n* = 116	6.4 (1.9) *n* = 185	0.11 (−0.32 to 0.55)	0.61	0.06 (−0.17 to 0.29)
VAS Tinnitus Annoyance (0–10)	7 (2.4) *n* = 116	6.7 (2.5) *n* = 184	0.25 (−0.32 to 0.83)	0.38	0.10 (−0.13 to 0.33)
VAS Tinnitus Life Impact (0–10)	6 (2.7) *n* = 116	5.7 (2.7) *n* = 183	0.22 (−0.39 to 0.85)	0.47	0.08 (−0.15 to 0.32)
Age (years)	54.6 (17) *n* = 120	53 (15) *n* = 191	1.5 (−2.1 to 5.2)	0.42	0.09 (−0.13 to 0.32)

Significant *p* values are indicated in bold font. The sixth column shows ES with 95% CIs values based on Cohen's *d*.

most of the factors that are associated with chronic tinnitus, such as recreational noise exposure and age-related hearing loss, usually affect both ears (Biswas et al. 2022). Consistent with some past studies, the result showed that age was not different between patients with unilateral and bilateral tinnitus (Cho et al. 2022; Alhazmi et al. 2016). Our results are not consistent with those of Genitsaridi et al. (2021), who reported that patients with unilateral tinnitus were older than those with bilateral tinnitus, or with those of Yang et al. (2015), who reported that patients with unilateral tinnitus were younger than those with bilateral tinnitus. The proportion of patients with bilateral tinnitus was much higher in our sample than in those two studies, which were 32% (Genitsaridi et al. 2021) and 49% (Yang et al. 2015), perhaps reflecting different characteristics of the populations tested. However, the mean age and gender distribution in these studies were not markedly different from those in our study. Overall, it seems likely that there is no clear difference in age between those seeking help for unilateral tinnitus and those seeking help for bilateral tinnitus.

Unlike Yang et al. (2015), who reported that the impact of tinnitus as measured via the Tinnitus Handicap Inventory (THI) (Newman, Jacobson, and Spitzer 1996) was more severe for patients with bilateral tinnitus than for those with unilateral tinnitus, our study showed no difference between patients with unilateral and bilateral tinnitus in the impact of tinnitus and symptoms of anxiety and depression as measured via the TIQ, VAS and SAD-T. It should be noted that Yang et al. (2015) also assessed their patients using the Beck Depression Index (BDI) (Beck and Steer 1984) and found no significant difference in symptoms of depression between patients with bilateral and unilateral tinnitus. This seems to be inconsistent with their findings on the impact of tinnitus, since research has shown strong links between THI scores and measures of anxiety and depression (Aazh and Moore 2017a).

Some other studies have reported an effect opposite to that reported by Yang et al. (2015), namely that unilateral tinnitus is more distressing than bilateral tinnitus (Genitsaridi et al. 2021; Alhazmi et al. 2016; Song et al. 2018). Some of these studies had very small sample sizes. For example, Alhazmi et al. (2016) and Song et al. (2018), assessed only 33 and 20 patients with tinnitus, respectively. Genitsaridi et al. (2021) used a larger sample and reported that unilateral cases were annoyed by their tinnitus for a greater percentage of time than bilateral cases. However, they did not use a validated questionnaire to measure the impact of tinnitus. Moreover, other measures used with the same population gave conflicting results. For example, there was no significant difference in tinnitus loudness ratings or the effect of stress on tinnitus between patients with unilateral and bilateral tinnitus.

According to psychological models of tinnitus distress based on cognitive behavioural therapy (CBT), the impact of tinnitus and the distress it causes are not directly linked with the loudness or character of the tinnitus itself (Aazh, Bryant, and Moore 2019; McKenna et al. 2014). Instead, they are related to the individual's thought processes and behaviours (Aazh and Moore 2018). It seems reasonable to assume that unhelpful thought process and behavioural reactions are equally likely to be triggered for patients with unilateral and bilateral tinnitus (Aazh, Bryant, and Moore 2019). Overall, it is likely that the impact of tinnitus is similar for patients with unilateral and bilateral tinnitus.

The mean HIQ score for our sample was slightly but significantly worse for patients with bilateral than with unilateral tinnitus, and 12% percent of patients with unilateral tinnitus compared to 17% of patients with bilateral tinnitus had hyperacusis. This is not consistent with symptoms of sound intolerance as measured via the SSSQ, the scores for which were not different for patients with unilateral and bilateral tinnitus. Future studies should use a wider range of hyperacusis questionnaires as well as Uncomfortable Loudness Levels to further explore hyperacusis symptoms for patients with unilateral and bilateral tinnitus.

Tinnitus is often associated with a steeply sloping audiogram, with elevated HTLs at high frequencies (Lewis et al. 2020; Tang et al. 2022). Our results showed that among the patients with unilateral tinnitus the absolute value of the slope was greater for the ear where the tinnitus was heard. For most patients the slope was greater for the tinnitus ear in the downward direction (greater loss at 8 than at 1 kHz), but for a few patients, the audiogram for the tinnitus ear had a steep upward slope, with less hearing loss at 8 than at 1 kHz. It appears that the ears with tinnitus tend to have an abnormal slope in either the positive or negative direction. This may reflect the characteristics of the underlying disorders that can lead to tinnitus. For example, Ménière's disease usually affects one ear and often leads to greater hearing loss at low frequencies than at high frequencies in the affected ear. In contrast, asymmetric exposure to intense noise tends to result in asymmetric hearing loss, with greater hearing loss at high frequencies in the more exposed ear, and tinnitus tends to be heard towards the ear with the greater hearing loss (Lowe and Moore 2021).

Our results also showed that the absolute value of the difference in HTLs across ears was greater for patients with unilateral than with bilateral tinnitus. An effect in this direction occurred for all audiometric frequencies, and it was significant for all tested frequencies from 0.25 to 4 kHz; see Table 1). This is consistent with the general idea that tinnitus is associated with some form of damage to the auditory system. When the damage primarily affects one ear, this results in greater asymmetry in HTLs and tinnitus only on the worse affected side. However, the PTA averaged across ears did not differ for those with unilateral and bilateral tinnitus. Thus, unilateral tinnitus was not associated with higher HTLs overall. There was a trend for the PTA for the worse ears to be higher for those with unilateral than with bilateral tinnitus, while the PTA for the better ears showed the opposite pattern, but these differences were not significant. Overall, it appears that unilateral tinnitus is associated with increased interaural asymmetry in HTLs. Consistent with this, the multinomial logistic regression analyses showed that the presence of unilateral tinnitus significantly increased the risk of having 2AF20 and 2AF15. This finding is of clinical importance, as in a recent study Vnencak et al. (2021) showed that for predicting vestibular schwannomas 2AF20 has a sensitivity of 88% and a specificity of 42%, while 2AF15 has a sensitivity of 89% and a specificity of 45.5%. Given the higher incidence of 2AF20 and 2AF15 among patients with unilateral tinnitus, as shown in our study, it is important to perform pure tone audiometry for those with unilateral tinnitus. Having said this, over 10% and 13% of patients with bilateral tinnitus also had 2AF20 and 2AF15 asymmetries, respectively. Hence, audiometry should also be performed for patients with bilateral tinnitus.

This study was based on a retrospective analysis of the available clinical data. Therefore, we were limited to the measures that were obtained as a part of routine clinical practice at the THTSC during that time. Consistent with this, 43% of the patients did not have audiograms at the time of data collection. This could make our results less representative. However, there were no significant differences in age and laterality of tinnitus between those with and without audiograms. Therefore, it is unlikely that the availability or not of audiograms markedly biased our results. Another limitation is that all patients were referred to an audiology clinic for tinnitus and/or hyperacusis management. Therefore, our results are probably not representative of all patients with tinnitus. It is possible that those who seek help with regard to their tinnitus have more severe symptoms than those who do not. Nevertheless, our sample is representative of patient seeking help from specialist tinnitus clinics in audiology departments.

Conclusions

Most of the patients seeking help for tinnitus with or without hyperacusis had bilateral tinnitus. For patients with unilateral tinnitus, the ears with tinnitus had higher HTLs and greater HTL slopes than the ears without tinnitus. The multinomial logistic regression analyses confirmed that unilateral tinnitus increases the risk of having interaural asymmetry in HTLs relative to those with bilateral tinnitus. Therefore, audiological investigation, especially for those with unilateral tinnitus, is recommended. There was no significant difference in the impact of tinnitus as measured via self-report questionnaires between those with unilateral and bilateral tinnitus. It seems likely that therapeutic interventions such as audiologist-delivered CBT and counselling will be of similar effectiveness for patients with unilateral and bilateral tinnitus.

Acknowledgments

We thank the members of the Tinnitus and Hyperacusis Therapy Specialist Clinic at the Audiology Department, Royal Surrey County NHS Foundation Trust for their help in data collection. We also thank two reviewers for helpful comments on an earlier version of this paper.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

This research was partially supported by a grant from the Saul and Theresa Esman Foundation to AD.

ORCID

Hashir Aazh http://orcid.org/0000-0002-6839-5649
Don McFerran http://orcid.org/0000-0002-4395-3405
Brian C. J. Moore http://orcid.org/0000-0001-7071-0671

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