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Prevalence of Hyperacusis and Its Relation to Health: The Busselton Healthy Ageing Study

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Importance: The prevalence of hyperacusis and its relationship with mental and general health is unknown in a non-clinical sample. Therefore, we aimed to determine the prevalence of hyperacusis and its relation with hearing, general and mental health in a population-based study.

Study Design: Prospective population-based study.

Material and Methods: This study uses data from the Busselton Healthy Ageing Study (BHAS). A sample of 5,107 eligible inhabitants aged 45 to 70 years completed a detailed questionnaire and a clinical assessment. A positive answer to "*Do you consider yourself sensitive or intolerant to everyday sounds*" was used to indicate hyperacusis. Logistic regression was used to examine the association between hearing, mental and general health factors, and hyperacusis.

Results: Of 5,107 participants, 775 (15.2%) reported hyperacusis. The majority of participants with hyperacusis reported an occasional effect on daily life (72.0%). Being female, older in age, having a lower income, physical or mental health difficulties, more severe hearing loss, and tinnitus were all associated with the presence of hyperacusis. Individuals who experience hearing impairment, poorer general or mental health have a higher possibility of hyperacusis having an effect on their daily life.

Conclusions: In this community population-based cohort study, we found a prevalence of hyperacusis of 15.2%. Individuals with hearing loss, mental health problems, and lower physical health have a higher possibility of experiencing effects on their daily life associated with their hyperacusis. Unravelling the relationship between hyperacusis hearing, general and mental health can be of major importance for a better understanding of the condition and its consequences.

Key Words: Hyperacusis, tinnitus, hearing loss, mental health, population study.

Level of Evidence: 2

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INTRODUCTION

Since the introduction of the term hyperacusis by Perlman in 1938,[1] several definitions have been proposed whereby a decreased *tolerance* of ordinary environmental sounds is the most commonly used.[2] The prevalence of hyperacusis varies widely depending on the populations studied and definitions used,[3] ranging from 8% to 15% in the general adult population.[4] Because of the strong association between hyperacusis and tinnitus, a common mechanism is suggested involving altered neural activity in auditory[5] and nonauditory cortical areas.[6] Hyperacusis is also a reported symptom of a wide range of conditions such as depression, migraine, Williams syndrome, head trauma, and post-traumatic stress syndrome.[4] Individuals with hyperacusis are often sensitive to ordinary daily sounds such as music, clatter, and mechanical sounds. Further, depression and anxiety disorders are over-represented in patients with this condition.[7] As such, both the hyperacusis itself and the accompanying problems can have severe consequences for the daily life of the individual.[8]

Recently, the Hyperacusis Priority Setting Partnership (PSP) was established to identify the questions about hyperacusis that are the most important to people with hyperacusis and to healthcare professionals.[9] This resulted in a top-10 list of research priorities, including focus on the prevalence of hyperacusis in the general

population, underlying physical or psychological conditions, and treatment possibilities.

Therefore, the aim of this study was to analyze in a population cohort study the prevalence of hyperacusis and to assess the relationship between hearing, general and mental health, and the presence and daily effects of hyperacusis.

MATERIALS AND METHODS

Study Sample and Recruitment Process

This study used data from the Busselton Healthy Ageing Study (BHAS),[10] which commenced in 2010 with the aim to identify the cumulative effects of multimorbidity that impacts on healthy aging. The BHAS includes detailed assessments of physical function, cognitive performance, and quality of life in baby boomers. Noninstitutionalized adults born between 1946 and 1964, who were living in the City of Busselton, Western Australia, and who were listed on the electoral roll were eligible for participation (6,690 individuals). The order of invitation to participate was randomized, with recruitment efforts focused on sequential 10% sample draws. For this study, cross-sectional data collected between May 2010 and December 2015 were used resulting in a cohort aged 45 to 70 years. Participants were invited via a letter of introduction, followed by a phone call to invite them to attend the testing center for a 4-hour appointment to complete health-related questionnaires and comprehensive physical and cognitive assessments. This article focuses on the methods for this study. The full protocol of the study, including all measurements, is described elsewhere.[10] The study has received approval from The University of Western Australia Human Research Ethics Committee (Number RA/4/1/2203).

Outcome Assessment

Several measurements were used to study the association between hyperacusis and general and mental health. All data used in this study, except hearing thresholds, were taken from the self-administered clinical history questionnaire.

Demographic data included age, sex, highest education level obtained (no school, primary, secondary school, other (e.g., technical school, college), or university), and household income.

Participants were asked "*Do you consider yourself sensitive or intolerant to everyday sounds (no, yes)*?". A positive response was recorded as a self-report of hyperacusis. The characteristics and effects of hyperacusis were determined by "*Are you sensitive to any of these sounds* (*sensitive to noise, paper, talk, music, clatter, mechanical, and monotonous sounds, other*)?", "*If you are intolerant to some sound, how often does it affect your daily life and activities (not at all, occasionally, frequently, constantly)*?" and "*How do you feel when you are exposed to these sounds (tense, afraid, pain, angry, vague, irritated, other)?"*.

Aspects of medical history (including self-reported history of chronic ear infection), diabetes, cardiovascular disease (CVD; coronary heart disease, hypertension, hypercholesterolemia, stroke, high blood pressure, carotid surgery, myocardial infarction, having a pacemaker, coronary bypass, or coronary angiogram), migraine, and previous hospital stay due to head injury for at least one day were recorded.

Mental health was assessed by the question "*Have you ever been told by a doctor that you have depression*" and "*Have you ever been given advice or treatment for your depression*". The 9-item Patient Health Questionaire-9 (PHQ-9) was used to score the presence of a depressive disorder against DSM-IV criteria[11] (none, other depressive disorder or major depressive disorder) as well as depression severity (levels of severity; score 1–4 = minimal depression; 5–9 = mild depression; 10–14 = moderate depression; 15–19 = moderately severe depression; and 20–27 = severe depression).[12] The validated 21 item-Depression and Anxiety and Stress Scale (DASS21) was used to measure the emotional states of depression, anxiety, and stress. Published cut-off scores were used for levels of severity.[13]

Self-reported general health rating, long standing disability or illness, and the impact of physical and mental function on daily activities were assessed using the Short Form SF-12.[14] Two subscales were derived from the 12 item-questionnaire: the Physical Component Summary (PCS) and the Mental Component Summary (MCS) with scores ranging from 0 (lowest physical or mental health level) to 100 (highest level).

Participants described their use of hearing aids or other hearing devices by responding "*no*", "*hearing aid in one ear*", "*hearing aid in both ears"*, "*cochlear implant"* or *"bone anchored hearing aid (BAHA)*". The effect of hearing loss/impairment on daily life was assessed by the question "*If you have a hearing impairment, does it affect your daily life and activities (not at all, occasionally, frequently, constantly)*?" and noise exposure was questioned by "*Have you worked in a place where it was so noisy that you had to raise your voice to be heard by others (no, yes)*?". Participants who answered yes to this question were asked if they wore hearing protection while working there (never, occasionally, frequently, always). Participants reported the presence of tinnitus by the question "*Do you experience tinnitus (sound in your ears and head) for longer than 5 minutes which does not have an obvious cause (no, yes)*?" .

Pure tone air conduction thresholds were determined using Automated Method for Testing Auditory Sensitivity (AMTAS) with headphones and conducted in a soundproof booth as previously described,[10] in accordance with the Hughson-Westlake methods. Air conduction thresholds were recorded at 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz. Pure tone average (PTA) was provided as mean of the air conduction hearing levels for 500, 1,000, 2,000, and 4,000 Hz for each ear. The PTA of the best and worst ear were calculated and bilateral hearing loss was indicated if the best ear PTA was ≥35 dB.[15]

Statistics

The main outcome measures were the prevalence of hyperacusis, and the association between demographic, health, audiological, mental and general health factors. Second, the daily effect of hyperacusis in relation to these variables was assessed. Demographic and health factors and the presence of hyperacusis were coded as present or absent. Mental and general health measured using the PHQ-9 and the DASS-21 were scored as continuous variables.[16] For each variable, we calculated the corresponding odds ratio and the associated 95% confidence interval, to express the association with the presence of hyperacusis as dependent variable by using logistic regression.

The effect of hearing protection on hyperacusis in individuals exposed to a noisy workplace was assessed using multivariate logistic regression. For the audiological data, audiograms of participants with "poor" or "failed" reliability as judged by the automated audiometer software were excluded. We used multivariate logistic regression to assess the possible confounding between hearing loss (mean PTA), diabetes, chronic ear infection, CVD, and hyperacusis. A cut off of 10% in difference between odds ratios was used to define confounding.[17,18] Mixed model linear regression analysis was used to assess the associations between hyperacusis and the hearing levels of different frequencies of the hearing test, using side of the ear (left or right) as a

repeated variable. Mixed model regression analysis provides a framework for analysing clustered data such as that from two ears.

IBM SPSS statistics version 25.0 was used for statistical analysis. A value of $P < .05$ was defined as statistically significant. This study is reported according to the STROBE statement.[19]

RESULTS

Hyperacusis Prevalence and Effect

A total of 82% of those on the electoral list could be contacted and confirmed eligible (noninstitutionalized and still living in the region), 76% of whom (5,107) completed a detailed questionnaire and attended the survey center for clinical assessment. Almost half the sample was male, with around 15% experiencing hyperacusis. Of those with a self-report of hyperacusis only a small percentage experienced a frequent (9.0%) or constant effect on daily life (2.2%). Albeit a small number (n = 24, .5%) did not respond (see Figure 1). Being female (OR 1.18, 95% CI 1.01–1.40) and older in age (per year) (OR 1.03, 95% CI 1.02–1.04) was associated with hyperacusis (Table I). Having an annual income of <20.000 $ (OR 2.16, 95% CI 1.56–2.97) or >20.000 to 60.000 $ (OR1.46, 95% CI 1.17–1.82) compared with an annual income of >100.000 $ both increased the odds of having hyperacusis. No statistically significant difference was observed between hyperacusis and highest education. The majority (n = 644; 83.1%) of participants reported that their hyperacusis affected daily life and activities, with nearly three quarters reporting an occasional, frequent or, for the smallest number, a constant effect. Around 16% reported no effect. In those reporting hyperacusis sensitivities were common (average of 2.2 per affected person) with sensitivity to mechanical or monotonous sounds, clatter, and noise the most commonly reported. Most of the people with hyperacusis felt irritated and one in four felt tensed when exposed to hyperacusis.

Hyperacusis and Health

A medical history of self-reported chronic ear infections (OR 2.17, 95% CI 1.68–2.80), noise exposure (OR 1.44, 95% CI 1.23–1.68), diabetes (OR 1.62, 95% CI 1.24–2.13), CVD (OR 1.37, 95% CI 1.17–1.59), and migraine (OR 1.49, 95% CI 1.23–1.79) increased the odds of having hyperacusis (Table I). There was no statistically significant relationship between participants with or without a hospital stay due to head injury and having hyperacusis (OR .13, 95% CI 0.90–1.43). Hearing protection when working in a noisy environment had a protective effect for having hyperacusis (OR 0.85, 95% CI 0.75–0.95). Hearing loss (best ear PTA) was a confounding factor for the relationship between chronic ear infection and hyperacusis whereby the adjusted OR changed from twice the odds to only slight increased odds. Hearing loss was not a confounding factor for the relationship between diabetes or CVD and the presence of hyperacusis (Table I adjusted OR). Participants with a lower general health score measured by the SF12-PCS had a higher odds of having hyperacusis (OR .96, 95% CI 0.95–0.97) (Table I).

Self-reported noise exposure was a risk factor for the reported effect of hyperacusis on daily life and activities (Table II). Those experiencing hyperacusis and also reporting a history of chronic ear infection were more likely to have hyperacusis that frequently affected their daily life (OR 3.11, 95% CI 1.32–7.29); no association was observed with hyperacusis occasionally or constantly affecting daily life (Table II). Lower SF12-PCS scores were a risk factor for experiencing an occasional (OR 0.96, 95% CI 0.94–0.98), frequent (OR 0.92, 95% CI 0.90–0.95), or constant (OR .92, 95% CI 0.88–0.96) effect of hyperacusis on daily life and activities (Table II).

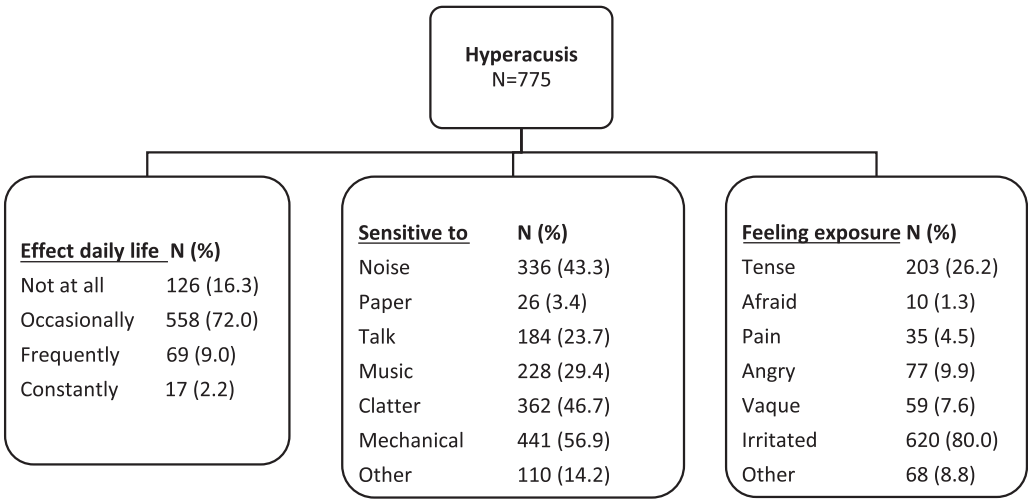

Fig. 1. Study population and experienced characteristics. Studied population with 5,107 participants wherein 775 (15.2%) experienced hyperacusis, 4,308 (84.4%) did not experience hyperacusis, and 24 (.5%) did not respond to the question on hyperacusis. Of the 775 with hyperacusis, 5 (.6%) did not answer the question about how it affected daily life and activities.

TABLE I.
Characteristics of Participants With and Without Hyperacusis and Outcomes of Univariate Logistic Regression Analysis.

	Hyperacusis (n = 775)	No Hyperacusis (n = 4,308)				
	N (%)	N (%)	OR (95% CI)	*P*	Adjusted OR (95% CI)[¶]	*P*
Demographics						
Gender			1.18 (1.01–1.40)	.04		
Male (ref)	323 (41.7)	1,970 (45.7)				
Female	452 (58.3)	2,338 (54.3)				
Age (yr)[†]	58.83 (5.82)	57.86 (5.77)	1.03 (1.02–1.04)	<.01		
45–50	53 (6.84)	468 (10.9)				
>50–55	178 (22.97)	1,050 (24.4)				
>55–60	192 (24.77)	1,095 (25.4)				
>60–65	225 (29.03)	1,162 (27.0)				
>65–70	127 (16.39)	533 (12.4)				
Highest education						
No school	1 (.1)	1 (.1)	ref			
Primary school	11 (1.4)	56 (1.3)	.20 (.01–3.38)	.26		
Secondary school	366 (47.2)	2,123 (49.3)	.17 (.01–2.76)	.21		
Other	239 (30.8)	1,299 (30.2)	.18 (.01–2.95)	.23		
University	158 (20.4)	824 (19.1)	.19 (.01–3.08)	.24		
Missing	0	5 (.1)				
Income						
None of the above	5 (0.6)	15 (.3)	2.44 (.87–6.81)	.09		
< $20.000	69 (8.9)	234 (5.4)	2.16 (1.56–2.97)	<.01		
$ 20.001–60.000	280 (36.1)	1,403 (32.6)	1.46 (1.17–1.82)	<.01		
$60,001 to $100,000	174 (22.5)	1,097 (22.5)	1.16 (.91–1.47)	.23		
More than $100,000	139 (17.9)	1,012 (23.5)	ref			
Prefer not to say	108 (13.9)	543 (12.6)	1.45 (.11–1.91)	<.01		
Missing	0	4 (0.1)				
Hearing						
Best ear PTA ≥35 dB			2.02 (1.34–3.04)	<.01		
No (ref)	743 (95.9)	4,218 (97.9)				
Yes	32 (4.1)	90 (2.1)				
Hearing best ear (PTA) [‡]	12.1 (10.4)	10.5 (9.3)	1.02 (1.01–1.02)	<.01		
Hearing worst ear (PTA) [‡]	20.2 (16.7)	16.8 (12.9)	1.02 (1.01–1.02)	<.01		
Effect hearing impairment						
Not at all	37 (4.8)	212 (4.9)	ref			
Occasionally	149 (19.2)	437 (10.1)	1.95 (1.32–2.90)	<.01		
Frequently	45 (5.8)	96 (2.2)	2.69 (1.63–4.42)	<.01		
Constantly	40 (5.2)	48 (1.1)	4.78 (2.77–8.24)	<.01		
Use of hearing aid/device						
No	738 (95.2)	4,207 (97.7)	ref			
Hearing aid one ear	9 (1.2)	24 (0.6)	1.23 (.57–2.69)	.60		
Hearing aid both ears	25 (3.2)	73 (1.7)	1.13 (0.70–1.81)	.63		
Cochlear implant	2 (.3)	3 (.1)	2.19 (.36–13.19)	.39		
BAHA	1 (.1)	1 (.0)	3.29 (.21–52.74)	.40		
Tinnitus			2.81 (2.39–3.31)	<.01		
No (ref)	461 (59.5)	3,468 (80.5)				
Yes	314 (40.5)	839 (19.5)				
Medical history and general health						
Chronic ear infection			2.17 (1.68–2.80)	<.01	1.02 (1.01–1.02)	.00
No (ref)	684 (88.3)	4,060 (94.2)				

(Continues)

TABLE I.
Continued

	Hyperacusis (n = 775) N (%)	No Hyperacusis (n = 4,308) N (%)	OR (95% CI)	*P*	Adjusted OR (95% CI)[¶]	*P*
Yes	89 (11.5)	244 (5.7)				
Noise exposure			1.44 (1.23–1.68)	<.01	0.85 (0.75–0.95)[§]	.01
No (ref)	375 (48.4)	1,702 (39.5)				
Yes	399 (51.5)	2,604 (60.4)				
Diabetes			1.62 (1.24–2.13)	<.01	1.55 (1.17–2.05)	<.01
No (ref)	702 (90.6)	4,045 (93.9)				
Yes	73 (9.4)	259 (6.0)				
CVD			1.37 (1.17–1.59)	<0.01	1.31 (1.12–1.53)	<.01
No (ref)	364 (47.0)	2,359 (54.8)				
Yes	411 (53.0)	1,949 (45.2)				
Hospital stay head injury			1.13 (.90–1.43)	0.29		
No (ref)	705 (91.0)	3,958 (91.9)				
Yes	70 (9.0)	350 (8.1)				
SF12-PCS	46.61 (10.65)	50.49 (8.66)	.96 (.95–.97)	<.01		
Migraine			1.49 (1.23–1.79)	<.01		
No (ref)	597 (77.1)	3,589 (83.4)				
Yes	177 (22.9)	715 (16.6)				
Mental health						
SF12-MCS	5.33(10.10)	53.61 (8.03)	.96 (.95–.97)	<.01		
DASS21 Depression scale			1.06 (1.05–1.07)	<.01		
Normal	457 (59.0)	3,318 (77.0)				
Mild	68 (8.8)	270 (6.3)				
Moderate	93 (12.0)	322 (7.5)				
Severe	48 (6.2)	100 (2.3)				
Extremely severe	109 (14.1)	297 (6.9)				
DASS21 anxiety scale			1.10 (1.08–1.11)	<.01		
Normal	442 (57.0)	3,244 (75.3)				
Mild	101 (13.0)	433 (10.1)				
Moderate	73 (9.4)	248 (5.8)				
Severe	41 (5.3)	147 (3.4)				
Extremely severe	118 (15.2)	235 (5.5)				
DASS21 Stress scale			1.07 (1.06–1.08)	<.01		
Normal	344 (44.4)	2,844 (66.0)				
Mild	71 (9.2)	362 (8.4)				
Moderate	131 (16.9)	552 (12.8)				
Severe	119 (15.4)	299 (6.9)				
Extremely severe	110 (14.2)	250 (5.8)				
PHQ9 depressive disorder						
None	696 (89.8)	4,153 (96.4)	ref			
Other	35 (4.5)	76 (1.8)	2.75 (1.83–4.13)	<.01		
Major	44 (5.7)	79 (1.8)	3.32 (2.28–4.85)	<.01		
PHQ9 depression severity			1.13 (1.11–1.15)	<.01		
Normal	156 (20.1)	1,965 (45.6)				
Minimal	333 (43.0)	522 (12.1)				
Mild	179 (23.1)	137 (3.2)				
Moderate	71 (9.2)	41 (1.0)				
Moderately severe	24 (3.1)	16 (.4)				
Severe	12 (1.5)	1,627 (37.8)				

(Continues)

TABLE I.
Continued

	Hyperacusis (n = 775) N (%)	No Hyperacusis (n = 4,308) N (%)	OR (95% CI)	P	Adjusted OR (95% CI)[¶]	P
Doctor told you depression			2.15 (1.83–2.52)	<.01		
No (ref)	459 (59.2)	3,265 (75.8)				
Yes	315 (40.6)	1,043 (24.2)				

ref = reference category.
[†]Outcomes in means (SD) instead of numbers (%).
[‡]Hearing level best ear PTA in dB (SD)).
[§]Adjusted OR for wearing noise protection.
[¶]Adjusted OR for hearing loss best or worst ear (PTA) mean average.

Hyperacusis and Mental Health

Participants with a poorer self-reported mental health assessed by the SF12-MCS more often had hyperacusis (OR 0.96, 95% CI 0.95–0.97) (Table I). Significantly higher DASS21 anxiety and stress scores were found in those participants with hyperacusis compared with those without hyperacusis. Depression was a statistically significant risk factor for having hyperacusis on all depression assessments, whether diagnosed by a physician (OR 2.15, 95% CI 1.83–2.52), assessed against DSM-IV criteria on the PHQ9, or based on PHQ9 cut-offs for minimal to moderately severe depression, or as having higher DASS21 depression scores compared with the group without hyperacusis (Table I). All variables measuring mental health as well as depression, anxiety, and stress and having a major depressive disorder were shown to be a risk factor for the experienced effect of hyperacusis on daily life and activities (Table II).

Hyperacusis, Tinnitus, and Hearing

Of the 775 participants with hyperacusis, 314 (40.5%) participants experienced tinnitus (Table I). Those with tinnitus were almost three times as likely to have hyperacusis than those without (OR 2.81, 95% CI 2.39–3.31). Of the 5,107 participants, 5,069 completed audiometry. Two (.01%) participants failed the test, and reliability was judged as good for 4,816 (94.3%) participants. After exclusion of the failed and poor tests, 5,067 (99.2%) audiometry outcomes were analyzed.

Of the 775 participants with hyperacusis, about 4% had significant bilateral hearing loss (defined as best ear PTA ≥ 35 dB) (Table I). Statistically significant poorer mean air-conduction thresholds of all individually measured frequencies (.5, 1, 2, 4, 8 kHz) (Table III) and a higher best ear PTA ≥ 35 dB were both related to the presence of hyperacusis. The best ear and worst ear PTA mean hearing thresholds of the participants with hyperacusis were both higher compared with those without hyperacusis (best ear PTA OR 1.02, 95% CI 1.01–1.02, worst ear PTA OR 1.02, 95% CI 1.01–1.02) (Table I). Of those individuals who experienced hyperacusis, those who experienced hearing impairment to have an occasional or frequent effect on their daily lives, were found to have higher odds of having an effect of hyperacusis on their daily life (Table II).

DISCUSSION

We assessed the prevalence and effects of hyperacusis and the hearing, general health, and mental factors associated with the presence of hyperacusis in a cohort of Western Australian baby boomers aged 45 to 70 years. In this cohort of 5,107 adults from the general population, 775 (15.2%) responders were identified as having hyperacusis by saying "yes" to: "*Do you consider yourself sensitive or intolerant to everyday sounds*?" Furthermore, we demonstrated that being female, older in age, with a lower income, having a medical history of self-reported chronic ear infection, diabetes, cardiovascular disease, migraine, experiencing depression, stress or anxiety, a higher hearing threshold, tinnitus, lower mental and general health scores were all associated with self-reported presence of hyperacusis. Second, we analyzed the effect of the presence of hyperacusis on daily life. The majority (72.0%) of those with hyperacusis reported an occasional effect on their daily life and activities with a small minority (2.2%) constantly affected.

Most previous studies about this topic have relied on selected clinical populations of individuals primarily with complaints of tinnitus and/or individuals with hyperacusis seeking medical care for their complaints.[7,20–22] To date the few published reports from population-based cohort studies describing participants with self-reported hyperacusis have reported prevalence rates of 8.6% (n = 1,147, age range 16–79)[23] to 9.2% (n = 3,406, age range 18–79 years).[4] The prevalence of 15.2% in this study is slightly higher, which might be explained by the higher age of included participants (45–70 years of age). Second, prevalence numbers are highly dependent on the initial screening question. Because there is no clear definition of hyperacusis,[24] and an outcome set for research in hyperacusis still needs to be developed, there has been marked variability in the exact question asked in research studies. The lower prevalence of 8.6% found in the population study by Andersson et al. could, therefore, be explained by the more extensive description of hyperacusis, which included several examples of adverse reactions to everyday sounds of moderate loudness.[23]

TABLE II.
Effect on Daily Life and Activities by Hyperacusis Calculated With Univariate Logistic Regression Analysis (OR (95% CI).

Effect of Hyperacusis on Daily Life and Activities	Not at all (ref) (N = 126)	Occasionally (N = 558)			Frequently (N = 69)			Constantly (N = 17)		
	N (%)	N (%)	OR (95% CI)	*P*	N (%)	OR (95% CI)	*P*	N (%)	OR (95% CI)	*P*
Gender (male)			1.09 (0.78–1.52)	.61		1.28 (0.74–2.23)	.38		1.22 (.46–3.22)	.69
Male	47 (37.3)	234 (41.9)			31 (44.9)			7 (41.2)		
Female	79 (62.7)	324 (58.1)			38 (55.1)			10 (58.8)		
Age	58.84 (5.85)	58.96 (5.78)	1.02 (0.99–1.05)	.09	58.23 (5.97)	1.00 (0.96–1.05)	.90	56.66 (6.78)	0.98 (.90–1.06)	.62
Highest education										
No school	0 (0.0)	1 (0.2)	E		0 (0.0)	0.96 (0.00–∞)	1.00	0 (0.0)	E	
Primary school	2 (1.6)	5 (.9)	0.48 (0.11–2.03)	.32	3 (4.3)	2.58 (0.46–14.62)	.28	1 (5.9)	3.44 (.27–44.32)	.34
Secondary school	70 (55.6)	252 (45.2)	0.70 (0.45–1.10)	.13	35 (50.7)	0.94 (0.44–2.02)	.87	7 (41.2)	0.84 (.21–3.34)	.80
Other	36 (28.6)	177 (31.7)	0.80 (0.49–1.30)	.36	19 (27.5)	0.88 (0.38–2.04)	.76	6 (35.3)	1.11 (.26–4.74)	.89
University	18 (14.3)	123 (22.0)	ref		12 (17.4)	ref		3 (17.6)	ref	
Income										
< $20.000	12 (9.5)	44 (7.9)	0.84 (0.40–1.78)	.65	26 (37.7)	0.82 (0.25–2.68)	.75	4 (23.5)	3.29 (.71–15.28)	.13
$20.001-$60.000	43 (34.1)	207 (37.1)	0.87 (0.51–1.49)	.62	14 (20.3)	0.77 (0.33–1.76)	.53	2 (11.8)	0.47 (.10–2.27)	.35
$60.001-$100.000	28 (22.2)	130 (23.3)	0.74 (0.42–1.30)	.29	12 (17.4)	0.55 (0.22–1.37)	.20	3 (17.6)	0.31 (.05–2.00)	.22
>$100.000	24 (19.0)	97 (17.4)	0.76 (0.42–1.38)	.36	11 (15.9)	0.64 (0.25–1.66)	.36	2 (11.8)	0.64 (.12–3.44)	.60
None of the above	2 (1.6)	3 (.5)	0.38 (0.06–2.43)	.31	6 (8.7)	E		6 (35.3)	E	
Prefer not to say	17 (13.5)	77 (13.8)	ref			ref			ref	
Chronic ear infection			1.70 (0.90–3.23)	.10		3.11 (1.32–7.29)	.01		2.95 (.75–11.62)	.12
no	115 (91.3)	495 (88.9)			56 (82.4)			14 (82.4)		
yes	11 (8.7)	62 (11.1)			12 (17.6)			3 (17.6)		
Noise exposure			1.70 (1.21–2.37)	.00		2.67 (1.52–4.69)	<.01		2.80 (1.04–7.55)	.04
No	84 (66.7)	277 (49.7)			28 (40.6)			6 (35.3)		
Yes	42 (33.3)	280 (50.3)			41 (59.4)			11 (64.7)		
Diabetes			1.37 (0.73–2.56)	.33		1.75 (0.69–4.42)	.24		0.80 (0.10–6.46)	.83
No	115 (91.3)	506 (90.7)			61 (88.4)			16 (94.1)		
Yes	11 (8.7)	52 (9.3)			8 (11.6)			1 (5.9)		
Doctor diagnosed depression			1.95 (1.35–2.81)	.00		5.32 (2.94–9.61)	<.01		3.78 (1.41–10.13)	.00
No	94 (74.6)	329 (59.0)			24 (35.3)			7 (41.2)		
Yes	32 (25.4)	229 (41.0)			44 (64.7)			10 (58.8)		
PHQ9 depression severity	2.60 (3.16)	4.20 (4.39)	0.99 (0.98-0.99)	.00	8.94 (5.70)	.97 (.96–.99)	<.01	9.35 (7.83)	0.98 (0.96–1.00)	.05
PHQ9 depressive disorder										
None	119 (94.4)	513 (91.9)	ref		46 (66.7)	ref		13 (76.5)	ref	
Other	6 (4.8)	21 (3.8)	1.06 (0.45–2.51)	.90	7 (10.1)	3.83 (1.28–11.46)	.02	1 (5.9)	1.84 (.21–16.00)	.58
Major	1 (.8)	24 (4.3)	4.68 (1.11–19.80)	.04	16 (23.2)	30.64 (6.81–137.85)	<.01	3 (17.6)	19.29 (2.97–125.13)	<.01

(Continues)

TABLE II.
Continued

Effect of Hyperacusis on Daily Life and Activities	Not at all (ref) (N = 126)	Occasionally (N = 558)			Frequently (N = 69)			Constantly (N = 17)		
	N (%)	N (%)	OR (95% CI)	P	N (%)	OR (95% CI)	P	N (%)	OR (95% CI)	P
DASS21 depression	3.14 (4.71)	5.73 (7.03)	1.09 (1.05–1.12)	<.01	11.59 (9.21)	1.17 (1.12–1.22)	<.01	12.47 (10.85)	1.18 (1.12–1.25)	<.01
DASS21 anxiety	2.30 (3.40)	3.92 (4.87)	1.34 (1.16–1.54)	<.01	8.23 (7.59)	1.94 (1.60–2.36)	<.01	11.76 (9.62)	2.36 (1.72–3.23)	<.01
DASS21 stress	6.13 (6.22)	9.18 (7.70)	1.33 (1.17–1.50)	<.01	15.45 (9.54)	2.16 (1.77–2.64)	<.01	16.00 (11.07)	2.25 (1.59–3.18)	<.01
SF12-PCS	50.47 (7.81)	46.49 (10.33)	0.96 (0.94–0.98)	<.01	41.79 (14.15)	0.92 (0.90–0.95)	<.01	40.6 (12.69)	0.92 (0.88–0.96)	<.01
SF12-MCS	53.67 (7.93)	50.89 (9.47)	0.96 (0.95–0.98)	<.01	42.54 (12.00)	0.90 (0.88–0.93)	<.01	39.44 (14.37)	0.88 (0.85–0.92)	<.01
Effect hearing impairment										
Not at all	7 (28.0)	27 (13.4)	ref		3 (8.6)	ref		0 (0.0)	ref	
Occasionally	17 (68.0)	123 (61.2)	0.06 (0.01–0.49)	.01	7 (20.0)	0.01 (0.00–0.13)	<.01	2 (22.2)	E	
Frequently	0 (0.0)	31 (15.4)	0.28 (0.04–2.22)	.23	12 (34.3)	0.02 (0.00–0.22)	<.01	2 (22.2)	0.02 (0.00–0.20)	<.01
Constantly	1 (4.0)	20 (10.0)	E		13 (37.1)	E		5 (55.6)	E	
Hearing best ear (PTA)	10.83 (9.43)	11.74 (10.03)	1.01 (1.00–1.03)	.17	15.00 (11.75)	1.01 (1.01–1.07)	<.01	18.05 (14.30)	1.07 (1.03–1.11)	<.01
Hearing worst ear (PTA)	16.88 (12.35)	19.61 (16.15)	1.02 (1.00–1.03)	.02	23.70 (17.71)	1.02 (1.00–1.04)	.01	35.44 (26.33)	1.04 (1.02–1.06)	<.01

E = variable had not enough discriminating ability to estimate coefficients.
ref = reference category.

However, using a similar question to our study, in the population study by Paulin et al. a prevalence rate of 9.2% was found.[4]

The presence of hyperacusis is not directly related to the impact of hyperacusis on daily life. This is demonstrated in our study by the 16.3% who reported their hyperacusis not affecting their daily life at all and only a small percentage reporting a constant (2.2%) or frequent (9.0%) affect. However, no distinctive patterns in association with factors of general and mental health were seen for the different categories of daily impact of hyperacusis.

In the this study, we reported outcomes of both prevalence and impact in relation to several variables. An in-depth discussion is necessary as to when to consider people as having pathological hyperacusis in order to reach a consensus for the definition of bothersome hyperacusis. This can then be used for future studies and clinical practice.

The demonstrated association between tinnitus, hearing (best and worst ear PTA), and hyperacusis corresponds with the findings of previous clinical studies.[4,23] One of the most commonly used theories to explain these relationships is that these symptoms are due to an increased central gain in the auditory pathway resulting from alterations of the cochlear signal and increased spontaneous and synchronous neural activity.[25] However, only 122 of the 5,083 (2.4%) participants had bilateral hearing loss in this population cohort of middle-aged people. Second, the mean PTA hearing threshold difference between participants with hyperacusis and those without was only about 2 to 4 dB for the lower and higher frequencies respectively, which is not clinically significant. Therefore, the hearing loss found in the higher frequencies in both groups might reflect the effect of aging, which can be expected in this sample of people aged 45 to 70 years.

The association between hyperacusis presence and the impact of hyperacusis on daily life and activities with mental health issues such as a depression, anxiety, and stress is not surprising. In a study by Jüris et al., of patients referred to an ENT clinic with a primary diagnosis of hyperacusis, 56% had at least one psychiatric disorder, 47% an anxiety disorder, 8% major depression, and 3% post-traumatic stress disorder.[7] If this can be explained by relatively higher scores of neurotic personality traits, more anxiety-prone phenotypes[7] in people with hyperacusis compared with those without, or in combination with a hypersensitive state,[22] is not fully understood.

The finding of an association between presence of hyperacusis and lower general health defined by lower SF12-PCS scores or self-reported general health issues such as chronic ear infections, diabetes, and cardiovascular disease is of particular interest. Because of the relation between these variables and hearing loss, we adjusted for hearing level but most of the associations remained. Besides this, a statistically significant relation was seen between a lower income and having hyperacusis. It is unclear whether this finding in our study can be explained by the fact that a lower general health is seen in people with lower income.[26] No differences were observed between the categories of effect of

TABLE III.
Mean Hearing Level in dB (and SD) for Air Conducted Audiometry at 250, 500, 1,000, 2,000, 4,000, and 8,000 Hz in Participants With Hyperacusis and Those Without.

Frequency (Hz)	Hyperacusis Mean (SD) (N = 1,514 Ears)	No Hyperacusis Mean (SD) (N = 8,508 Ears)	*P*
250	8.8 (12.0)	10.6 (12.4)	<.01
500	12.4 (13.7)	10.5 (11.7)	<.01
1,000	11.8 (13.6)	9.9 (11.3)	<.01
2,000	14.6 (16.7)	12.0 (14.2)	<.01
4,000	22.7 (21.5)	19.9 (19.32)	<.01
8,000	38.5 (24.5)	34.3 (22.4)	<.01

hyperacusis in daily life and their associations with measures of health. However, comparable studies describing these relationships are scarce, only indicating lower general health in the individuals with hyperacusis compared with those without.[4] This raises questions about the underlying mechanism such as hemodynamic or neural effects to link these entities, which needs exploration in future studies.

Some methodological issues in this study are worth considering. Critically, the study was conducted at a time when there is currently no consensus about how the question about hyperacusis should be formulated.[24] Further, because no such instrument was available at the time of study design, we did not use a validated questionnaire to assess the impact of hyperacusis on daily life, which hinders validation and comparability with other studies. Moreover, the methodological quality of recently developed instruments to measure these effects is still insufficient.[2] Second, the use of the word *tolerate* in the index question reflects the general use of "tolerance" in definitions of hyperacusis, but may also capture individuals with issues of impatience or misophonia rather than a disorder of loudness perception. Indeed, it could be that more severe depression, anxiety, or stress are associated with reduced tolerance of sounds, and that this is what is being captured in our data.

Considering the high prevalence of hyperacusis, its association with hearing impairment, tinnitus, general and mental health, with clear associations for quality of daily life, further research is needed to determine the underlying mechanisms and relationships. To facilitate such research, high quality instruments are needed to assess the impact of hyperacusis on daily life and to diagnose associated conditions.

CONCLUSION

In conclusion, in this noninstitutionalized population-based cohort study we assessed the prevalence, hearing, mental and health factors influencing the presence of hyperacusis, and its impact on daily life. Being female, having a higher age, a medical history of chronic ear infections, diabetes, cardiovascular disease, migraine, having a depression, stress or anxiety, a higher hearing level, lower mental and general health were all associated with the presence of hyperacusis. This outcome can be of major importance for a better understanding of the condition and its consequences.

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