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Tinnitus and Subjective Hearing Loss are More Common in Migraine: A Cross-Sectional NHANES Analysis

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Objectives: To investigate whether migraine is independently associated with tinnitus and subjective hearing loss (HL) in a large national database.

Methods: The de-identified 1999 to 2004 National Health and Nutrition Examination Survey database was retrospectively queried for subjects aged 18 to 65. HL and tinnitus were subjectively reported by subjects.

Results: A total of 12,962 subjects (52.9% female) with a mean age of 38.1 ± 14.6 years were included. This consisted of 2,657 (20.5%), 2,344 (18.1%), and 2,582 (19.9%) subjects who had migraine, subjective-HL, and tinnitus, respectively. In patients with tinnitus or subjective-HL, migraine was reported in 35.6% and 24.5%, respectively. Migraineurs were more likely to have subjective-HL (25.0% vs. 16.6%, $p < 0.001$) and tinnitus (34.6% vs. 16.9%, $p < 0.001$) compared to the nonmigraineurs. This corresponded to migraine having an odds ratio of 1.5 (95% confidence interval [CI] 1.3–1.7, $p < 0.001$) and 2.2 (95% CI 2.0–2.4, $p < 0.001$) for subjective-HL and tinnitus, respectively. After adjusting for confounders, subjective-HL (odds ratio [OR] = 1.2, 95% CI 1.1–1.4, $p = 0.003$), tinnitus (OR = 2.1, 95% CI 1.9–2.3, $p < 0.001$), and neck pain (OR = 4.0, 95% CI 3.6–4.5, $p < 0.001$) were more common in migraineurs. Among migraineurs, a higher proportion of those with tinnitus also had subjective-HL compared to those without tinnitus (40.0% vs. 15.3%, $p < 0.001$), and a higher proportion of those with subjective-HL also had tinnitus compared to those without HL (58.1% vs. 27.3%, $p < 0.001$).

Conclusions: This study suggests an independent association between migraine with subjective-HL and tinnitus. Otologic migraine, which is the effects of migraine on the ear, may be partly responsible for the link between HL, tinnitus, neck pain, and migraine. **Key Words:** Hearing loss—Migraine—NHANES—Otologic migraine—Tinnitus.

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Migraine affects approximately 12% of U.S. individuals with significant quality of life consequences (1). The pathophysiology of migraine is not fully elucidated, but its association with related neuro-otological conditions has been known for years (2). Two such conditions are tinnitus and hearing loss (HL), which are debilitating chronic conditions experienced by approximately 25% (3) and 20% (4) of the adult population, respectively. An association between migraine and tinnitus among French young individuals was recently reported (5). Similarly, a study of Australian patients found migraine to increase the risk of developing mild tinnitus (6). Migraine has also been found to be a risk factor for developing sudden sensorineural HL (7,8). These possibly secondary conditions have significant effects on patients' health and well being (9,10), warranting continued investigation of their relationship with migraine. Although the aforementioned studies utilized French, Taiwanese, and Korean national databases; these associations have yet to be evaluated using U.S. population-based data.

Recent suggestions that migraine may be a risk factor for developing HL and tinnitus have warranted testing this hypothesis on the general U.S. population (5–8). Investigating these relationships via different approaches and populations will encourage future research into the underlying pathophysiologies and shared otologic principles between them. This is important because if migraine is independently related to tinnitus and HL, comprehensive migraine prevention/treatment protocols may improve the outcomes of these associated otologic conditions. The objective of this study was to investigate

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TABLE 1. *Cohort's demographics and the prevalence of tinnitus and hearing loss*

Variable	Migraineurs (N = 2,657)	Nonmigraineurs (N = 10,305)	*p*
Age	39.4 ± 12.5	37.8 ± 15.1	**<0.001**
Body mass index	29.1 ± 7.1	27.8 ± 6.4	**<0.001**
Gender: female	1,821 (68.5%)	5,038 (48.9%)	**<0.001**
Race			0.440
White	1,169 (44.0%)	4,443 (43.1%)	
Hispanic/Mexican	818 (30.8%)	3,136 (30.4%)	
Black	559 (21.0%)	2,285 (22.2%)	
Neck pain	1,019 (38.4%)	1,214 (11.8%)	**<0.001**
Subjective hearing loss	663 (25.0%)	1,711 (16.6%)	**<0.001**
Major subjective hearing loss[a]	84 (3.2%)	190 (1.8%)	**<0.001**
Tinnitus: any duration	920 (34.6%)	1,737 (16.9%)	**<0.001**
Tinnitus: constant duration	147 (5.5%)	327 (3.2%)	**0.018**

Statistically significant *p* values are bolded.
[a]Major hearing loss was defined as answering ''lots of trouble'' or ''deaf'' to the hearing question.

the National Health and Nutrition Examination Survey (NHANES) U.S. national database to elucidate whether migraine was associated with subjective-HL and tinnitus after adjusting for confounders.

METHODS

This study did not require institutional review board approval because of the publicly available nature of the database and lack of identifying patient information. The NHANES database has been conducted by the National Center for Health Statistics, which is part of the Centers for Disease Control and Prevention since 1971. Since 1999, NHANES has gathered extensive health and diet-related information from thousands of subjects through interviews, physical examinations, and laboratory tests (11). The 1999 to 2004 NHANES database was queried for this study, as this was the only timeline that included a migraine question. This is in-line with a 2016 study by Pogoda et al. which used the same 1999 to 2004 NHANES cohort to investigate the association between sodium intake and migraine (12). Since NHANES provides data categories (e.g., demographic, laboratory, physical, etc.) as separate files, subject-specific sequence numbers were used to merge data into a compiled file. Since migraine was the independent variable, patients with unknown headache status were excluded.

Only patients aged 18 to 65 were included to exclude subjects with otitis media-related, age-related HL, or a low-reliability test. The upper cutoff for age was set as 65 because prior U.S. population studies have reported a high prevalence of age-related HL in people older than 65 (13,14), which is in-line with several population-based hearing loss studies that have similarly excluded elderly patients (15–17). Migraine and tinnitus sufferers were identified from the questions ''During the past 3 months, did you have severe headache or migraine?'' and ''In the past 12 months, have you ever had ringing, roaring, or buzzing in your ears?'' Subjective hearing quality was evaluated by ''Which best describes your hearing?'' with answers ''good,'' ''little trouble,'' ''lots of trouble,'' and ''deaf.'' Subjects choosing any of the latter three answers were categorized as having subjective-HL. PASW Statistics 18.0 software (SPSS Inc., Chicago, IL) was used for statistical analysis. Two-tailed unpaired *t* test and Chi-squared analyses were used to compare continuous and categorical variables, respectively, with a threshold of $p < 0.05$ for significance. Multivariate binary logistic regression was performed to investigate independent associations between migraine and other variables while adjusting for confounders. For logistic regression analysis, the cohort's median age and body mass index (BMI) were used as threshold for binarizing age/weight variables.

RESULTS

A total of 12,962 patients (52.9% female) with a mean age of 38.1 ± 14.6 years were included. Migraine headache was reported by 2,657 (20.5%) subjects. Patients with migraine tended to be women (68.5% vs. 48.9%), slightly older (39.4 ± 12.5 vs. 37.8 ± 15.1 years), with higher BMI (29.1 ± 7.1 vs. 27.8 ± 6.4), and experience neck pain (38.4% vs. 11.8%) (all $p < 0.001$) (Table 1). Tinnitus and HL were reported by 2,582 (19.9%) and 2,344 (18.1%) subjects, respectively. A higher proportion of subjects with any reported tinnitus (34.6% vs. 16.9%, $p < 0.001$) or constant tinnitus (5.5% vs. 3.2%, $p = 0.018$) existed among migraineurs compared to nonmigraineurs (Table 1). There was also a higher proportion of subjects with subjective-HL among migraineurs compared to nonmigraineurs (25.0% vs. 16.6%, $p < 0.001$).

In patients with tinnitus or subjective-HL, migraine was reported in 919 (35.6%) and 574 (24.5%), respectively. Among patients with tinnitus, migraineurs tended to be younger than nonmigraineurs (41.5 ± 12.7 vs. 44.4 ± 13.8 years, $p < 0.001$). However, patients reporting migraine, tinnitus, and HL (n = 353, 2.7%) were significantly older than the rest of the cohort (45.0 ± 12.2 vs. 37.9 ± 14.6 years, $p < 0.001$). Among migraineurs, a higher proportion of those with tinnitus also had subjective-HL compared to those without tinnitus (40.0% vs. 15.3%, $p < 0.001$). In migraineurs with HL, tinnitus was reported significantly more than those without HL (58.1% vs. 27.3%, $p < 0.001$).

Multivariate logistic regression demonstrated that patients with age ≥39 years (odds ratio [OR] = 1.16), BMI ≥ 28.1 (OR = 1.30), female gender (OR = 2.38),

TABLE 2. *Multivariate binary logistic regression of factors predictive of an existence of migraine headache while accounting for confounders*

Covariate	Multivariate OR (95% CI)	*p*
Age, yrs		
<39	1 [Reference]	
≥39	1.16 (1.05–1.28)	**0.003**
Body mass index		
<28.1	1 [Reference]	
≥28.1	1.30 (1.18–1.43)	**<0.001**
Gender		
Male	1 [Reference]	
Female	2.38 (2.15–2.63)	**<0.001**
Subjective hearing loss		
No	1 [Reference]	
Yes	1.21 (1.07–1.37)	**0.003**
Tinnitus		
No	1 [Reference]	
Yes	2.09 (1.87–2.34)	**<0.001**
Neck pain		
No	1 [Reference]	
Yes	4.04 (3.62–4.50)	**<0.001**

All variables were binarized and odds ratios (OR) were calculated for the second option compared to the first option labeled as ''[reference]''. For instance, compared to patients <39 yrs of age (reference), patients ≥39 yrs old were 1.16 times (95% CI 1.05–1.28) more likely to experience migraine headache. Age and body mass index cutoffs were according to the mean values in the cohort. Statistically significant *p* values are bolded. CI indicates confidence interval; OR, odds ratio.

neck pain (OR = 4.04), HL (OR = 1.21), and tinnitus (OR = 2.09) were all more likely to have migraine (all $p < 0.01$) (Table 2). After controlling for age, gender, race, BMI, and neck pain as possible confounders, patients with migraine were significantly more likely to have subjective-HL (OR = 1.46, 95% confidence interval [CI] 1.30–1.65, $p < 0.001$) and tinnitus (OR = 2.17, 95% CI 1.95–2.43, $p < 0.001$) compared to nonmigraineurs. These results remained statistically significant for patients aged 18 to 60 after excluding patients aged 61 to 65 (n = 1,213). Lastly, 2,200 patients had reported answers for presence or absence of positive diagnosis for depression, panic disorder, or generalized anxiety disorder. After adjusting for age, gender, race, BMI, neck pain, depression, panic, and anxiety for these patients, those with migraine were significantly more likely to have subjective-HL (OR = 1.42, 95% CI 1.04–1.92, $p = 0.026$) and tinnitus (OR = 2.17, 95% CI 1.70–2.76, $p < 0.001$).

DISCUSSION

This study of approximately 13,000 U.S. adults demonstrated that migraineurs were more likely to have subjective-HL and tinnitus than nonmigraineurs even after adjusting for confounders. The observed relationships are not new, yet many otolaryngologists are unaware of this association due to a paucity of literature on the topic. We believe that this paper adds to the current literature on the topic of migraine's association with tinnitus and HL.

HL and tinnitus can be seen during migraine episodes (18,19). In addition to any subjective-HL, major HL (subjectively described as lots of trouble hearing or being deaf) was also significantly more common among migraineurs, although it is difficult to infer that major HL signifies sudden HL with the current data limitation. In-line with our findings, previous analyses have reported a significantly greater risk of developing sudden HL among subjects with migraine (7,8) or nonmigraine headache (20). Specifically, Chu et al.'s study of 10,280 Taiwanese subjects reported a 1.8 times greater risk of developing sudden HL among migraineurs compared to those without migraine headache (7). Likewise, Kim et al.'s study of 44,714 Korean subjects found that the adjusted hazard ratio of migraine for sudden HL was 1.3 (8). Among a cohort of sudden HL patients evaluated by Arslan et al., 40% fulfilled migraine criteria as well (21). It has been suggested that sudden HL in patients with migraine can be attributed to ischemia from migraine-associated vasospasm (22). A recent study reported improvement in sudden HL outcomes when adjunctive migraine medication was used in addition to standard oral and intratympanic steroids therapy (23). The improved outcome of sudden HL patients with migraine therapy is likely due to the role of migraine in sudden HL in some of the patients.

In 1996, it was hypothesized that idiopathic HL in preexisting migraine may be related to migraine-induced vasospasm of cochlear vasculature (19). This shared epidemiology between migraine and HL or tinnitus may suggest related underlying pathophysiologies. The precise details regarding how migraine occurs are unknown, but cortical spreading depression resulting in release of neuropeptides particularly from the trigeminal nerve may play an important role (24–26). Trigeminal nerve fibers innervate the spiral modiolar artery and stria vascularis, both important components of the cochlear vascular network (27,28). When the ophthalmic branch of the trigeminal nerve has been stimulated in an animal model, fluid extravasation within the cochlea was observed, which increased with a greater degree of stimulation (29). Therefore, it has been proposed that the trigeminal innervation of the cochlear vasculature and stria vascularis likely links migraine and HL (30).

In addition to subjective-HL, tinnitus was also independently associated with migraine in the studied cohort. The high prevalence of tinnitus in different types of migraine has been previously reported (5,31,32). Tinnitus can also worsen in intensity with migraine episodes (33,34), or only appear as a concurrent symptom and subside after the headache (18). For instance, a study by Langguth et al. comparing tinnitus patients with (n = 193) or without (n = 765) headache reported that those with both tinnitus and headache had higher tinnitus severities (34). A significant relationship between headache laterality and tinnitus laterality has also been reported (35). Additionally, HL and tinnitus are prominent features of Meniere's disease (MD),

which is strongly associated with migraine (36,37). MD can also be described as ''migraine of the ear'' with HL occurring secondary to vasospasm of the inner ear microvasculature (36,38,39). It has been reported that migraine is common in MD and that migraine prophylaxis medications improves the quality of life in MD, indicating a link between the two conditions (40). This study further supports the association between migraine and HL/tinnitus. As such, the authors suggest the umbrella term ''otologic migraine'' to describe migraine-induced ear (otalgia (41) and pressure (42)), cochlear, and vestibular symptoms.

Although we took diligent care in the analysis and interpretation of data, this study contains several limitations. First, the main variables of this study (i.e., migraine, tinnitus, and HL) were qualitatively reported by the patients without objective measures, and further details (e.g., migraine with/without aura, sudden/gradual or conductive/sensorineural HL, unilateral/bilateral tinnitus) could not be elucidated. As such, future institutional studies with more controlled and objective measures are warranted to further evaluate the cross-sectional relationship between migraine with hearing loss and tinnitus. Also, although the migraine cohort may include chronic-severe-headache patients without migraine, a relationship between nonmigraine headache and both tinnitus and HL has already been demonstrated (20). Furthermore, it is difficult to infer that minor or major HL within these patients signify sudden HL due to database limitations. NHANES is a national de-identified database which makes it susceptible to selection bias, recall/reporting bias, inaccurate coding, missing values, and variable limitations. Therefore, the results should be interpreted with caution and future in-depth studies to investigate these relationships are warranted. Despite these limitations, this is the first study utilizing U.S. population-based data to identify significant and independent relationships between migraine, tinnitus, and HL. This encourages future studies to investigate whether migraine prevention/treatment protocols can prevent or decrease these potentially secondary otologic conditions.

CONCLUSIONS

In a large representative population of U.S. adults, migraine was independently associated with an increased likelihood of subjective tinnitus and HL. Patients with subjective-HL or tinnitus were also more likely to have migraine after adjusting for various confounders. Female patients, those with a higher than median age, higher BMI, and neck pain had significantly higher representations in the migraine group.

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