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ORIGINAL ARTICLE

Occupational noise exposure, psychosocial working conditions and the risk of tinnitus

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Abstract
Purpose The purpose of this study was to evaluate the influence of occupational noise (current and cumulative doses) and psychosocial work factors (psychological demands and decision latitude) on tinnitus occurrence among workers, using objective and non-self-reported exposure measures to prevent reporting bias.
Methods In a cross-sectional study, we analyzed data from a Danish survey from 2009 to 2010 that included 534 workers from children day care units and 10 manufacturing trades. Associations between risk factors (current noise exposure, cumulative noise exposure and psychosocial working conditions) and tinnitus were analyzed with logistic regression.
Results We found no statistically significant associations between either current [OR 0.95 (95% CI 0.89; 1.01)] or cumulative [OR 0.93 (95% CI 0.81; 1.06)] occupational noise exposure and tinnitus. Likewise, results for psychosocial working conditions showed no statistically significant association between work place decision latitude [OR 1.06 (95% CI 0.94; 1.13)] or psychological demands [OR 1.07 (95% CI 0.90; 1.26)] and tinnitus.
Conclusions Our results suggest that current Danish occupational noise levels (in combination with relevant noise protection) are not associated with tinnitus. Also, results indicated that the psychosocial working conditions we observed in this cohort of mainly industrial workers were not associated with tinnitus. Therefore, psychosocial working conditions comparable to those observed in this study are probably not relevant to take into account in the evaluation of workers presenting with tinnitus.

Keywords Tinnitus · Noise · Psychological demands · Decision latitude · Psychosocial work factors

Introduction

Tinnitus is the perception of sound in the absence of an external sound. It represents a frequent disorder with a prevalence of around 10–15% depending on study population and criteria applied (Henry et al. 2005). Though tinnitus is a frequent complaint, only around 0.5% of the population have debilitating symptoms such as severe annoyance, concentration difficulty and insomnia (Baguley et al. 2013).

The etiology of tinnitus is heterogeneous and includes both somatic and psychological factors. Among somatic factors, hearing loss is probably the most important risk factor for tinnitus (Henry et al. 2005; Axelsson and Prasher 2000). Factors contributing to hearing loss therefore also represent potential risk factors for tinnitus including age, acute and long-term (occupational) noise exposure, middle- and inner ear diseases, and ototoxic medications (Baguley

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et al. 2013). However, many people without hearing loss also experience tinnitus and often no obvious cause is found in the individual patient (Meikle and Griest 1989).

In spite of stricter occupational noise legislation, millions of workers worldwide are still exposed to occupational noise levels that increase the risk of hearing loss and tinnitus (Axelsson and Prasher 2000; Verbeek et al. 2012). Prevention programs in developed countries that include noise assessment, noise controls, audiometric monitoring of workers' hearing, worker education and appropriate use of hearing protection have, however, resulted in a decreasing incidence of hearing loss in this part of the World (Nelson et al. 2005).

Psychological factors such as mental stress, psychosocial strain, anxiety and depression have been suggested to either cause tinnitus or exacerbate tinnitus symptoms (Oishi et al. 2011; Holgers et al. 2005; Salviati et al. 2014; Evered and Lawrenson 1981). As high job strain is associated with increased mental stress (Nieuwenhuijsen et al. 2010; de Jonge et al. 2000), the risk of tinnitus may be affected by psychosocial working conditions.

A Taiwanese study from 2008 (Lin et al. 2009) found a statistically significant association between feeling stressed at work and tinnitus. Correspondingly, a Swedish study from 2011 revealed a relationship between work-related stressors and hearing problems (tinnitus and hearing complaints) (Hasson et al. 2011), but otherwise epidemiologic evidence of a possible association between job-related stress factors and tinnitus is scarce.

Retrospective evaluation of noise exposure and psychosocial factors often causes problems in epidemiological studies, especially if evaluation relies on self-reported data. People suffering from tinnitus may search their memory more thoroughly for explanatory factors than unaffected individuals, potentially leading to differential misclassification of exposure levels and inflated results. This problem is potentially circumvented by using work unit-aggregated levels of psychosocial exposures (Kolstad et al. 2011), objective noise measurements and construction of noise exposure matrices (Seixas and Checkoway 1995; Davies et al. 2009).

The two main objectives of this study were: (1) to evaluate the association between objective measures of occupational noise (based on noise dosimetries) and tinnitus and (2) to evaluate the association between work unit-aggregated measures of psychosocial work factors (psychological demands and decision latitude) and tinnitus.

Materials and methods

Participants

This cross-sectional study takes advantage of an initial survey of 819 workers conducted between 2001 and 2002 in Aarhus, Denmark, with the purpose of monitoring occupational noise exposure and auditory function among noise-exposed workers. Participants were recruited from randomly selected companies within 12 trades: children day care, financial services and the 10 manufacturing trades in Denmark with the highest reporting of noise-induced hearing loss according to the Danish Working Environment Authority. Financial workers were selected as a reference group. In 2009–2010, the same companies and workers were asked to participate again. This time the purpose was extended to also include psychosocial work factors and medical risk factors. A total of 271 workers (33.1%) agreed to participate again, and further 394 workers were recruited de novo, making a total of 665 participants in 2009–2010. At the company level, all participants were as far as possible selected at random. However, to avoid disruption of workflow, selection in some cases had to be done in accordance with the local manager. Only participants from the 2009–2010 study were included in the present study, as psychosocial work factors were not accounted for in the 2001–2002 survey. To restrict the analyses to potentially noise-exposed workers, 67 financial workers and 64 workers from the original 2001 cohort now either unemployed ($n = 44$) or no longer working in noise-exposed industries ($n = 20$) were excluded, leaving 534 participants eligible for this study. The local ethical scientific committee (Central Region Denmark) approved the study (M.20080239), and informed consent was obtained from all individual participants included.

Occupational noise exposure

Individual dosimeters (Bruel & Kjær, model 4443, Nærum, Denmark) measuring A-weighted equivalent sound levels (L_{Aeq}) in 5-s intervals were handed out to the participants. Microphones were fitted at the right side collar if right handed and vice versa if left handed. Measuring range was set to 70–120 dB(A). Individual A-weighted equivalent noise levels were computed for the full work shift ($L_{Aeq,\,work}$).

Based on 1268 noise exposure recordings from the 2001–2002 study and the 2009–2010 study, we predicted noise exposure levels for each combination of trade, occupation and calendar year (1980–2010) by mixed regression analyses including these as fixed effects and the participants as random effect resulting in a noise exposure matrix. Based on information on historical employment status (1980–2010) retrieved from the Danish Supplementary Pension Fund and the noise exposure matrix, we calculated cumulative occupational noise exposure levels for each participant as the product of estimated noise exposure level [L_{Aeq} in dB(A)] and duration of employment (T) using the formula: $10 \times \log [\Sigma(10^{dB(A)/10} \times T]$, resulting in "dB(A)-year" on a logarithmic scale.

Audiometric measures

Air conduction thresholds were determined for each ear at 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz by pure tone audiometry at the workplaces, using a Voyager 522 audiometer equipped with TDH-39 headphones (Madsen Electronics, Taastrup, Denmark). The audiometer was installed in a mobile examination unit equipped with a soundproof booth (model AB-4240, Eckel Noise Control Technologies, Bagshot, UK). Audiometry was performed by trained examiners using a standardized protocol.

To avoid temporary threshold shifts from possible noise sources, all participants were asked to wear hearing protection from the beginning of the day until the audiometry was done. Otoscopy was performed initially to verify that ears were free of wax and the tympanic membrane was visible. The audiometer was calibrated every 6 months according to ISO standards. We defined two hearing measures: 0.5–4.0 kHz hearing threshold (0.5–4.0 kHz HT) was computed as the average of pure tone hearing thresholds at 0.5, 1, 2, 3 and 4 kHz in the worse ear. 0.5–4.0 kHz hearing handicap was defined if 0.5–4.0 kHz HT >25 dBHL (according to WHO hearing impairment definition). Worse ear hearing ability was chosen over better ear, as we assumed that hearing levels at the worse ears were the most predictive of tinnitus status.

Questionnaire information

A questionnaire was handed out to the participants at the time of the audiometric examination to provide information on tinnitus and its related symptoms, psychosocial work factors, mental symptoms, use of hearing protection device, income and education (as described below).

Tinnitus

Tinnitus was defined in the questionnaire as "ringing or buzzing in one or both ears." Related questions included frequency of tinnitus [(1) almost never experiencing tinnitus, (2) experiencing periods of tinnitus at least monthly, (3) experiencing periods of tinnitus at least weekly or (4) experiencing tinnitus daily], frequency of annoyance when experiencing tinnitus [(1) almost never or never, (2) rarely, (3) sometimes, (4) often or (5) always] and frequency of insomnia due to tinnitus [(1) almost never or never, (2) rarely, (3) sometimes, (4) often or (5) always]. A person was classified as having tinnitus if experiencing tinnitus daily accompanied by either annoyance (sometimes, often or always) or insomnia (sometimes, often or always).

Measures of psychosocial working conditions

Psychosocial working conditions were measured according to Karasek and Theorell's demand-control model (Karasek 1990) with scales from the Copenhagen Psychosocial Questionnaire (Kristensen et al. 2005). Psychological demands, decision authority and skill discretion were each measured by four items on a scale from "always" (1) to "never" (5). For each scale, a mean value of the four items was calculated. Decision latitude was computed as the mean value of decision authority and skill discretion.

Furthermore, we calculated mean values of decision latitude and psychological demands for each work unit after exclusion of participants with tinnitus. Participants with tinnitus were excluded from the calculation of the mean scores as tinnitus distress could influence their assessment of the psychosocial work environment, thus introducing reporting bias. The mean values were then assigned to all employees at the particular work place. This method was recently used in a study of depression (Grynderup et al. 2012).

Measures of mental symptoms

Symptoms of depression, anxiety and somatoform disorder (illness worries) were assessed using the Common Mental Disorders Questionnaire (CMDQ) (Christensen et al. 2005). The CMDQ is a brief case finding instrument designed to screen for mental symptoms in general practice. All questions referred to the last 4 weeks and were measured on a 5-point response scale from "not at all" (0 points) to "extremely" (4 points). We used the six-question subscale for depression, the four-question subscale for anxiety and the seven-question subscale for somatoform disorder. Participants were classified as depressive if scoring $\geq$3 on $\geq$3 of the 6 depressive symptom questions. Anxiety was classified if the score was $\geq$3 on $\geq$3 of the 4 anxiety symptom questions, and somatoform disorder was classified if the score was $\geq$3 on $\geq$3 of the 7 somatoform disorder symptom questions. These selection criteria were chosen to obtain optimal validity (Christensen et al. 2005).

Use of hearing protection devices

Of the 534 workers, 333 reported to use HPD. Among HPD users, 140 participants completed a detailed log-book specifying when they used HPD during the day of noise measurements.

Income and education

Participants were asked about gross household income (<299,999 DDK, 300,000–499,999 DDK, >500,000 DDK) and educational level (none, short courses, skilled worker, short-range training, middle-range training, long-range training).

Statistics

We tabulated possible confounders and information on occupational background according to presence of tinnitus. Odds ratios of tinnitus according to noise exposures were analyzed by logistic regression and performed using both continuous-scale exposure information (if available) and exposure divided into relevant groups or tertiles. These analyses were adjusted for age and sex.

Associations between psychosocial working conditions and tinnitus were analyzed by logistic regression with robust clusters based on the work unit of the participants and adjusted for: (1) age and sex, and (2) age, sex, depression, anxiety, somatization disorder, income and education. These potential confounders were decided upon a priori. Analyses were performed using both continuous-scale exposure information and exposure divided into tertiles. We analyzed for interaction between psychological demands and decision latitude. The interaction term was calculated based on both continuous and trichotomized data.

To test whether associations were independent of auditory function, we performed additional analyses adjusting for mean hearing levels at worse hearing ear (mean of 0.5, 1, 2, 3 and 4 kHz HL). Another subanalysis was conducted to investigate whether the use of hearing protection devices (HPD) influenced the observed associations between current noise exposure and tinnitus. In this analysis, we subtracted 10 dB(A) from each 5-s noise recording obtained at work while using HPD. This analysis was restricted to the 342 workers with valid information on HPD use (140 workers returning the HPD log-book and 202 workers reporting not to use HPD at work).

All analyses were conducted using Stata 13 statistical software (StataCorp LP, College Station, TX, USA).

Results

A total of 41 (8%) participants were classified as suffering from tinnitus according to our criteria. Characteristics of participants according to tinnitus status are presented in Table 1. Of the 534 participants, 126 were women (23.6%). Age range was 20–64 years (mean 43.0 years). Among participants with tinnitus, we observed a tendency toward higher prevalence of males, workers above 45 years of age, workers with anxiety and somatization disorder and workers with hearing impairment compared with participants without tinnitus. Median speech frequency hearing thresholds (0.5–4 kHz) were on average 7.5 dB higher in the tinnitus group. The highest number of tinnitus cases was found among workers manufacturing fabricated metals.

For each 10 dB(A) increase in current occupational noise exposure level, we observed an age-and-gender-adjusted OR_{adj1} of 0.95 (95% CI 0.89; 1.01) for tinnitus, and the association seemed to decrease with higher noise levels (Table 2). Further adjustment for mental disorders, education and income did not change this result markedly. Results for cumulative occupational noise exposure showed no statistically significant association with tinnitus [OR_{adj1} 0.94 (95% CI 0.82; 1.07 for each dB(A)-year)]. Again, further adjustment for mental disorders, education and income did not change this result.

For psychosocial working conditions, we observed no statistically significant associations between either low decision latitude [OR_{adj1} 1.09 (95% CI 1.02; 1.16) for one unit increase on a 32-level scale] or psychological demands and tinnitus [OR_{adj1} of 1.04 (95% CI 0.91; 1.91) for one unit increase on a 16-level scale]. Results for decision latitude and psychological demands did not change noticeably when further adjusting for mental disorders, education and income.

We observed no interaction between psychological demands and decision latitude (all p values >0.05 for both continuous and trichotomized exposure variables).

Accounting for the use of HPD by subtracting 10 dB(A) from every 5-s noise recording obtained at work for the subgroup with valid HPD information did not change the OR for the association between current occupational noise and tinnitus [OR_{Adj2} after 10 dB(A) subtraction: 0.97 (95% CI 0.91; 1.05)].

Testing whether associations were independent of participant's hearing levels by further adjusting analyses for hearing levels at worse hearing ear, resulted in minimal changes in the association between current occupational noise exposure and tinnitus. Thus, the OR_{Adj2} changed from 0.95 (95% CI 0.89; 1.01) to 0.96 (95% CI 0.89; 1.05) for the association between continuous current noise exposure and tinnitus. Associations between cumulative noise exposure and psychosocial working conditions and tinnitus were practically unchanged.

Discussion

The objectively measured current and cumulative occupational noise levels observed in this study were not statistically significantly associated with tinnitus. Moreover, for psychosocial working conditions, we found no association with tinnitus.

In previous epidemiological studies on risk factors for tinnitus such as "The Blue Mountain Hearing Study" and "The Beaver Dam Offspring Study," rather strong associations between both cumulative and current occupational noise and tinnitus have been reported (Nondahl et al. 2011; Sindhusake et al. 2003). Both current and historical exposure assessment, however, relied on self-reported noise

Table 1 Characteristics of 534 noise-exposed workers aged 20–64 years, Åarhus, Denmark, 2009–2010

Characteristic	Tinnitus ($n = 41$)				No tinnitus ($n = 493$)			
	n	%	Median	p10; p90	*n*	%	Median	p10; p90
Sex, no (%)								
Female	6	(14.6)			120	(24.3)		
Male	35	(85.4)			373	(75.7)		
Age, no (%)								
<35 years	5	(12.2)			99	(20.1)		
35–44 years	9	(22.0)			174	(35.3)		
45–54 years	17	(41.5)			158	(32.1)		
≥55 years	10	(24.4)			62	(12.6)		
Education								
None	3	(7.3)			62	(12.6)		
Short courses	7	(17.1)			61	(12.4)		
Skilled worker	26	(63.4)			273	(55.4)		
Short-range training	1	(2.4)			22	(4.5)		
Middle-range training	3	(7.3)			72	(14.6)		
Long-range training	1	(2.4)			3	(0.6)		
Annual income								
0–299,999 DDK	18	(43.9)			232	(47.3)		
300,000–499,999 DDK	23	(56.1)			242	(49.4)		
>500,000 DDK	0	(0)			16	(3.3)		
Hearing thresholds at 0.5–4 kHz (dB HL),			20.0	6.3; 33.8			12.5	3.8; 28.8
Hearing impairment[a]								
No	24	(58.5)			424	(86.0)		
Yes	17	(41.5)			69	(14.0)		
Depression								
No	35	(85.4)			416	(84.4)		
Yes	6	(14.6)			77	(15.6)		
Anxiety								
No	35	(85.4)			445	(90.3)		
Yes	6	(14.6)			48	(9.7)		
Somatoform disorder								
No	33	(80.5)			416	(84.4)		
Yes	8	(19.5)			77	(15.6)		
Industry								
Manufacture of food	5	(12.2)			76	(15.4)		
Manufacture of wood products	4	(9.8)			41	(8.3)		
Publishing and printing	5	(12.2)			61	(12.4)		
Manufacture of non-metallic mineral products	2	(4.9)			35	(7.1)		
Manufacture of basic metals	3	(7.3)			37	(7.5)		
Manufacture of fabricated metals	7	(17.1)			58	(11.8)		
Manufacture of machinery	5	(12.2)			58	(11.8)		
Manufacture of motor vehicles	3	(7.3)			42	(8.5)		
Manufacture of furniture	1	(2.4)			5	(1.0)		
Construction	2	(4.9)			24	(4.9)		
Day care	4	(9.8)			56	(11.4)		

[a] WHO definition. See "Audiometric measures" section

Tabel 2 Odds ratios (OR) of having tinnitus according to occupational noise exposure and psychosocial working conditions

Exposure	Tinnitus ($n = 41$)	No tinnitus ($n = 493$)	OR_{Crude}	95% CI	OR^{a}_{Adj1}	95% CI	OR^{b}_{Adj2}	95% CI
Occupational noise exposure								
Current occupational noise ($L_{Aeq, work}$), dB(A)								
<80	17	142	1		1		1	
80–84	15	192	0.65	0.31; 1.35	0.67	0.44;1.33	0.67	0.32; 1.42
85–90	7	107	0.55	0.22; 1.36	0.52	0.53; 2.92	0.52	0.20; 1.33
>90	2	40	0.42	0.51; 2.71	0.46	0.10; 2.15	0.51	0.11; 2.41
Missing	0	12						
Continuous pr. 10 dB(A)			0.95	0.89; 1.01	0.95	0.89;1.01	0.95	0.89; 1.01
Cumulative occupational noise (dB(A)-years)								
Low (79.6–94.9)	11	167	1		1		1	
Medium (95.0–97.4)	12	166	1.10	0.47; 2.56	0.67	0.27;1.68	0.63	0.24; 1.61
High (97.5–101.1)	18	160	1.71	0.78; 3.73	0.63	0.23; 1.76	0.58	0.24; 1.67
Missing	0	0						
Continuous			1.08	0.96; 1.19	0.94	0.82; 1.07	0.93	0.81; 1.06
Psychosocial working conditions (exposure range[c])								
Psychological demands								
Low (0–3)	12	157	1		1		1	
Medium (4–6)	12	158	0.99	0.47; 2.07	1.08	0.50; 2.36	0.98	0.44; 2.20
High (7–16)	15	176	1.12	0.54; 2.07	1.18	0.57; 2.45	1.09	0.53; 2.22
Missing	2	2						
Continuous (0–16)			1.06	0.88; 1.28	1.09	0.90; 1.30	1.07	0.90; 1.26
Decision latitude								
High (20–32)	11	166	1		1		1	
Medium (15–19)	13	165	1.18	0.53; 2.64	1.13	0.51; 2.52	1.07	0.51; 2.21
Low (0–14)	15	160	1.41	0.65; 3.06	1.46	0.67; 3.16	1.37	0.67; 2.78
Missing	2	2						
Continuous (32-0)			1.05	0.97; 1.15	1.05	0.96; 1.15	1.06	0.94; 1.13

[a] Adjusted for age and gender

[b] Adjusted for age, gender, depression, anxiety, somatization disorder, education and income

[c] According to method described in "Measures of psychosocial working conditions" section

levels, and results could therefore potentially be biased. Moreover, these studies were conducted a decade or two before this study, and participants were generally older, meaning that both historical and current occupational noise exposure levels for participants in these studies were probably higher.

We analyzed objective measures of occupational noise exposure in relation to tinnitus and were not able to reproduce comparable risk estimates. As long-term exposure to high noise levels [>85 dB(A)] is generally accepted to cause hearing loss (International Organization for Standardization (ISO) 1990) which is a well-established risk factor for tinnitus, we found our negative results surprising. As described in "Occupational noise exposure" section, we calculated individual "dB(A)-years" as a sum-measure of the average daily occupational noise exposure through each year of employment back to 1980. Tabulating the number of years exposed to average daily occupational noise levels >85 dB(A) for each participant revealed that, with regard to the risk of inner ear damage, the retrospective noise exposure for our participants was generally low. Thus, 62.9% of the population had never been exposed to more than one year with average daily occupational noise exposure above 85 dB(A) and only 21.7% had been exposed for more than 5 years above this level. No participants had been exposed to a full year of average daily occupational noise exposure above 90 dB(A). If the causal pathway from noise to tinnitus is through hearing loss, the low historical noise exposure levels in this cohort may therefore partly explain our finding.

Potential selection bias from a healthy worker effect is another possible explanation for our results: As tinnitus is often accompanied by hearing loss and hypersensitivity to noise (Gilles et al. 2014; Nelson and Chen 2004b), this

Tabel 3 Reported use of hearing protection device according to current occupational noise exposure levels

	Using hearing protection device at work			
	No ($n = 202$)		Yes ($n = 332$)	
	n	%	*n*	%
Current occupational noise($L_{Aeq, work}$), dB(A)				
<85	166	45.4	200	54.6
85–90	27	23.7	87	76.3
>90	5	11.9	37	88.1
Missing	4	33.3	8	66.7

may exclude workers with low thresholds for developing tinnitus and hearing loss from noise-exposed employment. If this argument holds true, our noise-exposed population may represent a selection of workers with a high resistance to noise in terms of developing tinnitus and hearing loss. Indeed, this cross-sectional study may have been particularly vulnerable to this type of bias as it consisted not only of newly recruited participants but also of "survivors" from the original study group from 2001.

Non-differential misclassification of historical noise levels which is an inherent limitation of exposure matrices is another possible source of bias affecting our results for cumulative occupational noise exposure.

Concerning current noise exposure, only 114 (21%) and 42 (8%) of workers were exposed to current average occupational noise levels >85 and >90 dB(A), respectively (Table 2). Table 3 shows that in these two groups there were many HPD users (76 and 88%, respectively). Again, if noise-related tinnitus is the result of either temporary or permanent threshold shifts [neither of which should occur at noise levels <85 dB(A)], we would not expect to observe strong associations between the observed current noise levels in this study and tinnitus, especially if HPD use was as adequate, as indicated in Table 3.

Furthermore, we performed additional regression analyses to see whether current or cumulative noise levels were associated with participant's hearing levels. Indeed, no significant association was observed, which again supports that the cumulative and current noise exposure levels we observed were not large enough to cause tinnitus, through a pathway including hearing loss.

The causal pathway from noise exposure to tinnitus could also, potentially, be mediated through mental stress resulting from noise exposure as suggested in some studies (Ising and Kruppa 2004; van Dijk et al. 1987). In this case, noise should only cause annoyance and would not have to be at deleterious levels to also cause tinnitus. Our results, however, do not support this hypothesis either, at least at the given noise levels.

Based on noise recordings and questionnaire data from 752 workers from the original 2001–2002 cohort (see "Participants" section), Rubak et al. conducted a study published in 2008, analyzing the association between occupational noise exposure and tinnitus with and without concomitant hearing handicap (Rubak et al. 2008). In Rubak's study, current occupational noise levels were higher than we measured in 2009–2010, and cumulative occupational noise was calculated from partly self-reported levels. The authors found no association between occupational noise exposure and tinnitus without concomitant hearing handicap, but interestingly an increased risk of tinnitus was observed if hearing handicap was also present.

According to Karasek & Theorell's job strain model, mental strain is the result of the interaction of high psychological demands and low decision latitude (Karasek 1990). Traditionally, the combined effect of the two factors has therefore been analyzed as a quadrant term with median splits of psychological demands and decision latitude. In this study, we found no statistically significant interaction effects between psychological demands and decision latitude and therefore decided to report associations separately, as this method, in our opinion, would give us more detailed information on the effect of each component (Mikkelsen et al. 2011).

Due to distressing tinnitus symptoms possibly affecting the individual's perception and reporting of the work environment, the association between self-reported psychological working conditions and tinnitus may be affected by reporting bias. This is potentially circumvented using work unit-aggregated measures as we did in the present study. These measures are independent of a specific worker's appraisal of his or her working conditions and thus provide a more objective description of the working environment (Kolstad et al. 2011; Kasl 1998).

Making use of the above-mentioned method in the analysis of our data for psychological working conditions, we found no statistically significant associations with tinnitus of either psychological demands or decision latitude. Prior studies have studied the association between self-reported (not job-related) mental stress and tinnitus; the majority finding positive associations (Canlon et al. 2013) (Heinecke et al. 2008; Horner 2003). We were able to find two studies evaluating the effect of job-related stress factors on tinnitus (Lin et al. 2009; Hasson et al. 2011) (both reporting positive associations with self-reported occupational stress factors), but no studies analyzing the association between non-self-reported psychosocial working conditions and tinnitus as performed in the present study. This study therefore offers a new perspective on this issue and indicates that current psychosocial working conditions in Danish industrial trades are not associated with tinnitus.

In our main analyses, we did not adjust for hearing level as it was our assumption that it was in the causal pathway from noise to tinnitus. Hearing disabilities can, however, cause mental distress and may also cause participants to avoid noise exposure (Nelson and Chen 2004a). In that regard, hearing ability could be a potential confounder. We therefore performed a sensitivity check by further adjusting for hearing levels. This resulted in practically unchanged results.

We also subtracted 10 dB(A) from every 5-s noise recording obtained during work while using HPD for those providing a log-book (Park and Casali 1991). This was done to investigate the potential effect of noise attenuation from HPD's on our results for current noise exposure. This did not alter results substantially.

This study has a number of strengths. Firstly, we used objective and non-self-reported exposure measures with little missing information, leaving little room for reporting biased results. Also, we had detailed information on potential confounders enabling us to perform analyses adjusted for other potential risk factors.

Among limitations is the cross-sectional nature of this study, preventing us from drawing strong conclusions regarding causality. Also, our definition of tinnitus may have led to misclassification of tinnitus status. Using a standardized tinnitus questionnaire as the Tinnitus Handicap Inventory (Zeman et al. 2012) possibly could have refined our tinnitus classification, but due to pressure of space in the questionnaire, we refrained from this. Regarding noise exposure, higher exposure levels (current and cumulative) and contrast would have enabled us to also explore the association between noise and tinnitus status at higher levels than given in this study. As occupational noise levels in other countries worldwide are possibly higher than what we measured, this limits the external validity of our results.

Conclusion

Overall, our results suggest that occupational noise exposure at the levels given in this study is not associated with tinnitus. However, our results do not rule out a possible increased risk of tinnitus from occupational noise levels exceeding the levels measured in this population.

Likewise, we found no indication of an association between psychosocial working conditions (in terms of high psychological demands and low decision latitude) and tinnitus, suggesting that psychosocial working factors comparable to those observed in this study are probably not relevant in the evaluation of a worker presenting with tinnitus.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflicts of interest.

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