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Occupation and the risk of hearing impairment – results from the Nord-Trøndelag study on hearing loss

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Objectives We studied the effect of occupation on hearing and if it remained after adjustment for noise exposure, education, income, and other risk factors.

Methods Audiometry and a questionnaire concerning exposure was administered to a general adult population sample in Norway (N=49 948). Information on occupation, education, and income was obtained from population census registers.

Results Occupation had marked effects on hearing loss. Occupation explained 2–3% of the variance in hearing loss among men ≥45 years in addition to the hearing loss due to age (10–19%). Occupation explained ≤1% of hearing loss among women of all ages and young men. Controlling for self-reported occupational noise exposure reduced the occupational effect by 20–40% in men ≥45 years. Controlling for leisure-time noise, ear infections, and head injuries did not change the effect of occupation, which was slightly reduced after controlling for education and income. The most elevated hearing thresholds in men were observed among: wood workers; miners; linemen and cable jointers; construction carpenters and workers; seamen; and workshop mechanics.

Conclusions There was a moderate association between occupation and hearing loss. Unbiased estimates of occupational hearing loss may help identify high-risk occupations, for which interventions are needed, and identify individuals with hearing loss.

Key terms audiometry; epidemiology; noise exposure; Norway; occupational health; prevalence.

Hearing loss is one of the most common health problems in the industrialized world (1); the World Health Organization (WHO) regards adult-onset hearing loss as the fifteenth most serious health problem. (2). According to the European Survey on Working Conditions (3), about 7% of European workers consider that their work affects their health in the form of hearing disorders. Occupational risk factors for hearing loss include occupational noise, whole body vibration, work-related diseases, and exposure to toxins.

According to the WHO, about 16% of disabling hearing loss worldwide is attributable to occupational noise exposure (4, 5). This estimate was based on established risk estimates and noise exposure data from the US National Institute for Occupational Safety and Health, mainly from 1981–1983 (6). The European Union also recognizes noise-induced hearing loss as one of the most prominent occupational diseases (3, 7). Sectors with a high reported prevalence include agriculture, forestry, fishing, mining and quarrying, extraction, energy and water supply, manufacturing, and construction (3).

Established prevalence estimates by health authorities are based on the number of reported cases, which may be biased. The threshold for reporting cases can vary among sectors and countries. Specifically, the number of reported cases may be influenced by the level of impairment required for financial compensation or pension eligibility; it may also be confounded by subjective beliefs about noise exposure or other risk factors and whether normal hearing is vital for work performance. For example, the Swedish Work Environment Authority reports that nursery schools are one of the noisiest work environments for women in Sweden, with a high rate of reported noise-related hearing losses (8). But

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such reporting may result from an elevated awareness of hearing problems in teachers or a work environment that demands good hearing; these factors may result in over-reporting of hearing loss. The actual hearing of nursery school teachers has not yet been studied in a systematic way.

There is thus a need for unbiased estimates of occupational hearing loss in the population. Epidemiologic studies of occupation-specific, work-related hearing loss are needed in order to identify high-risk occupations, in which specific types of harmful exposure are identified and protection is provided.

Previous analyses of data from the Nord-Trøndelag study on hearing loss (9, 10) have clearly shown the effects of self-reported occupational and impulse noise exposure on hearing. Detailed information on occupation type was not provided in the previous analyses (9, 10). A recent set of analyses of a subsample of the Nord-Trøndelag study showed a negative relationship between occupational status and hearing loss (11). The analyses in this paper are based on data from the total Nord-Trøndelag study on hearing loss sample together with information from the nationwide occupation register administered by the governmental agency, Statistics Norway. Our primary aim was to determine the effects of specific types of occupation on hearing loss. We also examined the extent to which occupational differences in hearing loss remained after adjustment for self-reported occupational noise exposure, non-occupational noise exposure, education, income, and other risk factors.

Methods

Study population

The Nord-Trøndelag study on hearing loss is part of the Nord-Trøndelag health study (HUNT). The entire adult population of Nord-Trøndelag County in Norway was invited to participate in HUNT, which was conducted from January 1996 to February 1998. Screening included several types of examinations; 17 of the 24 municipalities were offered hearing examinations, consisting of pure-tone audiometry and two questionnaires, as part of the screening program.

The subjects ranged in age from 20–101 years (median age 48.0 years; mean 50.2 ± 17.0 years). The participation rate for all municipalities together except one (Levanger) was 69%, 65% among men and 73% among women. The corresponding rates for Levanger (in which the HUNT participants had to be re-invited to have their hearing examined) were 42%, 39%, and 45%, respectively. The participation rates varied with age, from around 40% for subjects <30 years or >80 years to 82% for subjects from 60–69 years. The low participation rate among young people was partly caused by the non-appearance of students and young persons doing their (compulsory) military service who, while formally keeping their childhood home address, had moved to other parts of the country.

A total of 51 574 persons arrived for their hearing examination and provided written informed consent. Audiometric data were missing for 774 persons (1.5%). Questionnaire data were missing or incomplete for 815 persons (1.6%). The sample is described in greater detail elsewhere (9). Information on occupation and education was obtained for all but 37 subjects by linkage to population register information from Statistics Norway. The data were matched on the basis of the personal identification number given to all Norwegian citizens. These identification numbers were removed before making the matched data material available to the researchers. In total, the sample consisted of 49 948 subjects with complete data.

Measures

Air conduction hearing thresholds were obtained by pure-tone audiometry at the following frequencies: 0.25, 0.5, 1, 2, 3, 4, 6, and 8 kHz. For details, please see Tambs et al (9). Two different pure-tone averages of permanent threshold shifts (PTS) were calculated: (i) $PTS_{3–4–6}$ (a binaural pure-tone average for frequencies of 3000 Hz, 4000 Hz, and 6000 Hz); and (ii) $PTS_{0.5–1–2–4}$ (a pure-tone average for the better ear for frequencies of 500, 1000, 2000, and 4000 Hz).

$PTS_{3–4–6}$ reflects the frequency range that is most susceptible to noise-induced hearing loss. $PTS_{0.5–1–2–4}$ identifies hearing loss in frequencies typical of normal conversational speech and is used to identify disabling hearing loss. Disabling hearing loss was defined as a $PTS_{0.5–1–2–4}$ of ≥35 dB hearing level. This criterion, which deviates from the former WHO definition of ≥41 dB hearing level (12), is based on the new consensus agreement by the recent Global Burden of Disease Hearing Loss meeting, London, October 2008 (HJ Hoffman, personal communication).

Occupation data were obtained using census records from 1970, 1980, and 1990. The most recent occupation information was used. For example, if a subject was not working in 1990, his or her occupation status from 1980 was used. About 22% (14% of men and 30% of women) were not working (ie, were occupationally inactive) at the time of any of the census registration years. Occupation was coded according to the Nordic Classification of Occupations (13) using a 3-digit code. The digits represent the major class ("felt"), the sector ("område"), and the occupation group. The codes consist of 13, 86, and 412 groups, respectively (14).

Education data were available for 1980, 1985, 1990, 1995, and 1998. We used the most recent education information; education was classified into 10 levels.

Income data from 1980, 1985, 1990, 1995, and 1998 were obtained from the Norwegian Revenue Service and made available through Statistics Norway. Income was calculated as the mean income over the years available, corrected for an increase in the general population income during the period 1980–1998.

Self-reported noise exposure and other risk factors were obtained from the questionnaire data. Participants were asked to complete a one-page questionnaire while in the waiting room prior to their audiometric examination.

Occupational noise exposure was measured by questionnaire items about loud noise at work in general (scored 0–3) and specific noise from the following: staple gun/hammering, metal hammering/riveting, circular saw/machine planing, chainsaw operation, tractor/construction machines, sledge hammer operation, blasting, and machine-room and other factory noise. (These items were scored using "yes" or "no".)

Non-occupational noise exposure was measured by questionnaire items about impulse noise (ie, explosions, shootings); playing in a band or going to discotheques, rock concerts, or similar loud events; recurrent ear infections (throughout the years); and hospitalization (ever) for a head injury (these items were scored using "no" = 0, "perhaps or I do not know" = 1, and "yes" = 2).

The items on the questionnaire are described in detail elsewhere (15).

Statistical analysis

We estimated the effects of occupation on hearing loss via multivariate analysis of variance (UNIANOVA command) using the Statistical Package in the Social Sciences (SPSS Inc, Chicago, IL, USA). Each of the two hearing measures (ie, $PTS_{3–4–6}$ and $PTS_{0.5–1–2–4}$) were specified as dependent variables in consecutive analyses entering age (in years) and occupation as fixed factors. The analyses were stratified by gender and age group (20–44 years, 45–64 years, and ≥65 years). Effect sizes were estimated as eta squared (η^2), which was calculated as:

$$\eta^2 = \frac{SS_{Effect}}{SS_T} \qquad \text{(equation 1)}$$

The SS_{Effect} was the sum of the squares for occupation and the SS_T was the total (corrected) sum of the squares (16). Changes in the effect of occupation after controlling for self-reported noise exposure, and socioeconomic and other risk factors were estimated as changes in η^2 after subsequently entering additional control variables in the model.

We calculated the estimated marginal means of hearing thresholds (using SPSS with the UNIANOVA EMMEANS command) for each occupation group for men and woman, after adjusting for age, and compared these to the estimated marginal mean of the occupation group 064 (ie, "teachers – primary and vocational schools"). This group was chosen as a reference because of its low hearing thresholds and sufficient male and female subjects. The estimated marginal means of hearing thresholds are simply referred to as the mean hearing thresholds.

We estimated the prevalence ratio for disabling hearing loss ($PTS_{0.5–1–2–4}$ ≥35 dB) for each occupation using a log-binomial model with occupation group as a factor and age as a covariate. The model, which is a generalized linear model in which the link function is the logarithm of the proportion under the study and the distribution of the error is binomial, was estimated using the computer program R. Teachers were again used as the reference occupation. Direct estimates of prevalence ratios by log-binomial regression have some advantages over odds ratios estimated with logistic regression analysis. Specifically, prevalence ratios are easier to interpret, especially in strata with a high prevalence of hearing loss (17).

Results

Occupation had marked effects on hearing loss for the two measures of hearing loss used (ie, $PTS_{3–4–6}$ and $PTS_{0.5–1–2–4}$). The explained variances (adjusted R^2) and the effect of occupation, estimated as η^2 are shown for models with (i) age only, (ii) age and occupation, and (iii) controlling for self-reported noise exposure and other socioeconomic and risk factors in tables 1 and 2.

Even though the age range was restricted for each group, age effects were far stronger than those of occupation. Age accounted for 6–24% of the variance, depending upon age, gender, and PTS. Occupation additionally explained 2–3% of the variance among men ≥45 years and explained ≤1% of the variance among young men and women of all ages. For men, self-reported occupational noise explained up to 2.2% of the variance over and above occupation type. Other risk factors, education, and income accounted for an additional ≤0.7% of the variance. While the effect of occupation was stronger for $PTS_{3–4–6}$ than $PTS_{0.5–1–2–4}$ in most of the age stratified groups, it was similar when the age groups were pooled. The effect of occupation (estimated as η^2) was 0.05–0.07 in men ≥45 years and was reduced 20–40% by controlling for self-reported occupational noise exposure. In contrast, occupation effects hardly reduced at all the already small effect of occupation among women.

Table 1. Multivariate analysis of variance (ANOVA). Explained variance (adjusted R^2) and effects of occupation [eta squared (η^2)] among men. (PTS_{3-4-6} = binaural pure-tone average for the frequencies of 3000, 4000, and 6000 Hz; $PTS_{0.5-1-2-4}$ = pure-tone average of the better ear for the frequencies of 500, 1000, 2000, and 4000 Hz)

Age group	Pure tone average	Model variables								
		Age	Age and occupation		Age, occupation and occupational noise exposure		Age occupation, all risk factors [a]		Age, occupation, all risk factors,[a] education, and income	
		Adjusted R^2 (%)	Adjusted R^2 (%)	η^2	Adjusted R^2 (%)	η^2	Adjusted R^2 (%)	η^2	Adjusted R^2 (%)	η^2
20–44 years	PTS_{3-4-6}	11.8	13.0	0.037	13.7	0.033	15.1	0.031	15.5	0.028
	$PTS_{0.5-1-2-4}$	7.7	8.1	0.031	8.6	0.028	9.6	0.027	10.2	0.025
45–64 years	PTS_{3-4-6}	19.1	21.6	0.051	23.6	0.030	26.1	0.029	26.4	0.026
	$PTS_{0.5-1-2-4}$	14.6	16.9	0.050	18.7	0.033	20.4	0.033	21.0	0.029
>64 years	PTS_{3-4-6}	10.2	13.4	0.073	16.0	0.052	18.2	0.050	18.3	0.045
	$PTS_{0.5-1-2-4}$	16.9	19.8	0.067	22.0	0.051	23.7	0.051	23.9	0.045
All ages	PTS_{3-4-6}	60.0	61.0	0.016	61.8	0.009	62.7	0.009	62.8	0.007
	$PTS_{0.5-1-2-4}$	55.1	56.1	0.016	56.8	0.010	57.4	0.010	57.6	0.008

[a] Self-reported occupational noise, leisure noise, recurrent ear infections, and head injuries.

Table 2. Multivariate analysis of variance (ANOVA). Explained variance (adjusted R^2) and effects of occupation [eta squared (η^2)] among women. (PTS_{3-4-6} = binaural pure-tone average for the frequencies of 3000, 4000, and 6000 Hz; $PTS_{0.5-1-2-4}$ = pure-tone average of the better ear for the frequencies of 500, 1000, 2000, and 4000 Hz)

Age group	Pure tone average	Model variables								
		Age	Age and occupation		Age, occupation and occupational noise exposure		Age occupation, all risk factors [a]		Age, occupation, all risk factors,[a] education, and income	
		Adjusted R^2 (%)	Adjusted R^2 (%)	η^2	Adjusted R^2 (%)	η^2	Adjusted R^2 (%)	η^2	Adjusted R^2 (%)	η^2
20–44 years	PTS_{3-4-6}	6.9	7.2	0.021	7.2	0.021	8.3	0.020	9.0	0.018
	$PTS_{0.5-1-2-4}$	5.5	5.8	0.021	5.8	0.021	6.9	0.020	7.6	0.018
45–64 years	PTS_{3-4-6}	12.8	14.0	0.031	14.2	0.029	15.2	0.029	15.3	0.024
	$PTS_{0.5-1-2-4}$	9.4	10.0	0.027	10.1	0.026	11.1	0.025	11.4	0.021
>64 years	PTS_{3-4-6}	24.2	24.0	0.017	24.5	0.017	26.0	0.017	26.1	0.014
	$PTS_{0.5-1-2-4}$	23.4	23.3	0.018	23.7	0.018	25.3	0.017	25.4	0.015
All ages	PTS_{3-4-6}	59.0	59.1	0.005	59.2	0.005	59.7	0.005	59.8	0.004
	$PTS_{0.5-1-2-4}$	53.6	53.8	0.006	53.8	0.006	54.4	0.006	54.6	0.004

[a] Self-reported occupational noise, leisure noise, recurrent ear infections, and head injuries.

Additional controls for leisure-related noise, recurrent ear infections, and head injuries did not change the effect of occupation. Controlling for education and income further reduced the effect of occupation, by about 10% among men aged 45–64 years and about 15–18% among women 45–64 years.

The mean hearing thresholds for different occupation groups in relation to those of primary and vocational school teachers (adjusted for age) are shown in tables 3 and 4. The tables are limited to occupations with the highest hearing thresholds and occupation groups with >39 subjects. (For a complete list of occupation groups, please see the supplemental material available on www.sjweh.fi/data_repository.php.) For men, the occupations with the highest hearing thresholds were wood work and mining, with about 11 dB elevated thresholds at 3000–6000 Hz compared to the reference group. Among women, there were only a few occupation groups with significant elevated hearing thresholds.

The prevalence of disabling hearing loss ($PTS_{0.5-1-2-4}$ ≥35 dB) was 10.3%, 12.5%, and 8.4% among the general population, men, and women, respectively. Age-adjusted prevalence ratios were calculated for disabling hearing loss for each occupation group (ie, the ratios expected if the mean age in the occupation group were equal to that of the whole population). Again, primary and vocational school teachers (prevalence among men 7.6% and woman 5.2%) were used as the reference group (tables 3 and 4).

Table 3. Predicted age-adjusted hearing threshold elevation (in dB) and adjusted prevalence ratio of $PTS_{0.5–1–2–4}$ ≥35 dB among men [a]. Occupational groups were sorted by mean $PTS_{3–4–6}$. The 31 groups with the highest means and >39 subjects are shown. ($PTS_{3–4–6}$ = binaural pure-tone average for frequencies of 3000, 4000, and 6000 Hz; $PTS_{0.5–1–2–4}$ = pure-tone average of the better ear for frequencies of 500, 1000, 2000, and 4000 Hz; 95% CI = 95% confidence interval)

Nordic Classification of Occupational Codes		$PTS_{3–4–6}$		$PTS_{0.5–1–2–4}$		Prevalence ratio		Sample size (N=23 374)
		Mean	95% CI	Mean	95% CI	Mean	95% CI	
77	Wood work	11.2	6.7–15.7	7.3	4.4–10.2	1.7	1.4–2.3	46
501	Miners – in underground mines, quarrymen, shot firers	10.9	8.4–13.3	5.7	4.1–7.3	1.8	1.4–2.4	171
765	Linemen & cable jointers	9.5	6.2–12.8	3.5	1.4–5.7	1.4	0.9–2.2	87
774	Construction carpenters & workers	9.2	7.9–10.5	5.6	4.7–6.4	1.6	1.3–2.1	911
612	Able & ordinary seamen	9.2	4.8–13.5	5.8	2.9–8.6	1.6	0.9–3.0	49
751	Workshop mechanics	8.5	6.2–10.9	4.3	2.8–5.9	1.1	0.7–1.8	183
753	Machine & motor repairmen	8.5	4.8–12.2	4.0	1.6–6.4	1.4	0.7–3.1	68
A30	Military – senior officers	8.2	4.1–12.2	3.8	1.2–6.4	1.5	0.9–2.5	58
876	Oilers and greasers etc	8.1	4.0–12.1	3.6	1.0–6.2	1.1	0.5–2.6	57
871	Stationary engine operators	7.9	3.1–12.7	2.5	-0.6–5.6	1.1	0.5–2.1	40
791	Masons, bricklayers & plasterers	7.3	4.2–10.4	3.4	1.4–5.4	1.1	0.7–1.8	101
755	Plumbers & pipe fitters	7.3	5.2–9.3	4.2	2.9–5.5	1.8	1.2–2.7	256
757	Metal plate & steel structural workers	7.2	4.8–9.7	4.6	3.0–6.2	1.8	1.2–2.7	174
75	Iron & metalware work	7.1	4.1–10.1	3.1	1.1–5.0	1.6	1.1–2.3	106
759	Others in 75 iron and metalware work	7.1	3.0–11.2	6.0	3.3–8.6	1.0	0.4–2.6	56
754	Sheet-metal workers	6.9	4.5–9.3	3.7	2.2–5.3	1.1	0.6–1.9	177
441	Forestry workers & loggers	6.9	4.9–8.9	4.1	2.8–5.4	1.3	0.9–1.8	276
836	Papermakers	6.8	3.9–9.6	3.2	1.4–5.0	1.5	1.0–2.3	124
872	Crane & hoist operators, etc	6.5	2.3–10.7	4.1	1.4–6.8	1.5	0.8–3.1	53
772	Sawmill & planing mill workers	6.4	4.5–8.4	4.2	2.9–5.5	1.4	1.0–1.9	282
874	Operators of earth-moving & other construction machinery	6.4	4.7–8.2	3.3	2.2–4.5	1.2	0.8–1.7	383
826	Butchers, sausage makers etc.	6.2	3.6–8.7	3.3	1.6–4.9	1.2	0.7–2.0	157
793	Cement finishers, excavators, etc	6.1	4.6–7.7	4.0	2.9–5.0	1.5	1.1–1.9	509
752	Fitter-machinists	6.1	4.7–7.5	3.6	2.7–4.5	1.7	1.3–2.3	695
834	Mechanical pulp workers	6.0	1.9–10.0	4.3	1.7–6.9	1.7	1.2–2.4	57
A20	Non-commissioned officers & subalterns	5.9	3.4–8.4	3.3	1.7–4.9	1.9	1.4–2.7	164
777	Wood working machine setters & operators	5.8	3.3–8.3	4.9	3.3–6.6	1.6	1.2–2.2	159
0X6	Personnel specialists	5.5	1.2–9.8	2.7	-0.1–5.5	1.5	0.7–3.2	50
821	Millers	5.5	1.2–9.8	3.4	0.6–6.2	1.2	0.7–2.1	51
X	Occupation not reported	5.3	4.2–6.4	3.7	3.0–4.5	1.7	1.3–2.1	3216
401	General farmers, livestock farmers – working on own behalf	5.3	4.3–6.3	3.1	2.4–3.7	1.4	1.1–1.8	2763

[a] In relation to the reference occupation group 064, "Teachers – primary and vocational schools."

Discussion

Our results showed that occupation had moderate effects on hearing loss. The effects of occupation on women's hearing were small, confirming previous reports that women are exposed to less occupational noise and have smaller threshold shifts due to occupational noise exposure (9). As expected, occupation had greater effects on thresholds averaged at 3000–4000 Hz than those averaged at 500–4000 Hz. The effect of occupation on hearing loss was much greater in older than younger people, and the most obvious explanation is cumulative noise exposure. However, vulnerability may increase with age, and the results may also reflect societal trends such as decreased occupational noise and improved ear protection during the 20th century although the size of such a trend might be questionable.

The effects of occupational exposure were comparable but somewhat weaker than those of self-reported exposure in previous analyses of data from the Nord-Trøndelag study on hearing loss (9, 10). Controlling for self-reported occupational noise exposure reduced the occupation group effect among men from negligible values up to 2.1% of the total variance ($PTS_{3–4–6}$, >64 years), but the effect of occupation generally did not change very much in any group after this adjustment. This indicates that there may be important occupational risk factors for hearing loss other than noise. Such factors might include whole-body vibration, work-related diseases, and exposure to occupation-related toxins; these factors were not examined in the present study. Self-reported occupational noise is far from perfect in terms of validity; this certainly reduced the extent to which the effect of occupation group could be explained by occupational noise, however.

Table 4. Predicted age-adjusted hearing threshold elevation (in dB) and adjusted prevalence ratio of $PTS_{0.5–1–2–4}$ ≥35 dB among women [a]. Occupational groups were sorted by mean $PTS_{3–4–6}$. The 31 groups with the highest means and >39 subjects are shown. ($PTS_{3–4–6}$ = binaural pure-tone average for frequencies of 3000, 4000, and 6000 Hz. $PTS_{0.5–1–2–4}$ = pure-tone average of the better ear for frequencies of 500, 1000, 2000, and 4000 Hz, 95% CI = 95% confidence interval)

Nordic classification of occupational codes		$PTS_{3–4–6}$		$PTS_{0.5–1–2–4}$		Prevalence ratio		Sample size (N=26 907)
		Mean	95% CI	Mean	95% CI	Mean	95% CI	
822	Bakers & pastry cooks	5.7	2.1–9.3	4.1	1.4–6.8	1.1	0.6–1.8	45
04	Nursing care	3.8	1.6–6.1	2.0	0.3–3.7	0.9	0.6–1.4	120
003	Other engineers, engineer technicians, industrial designers	3.5	0.0–7.0	1.5	-1.1–4.2	1.6	0.2–11.5	48
681	Postmen	3.4	-0.3–7.2	1.2	-1.6–4.1	0.8	0.1–5.3	41
913	Kitchen assistants	3.3	2.0–4.6	2.4	1.4–3.4	1.1	0.8–1.5	404
41	Farm work & livestock work	3.3	0.1–6.5	1.5	-1.0–3.9	0.9	0.5–1.7	56
X	Occupation not reported	2.8	2.1–3.5	2.2	1.7–2.6	1.0	0.8–1.3	7946
932	Char workers & cleaners	2.7	1.9–3.5	1.9	1.3–2.5	1.0	0.8–1.3	1888
049	Others in 04 (nursing care)	2.5	1.1–3.9	2.0	1.0–3.1	1.3	0.9–1.8	355
915	Housekeepers – public service	2.5	1.4–3.5	1.6	0.8–2.3	1.0	0.8–1.2	842
912	Cooks	2.5	0.8–4.1	1.7	0.5–3.0	0.9	0.7–1.3	247
921	Headwaiters, waiters	2.4	0.9–3.9	1.8	0.7–2.9	1.2	0.9–1.6	295
825	Canning & other preservation workers	2.4	-0.4–5.1	2.2	0.1–4.2	1.3	0.6–2.7	80
411	Farm helpers – general	2.3	1.3–3.3	1.3	0.6–2.1	1.0	0.8–1.3	843
914	Housekeepers, maids – private service	1.8	0.0–3.5	1.2	-0.1–2.5	0.9	0.6–1.4	212
716	Sewers & embroiderers – textile products, leather garments	1.7	-0.8–4.2	0.8	-1.1–2.7	0.8	0.4–1.5	94
412	Livestock workers – general	1.7	0.4–3.0	1.1	0.2–2.1	0.9	0.7–1.2	439
413	Nursery workers & gardeners	1.7	-0.7–4.1	1.5	-0.3–3.3	0.9	0.5–1.5	106
919	Others in 91 (public safety & protection work)	1.5	0.1–3.0	0.7	-0.4–1.8	0.6	0.2–1.5	310
922	Other waiting personnel	1.4	-0.7–3.6	1.1	-0.5–2.7	0.6	0.3–1.3	136
911	Housekeepers etc (not private or public service)	1.4	-0.8–3.6	1.3	-0.3–3.0	1.0	0.7–1.6	129
043	Practical nurses in psychiatric institutions	1.4	-1.6–4.4	-0.4	-2.7–1.8	0.5	0.1–3.0	67
047	Nursemaids in hospitals & other institutions	1.4	-0.9–3.6	1.0	-0.7–2.7	0.4	0.1–3.1	119
292	Bank clerks	1.3	-0.5–3.1	0.6	-0.7–1.9	0.6	0.1–2.2	202
203	Other cashiers	1.2	-0.7–3.1	0.5	-0.9–1.9	0.4	0.2–1.0	176
294	Clerks – public health insurance	1.0	-2.0–3.9	1.0	-1.3–3.2	1.5	0.6–3.4	68
111	Directors, managers & working proprietors	1.0	-2.7–4.7	-0.2	-3.0–2.5	0.6	0.2–1.6	42
0X2	Social workers	1.0	-0.6–2.6	1.0	-0.2–2.2	0.6	0.3–1.4	263
951	Laundry & dry-cleaning workers	1.0	-1.7–3.7	0.4	-1.6–2.4	0.8	0.4–1.4	81
861	Packers, labelers & related workers	0.9	-1.4–3.2	1.3	-0.4–3.1	0.8	0.5–1.5	111
853	Plastic product makers	0.9	-1.5–3.3	0.6	-1.2–2.4	0.4	0.1–1.4	102

[a] In relation to the reference occupation group 064, "Teachers – primary and vocational schools."

Other risk factors, such as noise during leisure activities, recurrent ear infections, and head injuries have been demonstrated to predict hearing loss and may well have some relation to occupation. Nevertheless, controlling for these factors did not change the effect of occupation on hearing loss in our study. However, controlling for education and income slightly reduced the effect of occupation, consistent with previous results showing a social gradient for both increased mortality and morbidity (18) and hearing loss (19–21). This result may reflect moderate effects of confounders associated with social background other than those observed in our study, such as risky health behaviour.

For men, the most elevated hearing thresholds were found among: wood workers; miners; linemen and cable jointers; construction workers and carpenters; seamen; and workshop mechanics. The magnitude of the hearing threshold elevation ranged from 7–11 dB at 3–6 kHz for the 20 occupations with the greatest effects on hearing loss; this was comparable to the 8–9 dB high-frequency loss reported in the Nord-Trøndelag study on hearing loss for the upper 10th percentile of men >44 years with self-reported occupational noise exposure (9).

Only a few previous studies have reported occupation-specific prevalence ratios. A German study of 4958 construction workers estimated an age-adjusted prevalence ratio for hearing loss of about 1.5 for blue- versus white-collar workers (22). In that study, hearing loss was defined as the sum of hearing thresholds at 2000, 3000, and 4000 Hz >105 dB in the worse ear. The reported specific estimated ratios for carpenters, unskilled workers, bricklayers, plumbers, and plasterers were 1.8, 1.8, 1.6, 1.5, and 1.3, respectively. These results are relatively consistent with our prevalence

ratios for disabling hearing loss ($PTS_{0.5–1–2–4}$ ≥35 dB), namely 1.6 for construction carpenters and workers and 1.8 for plumbers (versus teachers). We also found significantly elevated mean hearing thresholds for masons, bricklayers, and plasterers, although the prevalence ratio for disabling hearing was not significant.

The prevalence of hearing loss was determined for 13 519 sheet metal workers and 18 397 office workers in the Swedish construction industry in the period 1971–1980 (23). The reported prevalence data gave prevalence ratios of 2.6 and 1.4 for workers aged 35–39 and 55–59 years, respectively, for hearing loss at 4000 Hz >30 dB. The corresponding prevalence ratios at 500 Hz were 2.9 and 1.7, respectively.

A study of the elderly in Wisconsin, USA, found an increased risk of hearing loss for people working in service, production, and operation occupations compared to those in management positions; the age- and gender-adjusted odds ratios were 1.8, 3.5, and 2.0, respectively. Hearing loss was defined as an average hearing threshold at 500–4000 Hz that was >25 dB for the worse ear (21).

In a recent analysis of self-reported hearing difficulties in 130 102 employed respondents to the US National Health Interview Survey, the industries with the greatest prevalence ratios were: railroads; mining; primary metal manufacturing; and furniture, lumber, and wood manufacturing with prevalence ratios of 2.7, 2.2, 2.0, and 1.8, respectively. Employees in the finance, insurance, and real estate industries were used as a reference group, and the prevalence ratios were adjusted for age, gender, race, smoking status, and education (24). The prevalence ratio in the construction industry was moderate (ie, 1.4), but construction still had the highest number of persons with hearing difficulties that were attributable to employment.

Strengths and limitations

The major advantages of our study were its prospective design and the fact that its population was representative of the general working population. Since occupation data were complete for all participants, and the participation rate in the population survey was relatively high (67% for the vast majority of the county), a substantial selection bias is unlikely. The occupation data were obtained from highly valid registry data, and the audiometric data were equally reliable (9); thus, we consider recall bias or other reporting bias to be minimal.

The mean hearing thresholds in each occupation were related to the mean of the teachers at primary and vocational schools. The rationale for choosing this group as the reference was to choose a group of sufficient size to make the estimation of prevalence ratios as precise as possible. Substantively, a completely non-exposed reference category may have been preferable. There may be some concern that noise levels at primary schools are harmful to hearing although daily levels are reported mostly to be ≤70 dB and only occasionally to be >80 dB (25).

A weakness of the study was the lack of information about the length of employment or duration of exposure. However, the estimated average hearing losses for each occupation group apply to workers whose age is equal to the sample mean. Accordingly, we have essentially adjusted for exposure duration. In addition, there is relatively high occupational stability in Nord-Trøndelag County: 86% of the men and 97% of the women reported to have had ≤2 types of work that lasted >2 years (9). Controlling for having had several types of work does not significantly change the estimated effects of occupation reported in tables 1 and 2.

The Nordic Classification of Occupations does not classify occupations on the basis of noise-exposure levels or other risk factors for hearing loss, but according to the tasks and duties undertaken in the job. Heterogeneity regarding noise and other exposure within occupational categories implies that occupation as an explanatory variable does not capture all effects of occupational exposure on hearing loss. Our results showed that adding information on self-reported occupational noise exposure improved the prediction of hearing loss somewhat.

Selection for good hearing in some occupations could in principle bias the results, but we think it unlikely that this type of selection had much effect on the results.

Concluding remarks

This study found a moderate association between occupation and hearing loss. Unbiased estimates of occupational hearing loss may help identify high-risk occupations, in which interventions are needed.

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