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Occupation and 20-year hearing decline: findings from The HUNT Study

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Background Studies show that certain occupations are associated with an increased risk of hearing loss. However, many studies are cross-sectional, and the few longitudinal studies are mostly small or focus on only one occupation.

Aims We aimed to quantify the long-term hearing decline among workers in different occupations and assess whether the change differs between the occupations.

Methods The study population was 4525 adults who participated in two population-based health studies in Norway, HUNT2 1996–1998 and HUNT4 2017–2019. Linear regression models assessed the association between occupations (clerks as reference) and 20-year hearing decline (hearing thresholds at 3–6 kHz, averaged over both ears) from HUNT2 to HUNT4. Models were adjusted for age, sex, recurrent ear infections, smoking and ear pathology.

Results Among the participants (40% men), the mean age at HUNT2 was 31.2 ± 5.4 years (range 20–39) and the average 20-year hearing decline was 11.3 ± 9.8 dB. Occupations that were associated with larger hearing decline included other craft and related trades workers (3.9 dB, 95% confidence interval [CI] 0.2–7.7) and building frame and related trades workers (3.4 dB, 95% CI 1.3–5.4). Among occupations with larger hearing decline, a higher proportion of the workers reported exposure to noise.

Conclusions This large longitudinal study shows a larger long-term hearing decline among building frame workers and craft and related trades workers. Differences between occupations were modest, which may indicate successful preventive measures in Norway during the last two decades.

Introduction

Sense organ disorders, among which hearing loss is the most common, were the second largest cause of years lived with disability in 2015 [1]. There is a strong association between hearing loss, sex and increasing age [2]. A Norwegian study reported that the prevalence of any hearing loss (2017–2019), as defined by the Global Burden of disease, was 3% among men aged 20–44 years and 73% among men above 64 years [3]. The prevalence was lower for women in corresponding age groups. Other moderate to severe risk factors include genetic factors, ear disease, occupational noise within certain occupations, impulse noise and gunfire [2].

In order to implement targeted preventive measures at work, it is important to investigate the occupational contribution to hearing loss and which occupations are most harmful. Such knowledge is important for workers, employers, occupational health services and policy makers. Systematic reviews [2, 4, 5] report that many occupations are associated with hearing loss, such as manufacturing, shipyard, farmers, construction and military occupations [2]. However, many of the included studies are cross-sectional, and the few longitudinal studies, addressing temporality and change in hearing, are often small, short-term or focus on only one occupation or one field of work.

This large longitudinal population-based study from Norway is based on audiometric data measured 20 years apart, linked with registry-based data on occupation. We aim to quantify the long-term hearing decline among workers in different occupations and assess whether the change differs between the occupations.

Methods

The Trøndelag Health Study (The HUNT Study) is a population-based health study performed in the Norwegian county of Nord-Trøndelag [6, 7]. HUNT is considered one of the most extensive cohort studies ever and has been conducted four times (HUNT1-4) since 1984. HUNT2 Hearing (1996–1998) and HUNT4 Hearing (2017–2019) were part of HUNT2 and HUNT4, respectively.

HUNT2 Hearing included participants from 17 of the 24 municipalities in the county. The participation rate was 63% and altogether 51 529 persons attended [3]. HUNT4 Hearing took part in the six larger municipalities, representing about two-thirds of the county population [3]. The participation rate was 43%, and altogether, 28 388 persons attended [3]. Both studies included pure-tone audiometry and detailed questionnaires, and are described in detail elsewhere [3, 8].

The present study is longitudinal and included participants who attended both HUNT2 Hearing and HUNT4 Hearing, which

Key learning points

What is already known about this subject:

- Several occupations are associated with hearing loss; among others manufacturing, shipyard, farmers, construction and military occupations.
- Many studies on the association between occupation and hearing loss tend to be small, cross-sectional or only considering one single occupation or work site.

What this study adds:

- This large longitudinal population study contributes with knowledge on long-term hearing decline in different occupations.

What impact this may have on practice or policy:

- This knowledge may help workers, employers, occupational health services and policy makers understand which workers have an increased risk of hearing loss, which could lead to targeted efforts to prevent this in the future.
- Our study suggests a possible effect of preventive measures, which could be encouraging in the work against occupational noise-induced hearing loss.

for simplicity are referred to as HUNT2 and HUNT4 hereafter. About 44% of the participants in HUNT2 were invited to HUNT4. The main reasons for not being invited were death, living outside the six larger municipalities and occasionally reduced test capacity. The participation rate in HUNT4 among the invited was 58%.

Individuals with missing questionnaires, non-complete audiometry, age 40+ years at baseline or missing information about occupation were excluded. Estimates by ISO [9] indicate that a large part of the noise-induced hearing threshold shift for workers with high levels of noise exposure occurs during the first 10–15 years of noise exposure. The age limit of this study was restricted to examine a population who had limited years of exposure prior to the study start, who was more homogeneous in relation to confounding, and who would not be likely to reach an age associated with retirement during the study period. The Regional Committee for Medical Research Ethics approved the study (23 178 HUNT hørsel). Only participants with written consent were included.

We used the first registered occupation in the study period as the exposure in this study. Occupational codes were provided by Statistics Norway. These codes were based on the Norwegian version of the International Standard Classification of Occupations ISCO-88 [10], with yearly registrations from 2003 to 2017. The first digit in the occupational codes (one-digit level) represents a general category of work (0 = armed forces and unspecified, 1 = legislators, senior officials and managers, 2 = professionals, 3 = technicians and associate professionals, 4 = clerks, 5 = service workers and shop and market sales workers, 6 = agricultural, forestry and fishery workers, 7 = craft and related trades workers, 8 = plant and machine operators and assemblers and 9 = elementary occupations). By using more digits, one gets a more specific occupation (e.g. 412 = numerical clerks).

Occupational codes 1–5 at the one-digit level have low anticipated work-related exposure to hearing-damaging noise. We combined these occupations into one group, with some exceptions: 4 clerks were chosen as the reference group, because of sufficient numbers of a relatively homogenous group. Other exceptions included: 332 pre-primary education teaching associate professionals, 345 police officers and 516 protective service workers, as these occupations (or subgroups within them) have been discussed in literature in relation to hearing loss [2]. Occupations 6–9 at the one-digit level mostly include workers with a higher probability of occupational noise exposure and were therefore considered relevant for the objective of the study. We categorised these occupations at the two-digit level, except occupational code 71 (extraction and building trades workers), which was categorised at the three-digit level, due to a high number of participants. Code 72 (metal, machinery and related trades workers) was also categorised at the three-digit level, as subgroups were expected to vary considerably regarding noise exposure.

Two teams, each consisting of one trained audiologist and two trained assistants, performed air-conduction pure tone audiometry in accordance with ISO 8253-1 (International Organization for Standardization, 2010). The audiometry is described in detail elsewhere [3, 8]. The main outcome was the difference in hearing threshold between HUNT4 and HUNT2, each estimated as an average of hearing thresholds at 3, 4 and 6 kHz over both ears. This variable was continuously scored and will hereby be referred to as hearing decline. We further assessed the association between occupation and hearing threshold at HUNT4 (3-6 kHz), in order to evaluate occupational differences in hearing after accumulated lifetime exposure including exposure prior to baseline (cohort design).

We used questionnaire data from HUNT2 to assess recurrent ear infections and smoking status, which are both linked to hearing decline [11, 12]. Ear pathology (otoscopy) was assessed in HUNT4. Missing values on any of these variables were set to no or no pathology, for instance never smoked.

We used Stata version 17.0 to perform statistical analyses. The statistical tests were calculated at a 95% CI ($P < 0.05$). Differences in 20-year hearing decline between occupations were tested by ANOVA F-test. We performed multiple linear regression analyses to estimate the association between occupation (clerks as reference category) and 20-year hearing decline (longitudinal design). In Model A, we adjusted for sex and age. In Model B, we also adjusted for ear infections, smoking and ear pathology. In all models, we used robust variance estimation. We present adjusted R^2 and the regression coefficients (Model A and Model B). We also estimated the associations using the hearing threshold in HUNT4 as the outcome variable (cohort design).

In loss to follow-up analyses, the longitudinal study population was compared to a population who only attended HUNT2. Average hearing threshold (3–6 kHz) at baseline in these two groups, adjusted for age and sex, was assessed in a linear regression postestimation test. Similarly, proportion of workers in occupations with assumed higher noise exposure (occupational codes 6–9 or 01 = armed forces) was assessed in the two groups, adjusted for age and sex, in a logistic regression postestimation test.

Results

Our study included participants who attended both HUNT2 and HUNT4, *N* = 13 022. After excluding individuals with age 40+ years at baseline (*N* = 8061), missing questionnaires (*N* = 294), non-complete audiometry (*N* = 7) or missing information on occupation (*N* = 135), our final sample comprised 4525 participants.

Table 1 displays the characteristics of the study population (*N* = 4525), among which 40% were men and mean age at baseline was 31.2 ± 5.4 years. The mean hearing decline for all participants during the study period was 11.3 ± 9.8 dB. For men, the mean hearing decline was 13.9 ± 10.4 dB, and for women, the hearing decline was 9.5 ± 8.8 dB.

Table 2 shows characteristics, work exposures and hearing thresholds at HUNT4 (3–6 kHz, mean of both ears) and hearing decline from HUNT2 to HUNT4, stratified by occupation, sex, age group and hearing protection. In occupations associated with a larger hearing decline in this study, a higher proportion of workers reported exposure to noise and vibration at HUNT4. For example, among building frame and related trades workers (concrete workers, iron fixers, construction workers, etc.), 68% reported exposure to occupational noise and 29% reported exposure to hand-arm vibration. There was overall a higher proportion of men in occupations with above average (compared to the mean proportions of this population) exposure to occupational noise, solvents and hand-arm vibration. Results for occupations with less than 20 participants are not shown because of confidentiality. During the study period, men lost on average 13.9 ± 10.4 dB of their hearing (at 3–6 kHz), whereas women correspondingly lost 9.5 ± 8.8 dB.

Table 1. Characteristics, hearing thresholds at HUNT4 (3–6 kHz, mean of both ears) and hearing decline from HUNT2 to HUNT4 among 4525 adults who participated in HUNT2 (1998) and HUNT4 (2018), Norway

	n (%)
Participants	4,525 (100)
Male	1,826 (40)
Female	2,699 (60)
Age	
HUNT2 (years), mean ± sd	31.2 ± 5.4
HUNT4 (years), mean ± sd	52.6 ± 5.4
Hearing thresholds	
HUNT2 (dB), 3-6 kHz, mean ± sd	5.6 ± 8.7
HUNT4 (dB), 3-6 kHz, mean ± sd	17.0 ± 13.9
Hearing decline through the study period (dB), 3-6 kHz, mean ± sd	11.3 ± 9.8
Recurrent ear infections, HUNT2	
No	3,487 (77)
Yes	1,038 (23)
Smoking, HUNT2	
Never smoked	2,577 (57)
Currently or previously smoking	1,948 (43)
Otoscopy, performed on both ears, HUNT4	
Normal, unspecified changes or eardrum cannot be assessed	4,261 (94)
Perforated ear drum or completely clogged ear canal (in at least one ear)	264 (6)

HUNT (2 and 4), The Trøndelag Health Study (numbers 2 and 4); sd, standard deviation; dB, decibel.

Table 3 displays characteristics among those who participated in HUNT2 only and among those who participated in both hearing studies. There were 10% more women in the longitudinal population. The average hearing threshold at HUNT2 was slightly better in the longitudinal population who attended both HUNT2 and HUNT4 (5.6 dB, 95% CI 5.3–5.8), compared to participants who only attended HUNT2 (6.2 dB, 95% CI 6.0–6.4). The proportion of workers in occupations with assumed higher noise exposure was also lower in the longitudinal population (25% compared to 31% in the HUNT2 only population).

To assess the variation in hearing decline explained by occupation, we ran regression models with and without the occupation variable, showing adjusted R^2 of 0.120 and 0.116, respectively. The small change in explained variance was significant, indicating minor occupational differences ($F = 39.76$, df = 24, $P < 0.001$). Similar analyses with hearing threshold at HUNT4 as the outcome show an adjusted R^2 of 0.194 with the occupation variable and 0.187 without the occupation variable. This change was also significant ($F = 34.19$, df = 24, $P < 0.001$).

Table 4 shows the associations (regression coefficients, measured in dB) between occupation and 20-year hearing decline from HUNT2 to HUNT4 (longitudinal design) and between occupation and hearing threshold at HUNT4 (cohort design). We here refer to the results of the fully adjusted model (Model B). Certain occupations showed larger 20-year hearing decline than the reference occupation (clerks), in particular other craft and related trades workers (3.9 dB, 95% CI 0.2–7.7) and building frame and related trades workers (3.4 dB, 95% CI 1.3–5.4). Results from the analyses using hearing threshold in HUNT4 as outcome showed stronger associations (larger differences, compared to clerks), particularly among other craft and related trades workers (7.3 dB, 95% CI 1.5–13.1), building frame and related trades workers (6.2 dB, 95% CI 3.5–9.0) and services elementary occupations (4.5 dB, 95% CI 2.2–6.9).

There were few missing covariates in the analyses: None for age and sex, 2.3% on smoking status, 1.0% on otoscopy and 0.9% on recurrent ear infections.

Discussion

Occupations associated with larger long-term hearing decline than clerks included building frame workers and craft and related trades workers. However, this recent study showed modest differences between occupations overall.

Strengths include the large population-based sample from cohorts that are considered representative of the population of Nord-Trøndelag county [3], long observation time, standardized

Table 2. Characteristics, work exposures and hearing thresholds at HUNT2 and HUNT4 (3–6 kHz, mean of both ears) and hearing decline from HUNT2 to HUNT4, stratified by occupation, sex, age group and hearing protection among 4525 adults who participated in HUNT2 (1998) and HUNT4 (2018), Norway

Occupation (with corresponding occupational codes)	*n*	Age HUNT2 (mean ± sd)	Men (%)	Exposed at work HUNT4[a]			Mean		
				Noise (%)	Solvents (%)	Vibration (%)	Hearing thresholds HUNT2 (dB ± sd)	Hearing thresholds HUNT4 (dB ± sd)	Change in hearing thresholds (dB ± sd)
4 Clerks (ref)	320	32.0 ± 4.8	23	11	3	2	4.8 ± 7.5	15.1 ± 12.3	10.3 ± 9.0
Occupations with low expected work-related exposure to noise	2,791	31.1 ± 5.5	27	17	2	2	4.9 ± 8.3	15.5 ± 13.0	10.6 ± 9.2
332 Pre-primary education teaching associate professionals	96	28.1 ± 5.9	4	26	0	0	3.6 ± 7.8	11.0 ± 10.0	7.4 ± 6.5
345 Police officers	24	31.7 ± 5.7	79	4	0	4	8.0 ± 13.5	22.3 ± 18.1	14.3 ± 11.3
516 Protective services workers	71	32.6 ± 5.0	72	42	3	4	6.2 ± 6.7	18.3 ± 14.6	12.1 ± 10.4
61 Agricultural workers	209	31.9 ± 5.1	71	51	4	11	6.3 ± 8.5	19.6 ± 15.1	13.3 ± 10.9
712 Building frame and related trades workers	147	30.4 ± 5.3	97	68	5	29	9.1 ± 9.1	24.9 ± 16.0	15.8 ± 11.4
713 Building finishers and related trades workers	31	30.5 ± 4.3	97	55	16	26	5.6 ± 7.2	17.1 ± 13.0	11.5 ± 8.6
714 Painters, building structure cleaners and related workers	26	28.7 ± 5.5	96	65	62	39	9.5 ± 13.1	19.0 ± 14.5	9.4 ± 12.2
721 Founders, welders, sheet-metal workers, etc.	58	31.1 ± 5.3	95	86	12	33	8.0 ± 8.9	21.5 ± 15.3	13.5 ± 9.6
723 Machinery mechanics and fitters	76	30.6 ± 5.5	96	66	30	38	7.6 ± 9.8	19.7 ± 15.4	12.1 ± 10.4
724 Electricians, electrical and electronic equipment mechanics and fitters	80	30.6 ± 5.2	94	54	5	18	5.3 ± 8.2	18.2 ± 15.3	12.9 ± 10.1
74 Other craft and related trades workers	36	30.1 ± 5.1	81	64	3	19	9.1 ± 13.9	24.7 ± 18.0	15.6 ± 11.2
81 Stationary-plant and related operators	78	32.6 ± 4.7	91	76	9	17	9.1 ± 11.2	23.2 ± 15.9	14.1 ± 11.9
82 Machine operators and assemblers	110	31.3 ± 5.4	73	59	17	13	7.3 ± 9.3	20.8 ± 14.5	13.4 ± 10.2
83 Drivers and mobile-plant operators	130	32.4 ± 4.8	97	55	9	12	9.7 ± 11.6	24.1 ± 16.5	14.5 ± 10.9
91 Services elementary occupations	161	31.7 ± 5.6	12	22	7	4	7.0 ± 8.6	18.8 ± 14.5	11.7 ± 10.0
93 Labourers in construction and manufacturing	36	32.0 ± 4.3	78	67	11	22	8.7 ± 10.1	20.7 ± 13.7	12.1 ± 11.5
All	4,525[b]	31.2 ± 5.4	40	27	4	6	5.6 ± 8.7	17.0 ± 13.9	11.3 ± 9.8
All men	1,826	31.5 ± 5.3		45	8	14	7.7 ± 10.1	21.6 ± 15.5	13.9 ± 10.4
Men, age 20–29 (at HUNT2)	629	25.3 ± 2.7		45	6	14	4.9 ± 8.8	15.8 ± 13.5	10.9 ± 9.8
Men, age 30–39 (at HUNT2)	1,197	34.8 ± 2.8		45	9	14	9.2 ± 10.4	24.7 ± 15.6	15.5 ± 10.4
All women	2,699	31.0 ± 5.5		15	2	1	4.3 ± 7.4	13.8 ± 11.7	9.5 ± 8.8
Women, age 20–29 (at HUNT2)	1,041	25.1 ± 2.7		14	2	1	2.4 ± 7.3	9.4 ± 9.4	6.9 ± 7.1
Women, age 30–39 (at HUNT2)	1,658	34.8 ± 2.8		16	2	1	5.4 ± 7.2	16.6 ± 12.2	11.2 ± 9.4
If exposed to noise, have you used hearing protection? (HUNT2)									
- Always	455	31.9 ± 5.5	84	53			8.3 ± 10.5	22.0 ± 16.0	13.7 ± 10.7
- Often	772	30.8 ± 5.1	86	53			7.2 ± 9.8	20.9 ± 15.7	13.7 ± 10.8
- Seldom/never	698	31.5 ± 5.3	42	34			5.8 ± 8.2	17.2 ± 13.3	11.4 ± 9.4
- Reported no noise or missing	2,600	31.2 ± 5.5	19	13			4.7 ± 8.0	14.9 ± 12.6	10.2 ± 9.1

[a]Noise: loud noise last 20 years—yes/no. Solvents (vapour): Frequently, at least 5 years—yes/no. Vibration: Powerful handheld vibrating tools at least 3 months—yes/no.

[b]The numbers in the column do not add up to the total, as results for occupations with less than 20 participants are not shown.

HUNT (2 and 4), The Trøndelag Health Study (number 2 and 4); sd, standard deviation; dB, decibel.

Table 3. Characteristics stratified by participation in HUNT2 (1998) only and participation in HUNT2 and HUNT4 (2018), Norway

	Participants HUNT2 only, *n* (%)	Participants HUNT2 & HUNT4, *n* (%)
Total	9,306 (100)	4,525 (100)
Age at HUNT2 (years), mean ± sd	30.2 ± 5.6	31.2 ± 5.4
Men	4,610 (50)	1,826 (40)
Recurrent ear infections	2,029 (22)	1,038 (23)
Currently or previously smoking	4,179 (45)	1,948 (43)
Proportion of workers with assumed higher noise exposure (adjusted for age and sex), %	31	25
Average hearing threshold (adjusted for age and sex), mean (95% CI) dB	6.2 (6.0–6.4)	5.6 (5.3–5.8)

HUNT (2 and 4), The Trøndelag Health Study (number 2 and 4); sd, standard deviation; CI, confidence interval; dB, decibel.

Table 4: Association between occupation and hearing decline from HUNT2 to HUNT4 or hearing thresholds at HUNT4 (3–6 kHz, mean of both ears), among 4525 adults who participated in HUNT2 (1998) and HUNT4 (2018), Norway

Occupations		Hearing decline, Model A[a]			Hearing decline, Model B[b]			Hearing thresholds HUNT4, Model A[a]			Hearing thresholds HUNT4, Model B[b]		
	n	Coef. (dB)	95% CI		Coef. (dB)	95% CI		Coef. (dB)	95% CI		Coef. (dB)	95% CI	
4 Clerks	320	Ref			Ref			Ref			Ref		
Occupations with low expected work-related exposure to noise	2,791	0.5	−0.5	1.5	0.5	−0.5	1.5	0.9	−0.4	2.2	0.9	−0.4	2.2
332 Pre-primary education teaching associate professionals	96	−0.3	−1.9	1.3	−0.3	−1.9	1.4	0.5	−1.8	2.9	0.6	−1.7	3.0
345 Police officers	24	2.0	−1.9	5.9	2.2	−1.6	6.0	3.8	−2.0	9.6	4.2	−1.6	10.0
516 Protective services workers	71	−0.4	−2.8	2.1	−0.4	−2.8	2.1	−0.6	−3.8	2.7	−0.5	−3.8	2.8
61 Agricultural workers	209	1.2	−0.5	2.9	1.3	−0.4	3.0	1.4	−0.9	3.8	1.6	−0.8	3.9
712 Building frame and related trades workers	147	**3.4**	**1.3**	**5.5**	**3.4**	**1.3**	**5.4**	**6.3**	**3.5**	**9.0**	**6.2**	**3.5**	**9.0**
713 Building finishers and related trades workers	31	−0.9	−3.9	2.0	−1.0	−4.0	1.9	−1.6	−5.9	2.6	−1.8	−6.1	2.4
714 Painters, building structure cleaners and related workers	26	−2.1	−6.7	2.4	−2.0	−6.6	2.5	1.9	−3.3	7.0	1.9	−3.3	7.1
721 Founders, welders, sheet-metal workers, etc.	58	0.9	−1.7	3.4	0.7	−1.8	3.3	2.5	−1.4	6.4	2.1	−1.9	6.0
723 Machinery mechanics and fitters	76	−0.3	−2.8	2.1	−0.4	−2.8	2.1	1.0	−2.6	4.6	1.0	−2.6	4.5
724 Electricians, electrical and electronic equipment mechanics and fitters	80	0.6	−1.7	2.9	0.6	−1.7	2.9	−0.3	−3.6	3.0	−0.3	−3.6	2.9
74 Other craft and related trades workers	36	**4.0**	**0.3**	**7.7**	**3.9**	**0.2**	**7.7**	**7.4**	**1.7**	**13.2**	**7.3**	**1.5**	**13.1**
81 Stationary-plant and related operators	78	0.9	−1.9	3.7	0.8	−2.0	3.7	3.1	−0.4	6.7	3.0	−0.6	6.6
82 Machine operators and assemblers	110	1.5	−0.6	3.6	1.5	−0.6	3.6	**3.0**	**0.0**	**5.9**	**2.9**	**0.0**	**5.9**
83 Drivers and mobile-plant operators	130	1.1	−0.9	3.2	1.1	−1.0	3.2	**3.8**	**0.8**	**6.8**	**3.7**	**0.7**	**6.6**
91 Services elementary occupations	161	**2.0**	**0.3**	**3.7**	**1.9**	**0.2**	**3.7**	**4.7**	**2.3**	**7.0**	**4.5**	**2.2**	**6.9**
93 Labourers in construction and manufacturing	36	−0.3	−4.1	3.5	−0.3	−4.1	3.4	2.0	−2.6	6.7	2.0	−2.6	6.6

[a]Model A is adjusted for age and sex.
[b]Model B is adjusted for age, sex, recurrent ear infections, smoking and ear pathology.
HUNT (2 and 4), The Trøndelag Health Study (numbers 2 and 4). Significant values in bold ($P < 0.05$); coef, coefficient; dB, decibel; CI, confidence interval; Ref, reference.

audiometric measurements, registry-based data on occupation and good confounder control. As the entire adult population within a geographical area was invited, selection bias based on invitations seems unlikely.

We believe that the longitudinal design, assessing temporality and change in hearing, is a major strength. Nevertheless, we may have somewhat underestimated the results for those with a long-term high degree of noise exposure and hearing

loss *before* study start. To reduce such bias, we excluded workers older than 40 years at baseline. We further estimated the associations using the hearing threshold in HUNT4 (cohort design), to study lifetime exposure. However, as this outcome is only measured at one-time point, the results could suffer from selection into occupations and unmeasured confounding. We believe the combination of hearing decline and hearing thresholds is unique and entails a better picture of work-related hearing loss.

Epidemiological studies are associated with a healthy volunteer effect [13]. Participants who attended both hearing studies had slightly better average hearing at baseline than participants who only attended HUNT2 hearing. Self-reported hearing loss was also somewhat higher among participants who attended the main HUNT studies only, compared to participants who also attended the hearing examinations [3]. Consequently, the results may be somewhat underestimated.

More women than men participated. Higher participation rate among women is not unique to this study, and men and women report different reasons for non-participation [14]. Men are more often exposed to loud noise at work and at leisure [15]. A study on attitude towards noise and hearing protection at concerts found that women viewed noise more negatively than men [16]. A gender-specific difference in safety behaviour regarding noise protection could potentially explain some of the sex differences regarding noise-induced hearing loss. Lower male participation could therefore have led to an underestimation of our results.

Occupation gives a coarse exposure classification, as hearing damaging exposure can vary within the same occupation. However, occupation is also a common measurement, which provides needed knowledge to target preventive measures. We had information on occupational noise, solvents and hand-arm vibration. The two latter have a confirmed or suspected association with hearing loss [17, 18]. In occupations associated with larger hearing decline, more workers reported exposure to noise and vibration. Information on leisure impulse noise at baseline was not available, which is a limitation.

Our study showed larger hearing decline among building frame and related trades workers. This complies with prior findings: A study of 1.8 million U.S. workers, with audiograms between 1981 and 2010, found the highest prevalence and incidence of hearing loss among workers in the construction and mining sectors [19]. A cross-sectional study based on HUNT2 data identified elevated hearing thresholds among male construction workers [20], and a retrospective study (N = 29 644) reported that 'Dutch construction workers exhibit greater hearing losses than expected based solely on ageing' [21], although this was not confirmed in a longitudinal follow-up [22].

Other workers who experienced a marked larger hearing decline compared to clerks in our study were other craft and related trades workers, in which the largest subgroup includes wood treaters, cabinet-makers and related trade workers. Woodworkers and construction carpenters were also among the male workers with the highest elevated hearing thresholds in the previously mentioned cross-sectional study [20].

Our analyses using hearing threshold at HUNT4 as outcome showed higher hearing thresholds among drivers and mobile-plant operators. Driver subgroups include locomotive-engine, bus, heavy truck, earth-moving operators, ships' machine crews, etc. Our study could not confirm larger hearing decline in some occupations previously suggested to be associated with increased risk of hearing loss, for example, protective service workers (firefighters, security guards, etc) and police officers. Regarding firefighters, a systematic review [23] states that 'there is limited evidence of hearing loss when firefighters are compared with control groups'. As to police officers, a cross-sectional study found an increased risk of having a selective 4 kHz hearing loss among French police officers (especially motorcycle policemen) compared to civil servants [24]. Similarly, studies have shown an increased risk of hearing loss among farmers [2, 25].

Our study does not show greater long-term hearing decline among pre-primary education teaching associates and professionals. In agreement, a systematic review [2] found that, 'literature suggests that the noise exposure is too low to cause any hearing loss among nursery staff, and their hearing does not differ from nonexposed controls'.

Our study showed modest differences in hearing decline between occupations. The findings may indicate successful preventive measures. Hearing in the general population has improved in more recent born cohorts in industrialized countries [3, 26]. A recent article [27] concluded that less occupational noise exposure was one of the factors that contributed substantially to improved hearing in Norway the last two decades. New and strict noise regulations were implemented in Norway in 1982 [28]. In addition, there has been a high focus on hearing conservation programs, and a Swedish study indicates positive trends regarding the use of hearing protection [29]. These could be reasons for the improvement. A Danish study from 2006 [30] 'observed no increased risk of hearing handicap in workers younger than 30 years of age or among workers entering a noise exposed job during the past 10–15 years', and suggested an effect of preventive measures.

This large longitudinal study from Norway spans the first two decades of this century. It shows larger long-term hearing decline among building frame workers and craft and related trades workers. Altogether the contribution from occupation to hearing decline was modest. This may indicate successful preventive measures, which could be encouraging in the work against occupational noise-induced hearing loss.

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Competing interests

None declared.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due to Norwegian legal restrictions and the current ethical approval for the study.

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