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A cross-sectional study of hearing thresholds among 4627 Norwegian train and track maintenance workers

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Abstract

Background

Railway workers performing maintenance work of trains and tracks could be at an increased risk of developing noise induced hearing loss, since they are exposed to noise levels of 75- 90 dB(A) with peak exposures of 130-140 dB(C).

Objective

To study hearing thresholds among train and track maintenance workers and to compare the results with reference groups not exposed to noise.

Methods

The most recent audiogram from a total of 1897 male train and 2730 track maintenance workers were obtained from the medical records of the occupational health service of the Norwegian State Railways (NSB), the largest Norwegian railway company. The results were compared with audiograms from a control group of 2872 male railway traffic controllers and office workers not exposed to noise and with reference values from the ISO 1999:2013. The frequencies from 0.5 to 8 kHz of the better ear and the prevalence of audiometric notches ($\geq$ 25 dB (A) at 4 kHz) were used for comparison.

Results

The train and track maintenance workers 45 years or older had a small mean hearing loss in the 3-6 kHz area of 3-5 dB and a higher prevalence of audiometric notches (25% vs. 17%) compared to the controls. The hearing loss was smaller among workers younger than 45 years.

Conclusion

Train and track maintenance workers 45 years or older on average have a slightly stronger hearing loss and more audiometric notches compared to reference groups not exposed to noise. Younger (<45 years) workers have hearing thresholds comparable to the reference groups.

Strengths and limitations of the study

Strengths:

- The size of the study with close to 100% participation rate
- The use of two groups for comparison
- High quality of the audiometric data and exposure assessment

Limitations:

- Cross sectional study with only the most recent audiogram from the participants

Introduction

Noise induced hearing loss (NIHL) accounts for more than 60 percents of occupational disorders reported to the Norwegian Labor Inspection Authority [1]. Age is, however, the main cause for hearing loss[2] . Heritability, gender, smoking, high blood pressure, diabetes, high cholesterol level, the use of ototoxic medication and exposure to ototoxic chemicals may affect the hearing and so may leisure time noise, first and foremost from the use of firearms[3-5].

Train and track maintenance workers are occupationally exposed to noise. Noise measurements in the railway companies that we have studied reveal average 8 hour noise exposure levels of 75-90 dB(A) in both groups with peak exposures reaching 130-140 dB(C).

In studies of train and track maintenance workers, noise induced hearing loss has been described by Virokannas[6], but the exposure levels were much higher than in our study. In the US National Health Interview Survey, railroad employees had the highest prevalence of hearing difficulties among the occupational groups examined, but the study did not present audiometric data, only self reported symptoms[7] .

Norwegian physicians are legally obliged to report occupational diseases, such as NIHL, to the Norwegian Labour Inspection Authority. More than 70 percents of the male 20-64 year old workers that we have studied, have an audiogram meeting the national criteria for NIHL, namely a sufficiently strong noise exposure and a hearing loss of 25 dB or more at either 3, 4 or 6 kHz or 20 dB or more for all of 3, 4 and 6 kHz, worse ear, not adjusted for age or sex[8] .

A recent study of hearing status among train drivers and train conductors in the Norwegian State Railways showed normal mean hearing threshold for their age[9]. Still many of them, just like the maintenance workers that we have studied, had audiograms compatible with the Norwegian criteria for NIHL.

The aim of this cross-sectional study was to assess the risk of noise induced hearing loss among train and track maintenance workers by comparing their audiograms with audiograms from a reference group of railway workers not exposed to noise and a Norwegian reference population (HUNT)[10] which recently has been included in the 2013 revision of the ISO 1999 reference data base[11] .

Methods

Exposure assessment

As a part of the risk assessment of the train and track maintenance workers, the occupational hygienists of the OH service has conducted an extensive programme of measurements of the noise exposure by dosimetry and peak noise measurements. The exposure shows a high variability, depending on the type of work being done. On an 8 hour average level the exposure varies from 75 dB(A) up to 90 dB(A), averaging 85-86 dBA, and with peak exposures up to 130 dB(C) - 140 dB(C). Since the workers should wear hearing protection when the exposure exceeds 85 dB(A), the actual exposure to the ear will become somewhat lower.

The study group

Most of the train and track maintenance workers have to perform an audiometric test as a part of a mandatory health assessment due to national and European Union regulations for railway safety personnel. In order to be certified, the test is to be done before employment and later, depending on age, with 1-5 year intervals. All the tests are conducted by the occupational health service (OHS) of the Norwegian state railways (NSB).

The most recent available audiogram of the participating subjects, recorded during the period 1994-2011, was obtained from the electronic medical records along with age, sex and type of job information. Since there were only a few female maintenance workers, only male workers were used in the analysis.

Audiograms from the train and track maintenance workers were compared with those of a control group of non-exposed male railway office workers, mainly doing traffic controlling, and with a similar social and educational background and salary as the maintenance workers. The study population was also compared with external reference data from the ISO 1999: 2013, annex B, table 2, based on a Norwegian reference population[11].

Audiotory examination

Madsen Xeta Otometrics pure tone audiometric testing using a TDH-39P earphone headset in a soundproof booth at frequencies of 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz was performed by trained nurses. The audiometric test was done in line with standard procedures according to the Norwegian Labour Inspection Authority[8] . The audiometer was calibrated every second year according to the requirements of the equipment provider.

Since grouped median and percentile values are used in the ISO 1990: 2013, the same values of the hearing threshold of frequencies from 0.5- 8 kHz from the better ear were computed and compared to the values from reference groups.

The prevalence of notches was calculated since audiometric notches are regarded as an indicator of NIHL[12]. A notch regarded as a hearing loss was $\geq$ 25 dB(A) at 4kHz and a difference in hearing loss between 4kHz and 2 and 8 kHz $\geq$ 10dB(A)[13] .

Finally, the prevalence of hearing loss meeting the Norwegian NIHL criteria, a hearing loss of 25 dB or more at either 3, 4 or 6 kHz or 20 dB or more for all of 3, 4 and 6 kHz, worse ear, was computed and compared to the reference group.

Ethical considerations

The audiograms have been obtained as a part of regular occupational health services work. Risk assessment of NIHL is a part of the OHS tasks. Therefore an application to the regional ethical committee is not necessary according to Norwegian regulations.

Statistics

Descriptive statistics were used in this study. Groups were compared using chi-square tests for categorical variables and ANOVA for continuous variables. The data analysis was performed using SPSS (IBM SPSS Statistics Version 20) with percentile values estimated by the FREQUENCIES /GROUPED command[14]. A significance level of 5% was chosen.

Results

Audiograms from 1897 train- and 2730 track maintenance workers, all males, were compared to audiograms from 2872 male railway office workers working as traffic controllers or in other types of jobs without any significant noise exposure.

An overview of age distribution in the train- and track maintenance workers and non-exposed office workers is shown in table 1.

Table 1: Background data and noise exposure in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Age, mean (SD)		47.6 (11.9)	46.2 (13.0)	45.7 (11.8)	<0.001[a]
Age, N=	-24	118	286	129	
	25-34	225	275	504	
	35-44	330	529	692	
	45-54	555	801	738	
	55-64	669	839	809	
	Total	1897	2730	2872	
Occupational noise exposure (dB(A))		75-90 + peak	75-90 + peak	< 70	

[a]) ANOVA

The average age and the distribution of age were similar in the 3 groups. The noise exposure of the train and track maintenance workers is in the order of 75-90 dB(A). In addition there may be peak exposures of 130-140 dB(C). Hearing protection in terms of ear muffs or ear plugs is to be used when the noise exposure exceeds 80 dB(A).

Figure 1 shows the grouped median values of the hearing thresholds of the maintenance workers, the internal control group and the ISO 1999. The largest difference between the noise exposed and the control groups, 2-7 dB for 3 kHz and 4 kHz, was found for the age groups 45 years or older compared with the control groups. The grouped 90 percentile (figure 2) of the hearing thresholds reveals similar findings with an elevated hearing threshold of 6-10 dB in the same age groups of the noise exposed workers compared to the control groups. In the younger age groups (25-44 years) there are only minor differences between those with noise exposure compared to the internal control group and ISO-standards.

The prevalences of audiometric notches in the maintenance workers compared with the internal control group are shown in table 2.

Table 2: Hearing loss (better ear) and prevalence of audiometric notches (worse ear) and NIHL (worse ear) in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Hearing loss mean 3,4 and 6 kHz, better ear (95% CI)					
	-24	2.3(0.8-3.7)	1.1(-0.1-2.3)[b]	0 (Ref)	
	25-34	0.8(-0.5-2.1)	0.0(-1.2-1.3)	0 (Ref)	
	35-44	1.8(0.3-3.3)	1.1(-0.2-2.4)	0 (Ref)	
	45-54	3.3(1.6-5.0)	3.1(1.5-4.6))	0 (Ref)	
	55-64	4.6(2.5-6.6)	4.9(2.9-6.8)	0 (Ref)	
	Total	4.6(3.5-5.6)	3.2(2.3-4.2)	0 (Ref)	
Audiometric notch, prevalence, worse ear (%)					
	-24	3	3	3	0.96[c]
	25-34	10	9	7	0.26
	35-44	21	19	13	0.002
	45-54	29	33	20	<0.001
	55-64	36	35	22	<0.001
	Total	25	25	16	<0.001
NIHL criteria hearing loss, prevalence, worse ear, (%)					
	-24	26	21	20	0.432[a]
	25-34	36	29	28	0.116
	35-44	63	56	50	<0.001
	45-54	87	85	74	<0.001
	55-64	95	95	92	0.005
	Total	76	70	63	<0.001

[a]) ANOVA [b]) ANOVA, Bonferroni post hoc [c]) Chi- square test

An increase in audiometric notches in all groups with increasing age is revealed with a significant higher prevalence in the exposed groups compared with the control group from the age of 35. In the younger age groups the hearing and prevalence of notches is comparable to that of the controls group.

The prevalence of the Norwegian criteria for NIHL is in line with the audiometric notches found in the present study (table 2). The prevalence of audiometric NIHL criteria is almost as high in the reference group (64%) as in the train- and track maintenance workers (70-76%). The results indicate that there is only a small, but significant noise induced hearing loss in the noise sensitive area (3-6 kHz) in the exposed workers from the age of 35.

Discussion

This cross-sectional study of 4627 male train- and track maintenance workers demonstrates hearing thresholds similar to that of the non-exposed groups, but the oldest workers have a small, but significant hearing loss with more notched audiograms than the control group. This indicates a small noise induced hearing loss (NIHL) in the noise exposed groups. The magnitude of the hearing loss of the noise sensitive area (3-6 kHz) is in the order of 5 dB or less, which is about as expected. According to ISO 1999[11] an unprotected noise exposure of 85 and 90 dB(A) at an 8 hour daily basis will lead to a median expected hearing loss of 4 dB and 9 dB, respectively, after 10 years of exposure.

The hearing of the younger workers is close to normal. This is probably due to better preventive measures, such as the use of noise protection and the use of hearing protection, during the last years and in line with studies of similar noise-exposed groups in the developed world[15-17] . The workers 45 years or older, however, had a small noise-induced hearing loss. This could be due to former high levels of workplace noise. This finding is also in line with previous studies showing that railroad workers are at risk of getting NIHL[6 7].

This present study has some strengths. The number of maintenance workers is large and so are the control groups. We also assess the audiometric measurements to be of good quality. Since audiometric testing is mandatory for most of the workers, we assume that the participation rate is close to100 %. The use of two comparison groups strengthens the study. The results from the two comparison groups are very similar. Furthermore, the internal control group of office workers was examined by the same OHS professionals and with the same audiometric equipment as were the train and track maintenance workers.

There are, however, also some limitations of this study.

This cross sectional assessment is based on only one audiogram from each of the participants, the most recent measurement. Longitudinal data would be favorable in such a study, because selective drop-out may have occurred. Since selection in and selection out of work due to hearing loss is quite uncommon, we believe that the limitation of using cross-sectional data in this study is of limited importance.

Information of factors other than noise that may modify hearing loss such as smoking, high blood pressure, metabolic syndrome, diabetes, exposure to ototoxic medication or chemicals, leisure time noise exposure etc were not available. Thus possible confounders were not assessed. The maintenance workers have probably been more exposed to chemicals than the reference groups. For the other factors we have no reason to believe that they would influence the results since we doubt that they have a different prevalence among the workers compared with the controls.

Most of the maintenance workers went through a health examination before they were employed, and a severe hearing loss would normally have been regarded as a disqualification preventing employment. One may therefore expect some selection at recruitment. The requirements regarding hearing acuity are not very strict, however, and identical for the maintenance workers and the control group of railway workers. Selection would be expected to result in superior hearing in the maintenance workers compared to the control groups in the youngest age groups, but this is not the case in our study. We therefore believe that selection factors are of minor importance.

We are lacking information of years of employment for the maintenance workers and even for the office workers. Most of the train- and track maintenance workers, however, are recruited at an early age and are quite stable with only a small turnover. The same is the case for the office personnel. We cannot rule out the possibility that these groups have had a previous job with occupational noise exposure, but we assess the possibility for this to influence the results to a significant degree to be unlikely.

Before we conducted this study, there was a general understanding that train and track maintenance workers are at risk for getting noise induced hearing loss. Based on individual assessments of workers

and their audiograms and using the diagnostic guidelines of the Norwegian Labor Inspection Authority, 70 to 76 percent were suspected to have NIHL. The prevalence according to these criteria was 63 percent in the internal control group with office workers. This indicates that the use of these criteria has strong limitations with respect to the validly diagnosing noise induced hearing loss.

To distinguish between noise induced and age related hearing loss based on audiograms only is problematic. Some indications of differences may be given by audiometric notches, but they are also present in workers without any noise exposure as shown in the present and other studies[18 19] .

In conclusion, this cross-sectional study has detected a small average hearing loss among the older part of the 4627 male train and track maintenance workers compared with non-exposed workers in the same company and reference values from ISO 1999: 2013.

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Figure legends

Figure 1: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 50 percentile.

Figure 2: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 90 percentile.

What this paper adds:

- Previous studies have suggested that railway maintenance workers are at risk for the development of noise induced hearing loss (NIHL).
- This study has detected only small hearing loss among older maintenance workers compared to reference values.
- Hearing loss meeting national criteria for NIHL and audiometric notches are highly prevalent among workers not exposed to noise and are therefore of limited use in the diagnosis of NIHL.

Acknowledgement

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Contributorship statement

Arve Lie and Marit Skogstad have written the first draft of manuscript. Bo Engdahl and Kristian Tambs have given valuable advice on the manuscript and statistics. Torstein Seip Johnsen has provided the data from the OHS and has also been involved in the forming of the manuscript.

All the authors have given substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting and revising of the article and final approval of the version to be published.

Competing Interests

There are no competing interests

Data Sharing Statement

No additional data are available

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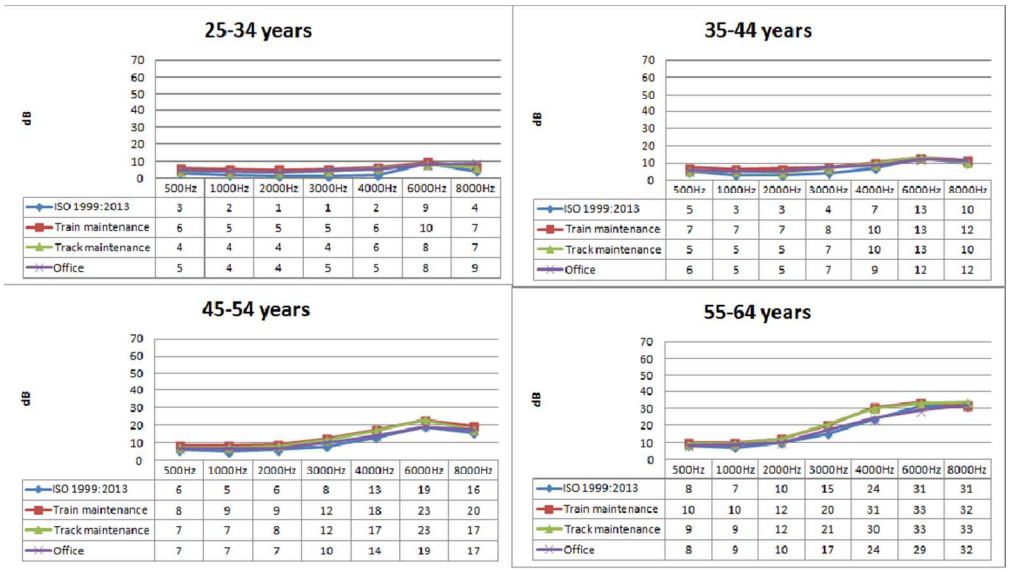
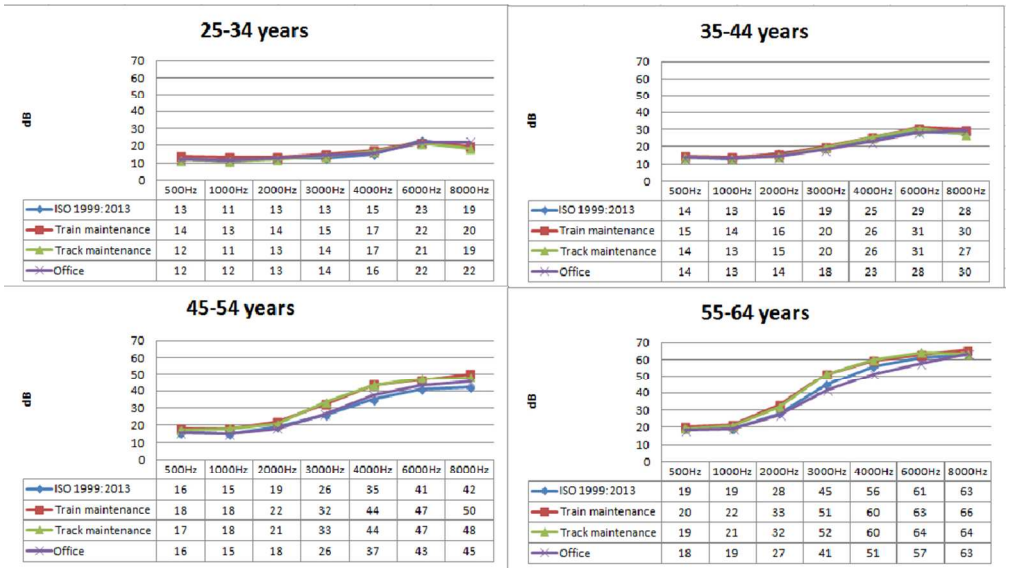


Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 50 percentile.
304x171mm (96 x 96 DPI)



Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 90 percentile.
304x171mm (96 x 96 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported
Objectives	3	State specific objectives, including any prespecified hypotheses
Methods		
Study design	4	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	9	Describe any efforts to address potential sources of bias
Study size	10	Explain how the study size was arrived at
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	21	Discuss the generalisability (external validity) of the study results
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Contributorship statement

Arve Lie and Marit Skogstad have written the first draft of manuscript. Bo Engdahl and Kristian Tambs have given valuable advice on the manuscript and statistics. Torstein Seip Johnsen has provided the data from the OHS and has also been involved in the forming of the manuscript.

All the authors have given substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting and revising of the article and final approval of the version to be published.

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A cross-sectional study of hearing thresholds among 4627 Norwegian train and track maintenance workers

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Abstract

Objective

Railway workers performing maintenance work of trains and tracks could be at risk of developing noise induced hearing loss, since they are exposed to noise levels of 75- 90 dB(A) with peak exposures of 130-140 dB(C). The objective was to make a risk assessment by comparing the hearing thresholds among train and track maintenance workers with a reference group not exposed to noise and reference values from the ISO 1999.

Design

Cross sectional

Setting

A major Norwegian railway company.

Participants

1897 male train and 2730 male track maintenance workers, all exposed to noise, and 2872 male railway traffic controllers and office workers not exposed to noise.

Outcome measures

The primary outcome was the hearing threshold (pure tone audiometry, frequencies from 0.5 to 8 kHz) and the secondary the prevalence of audiometric notches (Coles notch) of the most recent audiogram.

Results

The train and track maintenance workers 45 years or older had a small mean hearing loss in the 3-6 kHz area of 3-5 dB. The hearing loss was smaller among workers younger than 45 years. Audiometric notches were slightly more prevalent among the noise exposed (59-64%) compared to the controls (49%).

Conclusion

Train and track maintenance workers 45 years or older on average have a slightly greater hearing loss and more audiometric notches compared to reference groups not exposed to noise. Younger (<45 years) workers have hearing thresholds comparable to the controls.

Strengths and limitations of the study

Strengths:

- The size of the study with close to 100% participation rate
- The use of two groups for comparison
- High quality of the audiometric data and exposure assessment

Limitations:

- Cross sectional study with only the most recent audiogram from the participants

Introduction

Noise induced hearing loss (NIHL) accounts for more than 60 percents of occupational disorders reported to the Norwegian Labor Inspection Authority [1]. Age is, however, the main cause for hearing loss[2] . Heritability, gender, smoking, high blood pressure, diabetes, high cholesterol level, the use of ototoxic medication and exposure to ototoxic chemicals may also affect the hearing and so may leisure time noise, first and foremost from the use of firearms[3-5].

Train and track maintenance workers are occupationally exposed to noise. Noise measurements in the railway companies that we have studied reveal average 8 hour noise exposure levels of 75-90 dB(A) in both groups with peak exposures reaching 130-140 dB(C).

In studies of train and track maintenance workers, noise induced hearing loss has been described by Virokannas[6], but the exposure levels were much higher than in our study. In the US National Health Interview Survey, railroad employees had the highest prevalence of hearing difficulties among the occupational groups examined, but the study did not present audiometric data, only self reported symptoms[7].

Norwegian physicians are legally obliged to report occupational diseases, such as NIHL, to the Norwegian Labour Inspection Authority. More than 70 percents of the male 20-64 year old workers that we have studied, have an audiogram meeting the national criteria for NIHL, namely a sufficiently strong noise exposure and a hearing loss of 25 dB or more at either 3, 4 or 6 kHz, worse ear, or 20 dB for all of 3, 4 and 6 kHz, worse ear, not adjusted for age or sex[8] .

A recent study of hearing status among train drivers and train conductors in the Norwegian State Railways showed normal mean hearing threshold for their age[9]. Still many of them, just like the maintenance workers that we have studied, had audiograms compatible with the Norwegian criteria for NIHL.

The aim of this cross-sectional study was to assess the risk of noise induced hearing loss among train and track maintenance workers by comparing their audiograms with audiograms from a reference group of railway workers not exposed to noise and a Norwegian reference population (HUNT)[10] which recently has been included in the 2013 revision of the ISO 1999 reference data base[11] .

Methods

Exposure assessment

As a part of the risk assessment of the train and track maintenance workers, the occupational hygienists of the occupational health service (OHS) have conducted an extensive programme of measurements of the noise exposure by dosimetry and peak noise measurements. The exposure shows high variability, depending on the type of work being done. On an 8 hour average level the exposure varies from 75 dB(A) up to 90 dB(A), averaging 85-86 dB(A), and with peak exposures up to 130 dB(C) - 140 dB(C). Since the workers should wear hearing protection when the exposure exceeds 85 dB(A), the actual exposure to the ear will become somewhat lower.

The study group

Most of the train and track maintenance workers have to perform an audiometric test as a part of a mandatory health assessment due to national and European Union regulations for railway safety personnel in order to be certified. The test is to be done before employment and later, depending on age, with 1-5 year intervals. All the tests are conducted by the occupational health service (OHS) of the Norwegian state railways (NSB).

The most recent available audiograms of the participating subjects, recorded during the period 1994-2011, were obtained from the electronic medical records along with age, sex and type of job information. Since there were only a few female maintenance workers, only male workers were used in the analysis.

Audiograms from the train and track maintenance workers were compared with those of a control group of non-exposed male railway office workers, mainly doing traffic controlling, and with a similar social and educational background and salary as the maintenance workers. The study population was also compared with external reference data from the ISO 1999: 2013, annex B, table 2, based on a Norwegian reference population[11].

Hearing examination

Madsen Xeta Otometrics pure tone audiometric testing using a TDH-39P earphone headset in a soundproof booth at frequencies of 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz was performed by trained nurses. The audiometric test was done in line with standard procedures according to the Norwegian Labour Inspection Authority[8] . The audiometer was calibrated every second year according to the requirements of the equipment provider.

Since grouped median and percentile values from the better ear are used in the ISO 1990: 2013, the same values of the hearing threshold of frequencies from 0.5- 8 kHz were computed and compared to the values from reference groups.

The prevalence of notches was calculated since audiometric notches are regarded as an indicator of NIHL[12]. The Coles notch was used. It is defined as hearing thresholds at 3, 4 or 6 kHz of 10 dB or more compared to that at 1 or 2 kHz and 8 kHz [13]. The criteria established by Coles et al. have been proven to correlate well with clinical assessments [14]

Finally, the prevalence of hearing loss meeting the Norwegian NIHL criteria, a hearing loss of 25 dB or more at either 3, 4 or 6 kHz or 20 dB for all of 3, 4 and 6 kHz, worse ear, was computed and compared to the reference group.

Ethical considerations

The audiograms have been obtained as a part of regular occupational health services work. Risk assessment of NIHL is a part of the OHS tasks. Therefore an application to the regional ethical committee is not necessary according to Norwegian regulations.

Statistics

Descriptive statistics were used in this study. Groups were compared using chi-square tests for categorical variables and ANOVA for continuous variables. The data analysis was performed using

SPSS (IBM SPSS Statistics Version 20) with percentile values estimated by the FREQUENCIES /GROUPED command[15]. A significance level of 5% was chosen.

Competing interests

None declared. The study did not receive any funding.

Results

Audiograms from 1897 train- and 2730 track maintenance workers, all males, were compared to audiograms from 2872 male railway office workers working as traffic controllers or in other types of jobs without any significant noise exposure.

An overview of age distribution in the train- and track maintenance workers and non-exposed office workers is shown in table 1.

Table 1: Background data and noise exposure in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Age, mean (SD)		47.6 (11.9)	46.2 (13.0)	45.7 (11.8)	<0.001[a]
Age, N=	-24	118	286	129	
	25-34	225	275	504	
	35-44	330	529	692	
	45-54	555	801	738	
	55-64	669	839	809	
	Total	1897	2730	2872	
Occupational noise exposure (dB(A))		75-90 + peak	75-90 + peak	< 70	

[a]) ANOVA

The average age and the distribution of age were similar in the 3 groups. The noise exposure of the train and track maintenance workers is in the order of 75-90 dB(A). In addition there may be peak exposures of 130-140 dB(C). Hearing protection in terms of ear muffs or ear plugs is to be used when the noise exposure exceeds 80 dB(A).

Figure 1 shows the grouped median values of the hearing thresholds of the maintenance workers, the internal control group and the ISO 1999. The largest difference between the noise exposed and the control groups, 2-7 dB for 3 kHz and 4 kHz, was found for the age groups 45 years or older compared with the control groups. The grouped 90 percentile (figure 2) of the hearing thresholds reveals similar findings with an elevated hearing threshold of 6-10 dB in the same age groups of the noise exposed workers compared to the control groups. In the younger age groups (25-44 years) there are only minor differences between those with noise exposure compared to the internal control group and ISO-standards.

The hearing loss, the prevalences of audiometric notches and NIHL criteria in the maintenance workers compared with the internal control group are shown in table 2.

Table 2: Hearing loss (better ear) and prevalence of audiometric notches (worse ear) and NIHL (worse ear) in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Hearing loss compared to the internal reference, mean 3,4 and 6 kHz, better ear (95% CI)					
	-24	2.3(0.8-3.7)	1.1(-0.1-2.3)[b]	0 (Ref)	
	25-34	0.8(-0.5-2.1)	0.0(-1.2-1.3)	0 (Ref)	
	35-44	1.8(0.3-3.3)	1.1(-0.2-2.4)	0 (Ref)	
	45-54	3.3(1.6-5.0)	3.1(1.5-4.6))	0 (Ref)	
	55-64	4.6(2.5-6.6)	4.9(2.9-6.8)	0 (Ref)	
Coles audiometric notch, prevalence, worse ear (%)					
	-24	50	56	39	<0.001[c]
	25-34	50	53	39	<0.001
	35-44	59	62	50	<0.001
	45-54	65	71	55	<0.001
	55-64	60	66	52	<0.001
	Total	59	64	49	<0.001
NIHL criteria hearing loss, prevalence, worse ear, (%)					
	-24	26	21	20	0.432[a]
	25-34	36	29	28	0.116
	35-44	63	56	50	<0.001
	45-54	87	85	74	<0.001
	55-64	95	95	92	0.005
	Total	76	70	63	<0.001

[a]) ANOVA [b]) ANOVA, Bonferroni post hoc [c]) Chi- square test

From the age of 45 there is a significant hearing loss among the maintenance workers of 3-5 dB compared to the controls. In the younger age groups the hearing is comparable to that of the controls group.

An increase in audiometric notches in all groups with increasing age up to the age of 54 and then declining, is revealed with a significant higher prevalences in the exposed groups compared with the control group for all age groups.

The prevalence of the Norwegian criteria for NIHL is in line with the audiometric notches found in the present study (table 2). The prevalence of audiometric NIHL criteria is almost as high in the reference group (63%) as in the train- and track maintenance workers (70-76%).

The results indicate that there is only a small, but significant noise induced hearing loss in the noise sensitive area (3-6 kHz) in the exposed workers from the age of 35.

Discussion

This cross-sectional study of 4627 male train- and track maintenance workers demonstrates hearing thresholds similar to that of the non-exposed groups, but the oldest workers have a small, but significantly greater hearing loss with more notched audiograms than the control group. This indicates a small noise induced hearing loss (NIHL) in the noise exposed groups. The magnitude of the hearing loss of the noise sensitive area (3-6 kHz) is in the order of 5 dB or less, which is about as expected. According to ISO 1999[11] an unprotected noise exposure of 85 and 90 dB(A) at an 8 hour daily basis will lead to a median expected hearing loss of 4 dB and 9 dB, respectively, after 10 years of exposure.

The hearing of the younger workers is close to normal. This is probably due to shorter time of noise exposure, better preventive measures, such as the use of noise protection and the use of hearing protection, during the last years and in line with studies of similar noise-exposed groups in the developed world[16-18]. The workers 45 years or older, however, had a small noise-induced hearing loss. This could be due to a longer time of noise exposure and former high levels of workplace noise. This finding is also in line with previous studies showing that railroad workers are at risk of getting NIHL[6 7].

The strengths of the present study include a large number of maintenance workers and large control groups. We also assess the audiometric measurements to be of good quality. Since audiometric testing is mandatory for most of the workers, we assume that the participation rate is close to100 %. The use of two comparison groups strengthens the study. The results from the two comparison groups are very similar. Furthermore, the internal control group of office workers was examined by the same OHS professionals and with the same audiometric equipment as were the train and track maintenance workers.

There are, however, also some limitations of this study.

This cross sectional assessment is based on only one audiogram from each of the participants, the most recent measurement. Longitudinal data would be favorable in such a study, because selective drop-out may have occurred. Since selection in and selection out of work due to hearing loss is quite uncommon, we believe that the limitation of using cross-sectional data in this study is of minor importance.

Information of factors other than noise that may modify hearing loss such as smoking, high blood pressure, metabolic syndrome, diabetes, exposure to ototoxic medication or chemicals, leisure time noise exposure etc were not available. Thus possible confounders were not assessed. The maintenance workers have probably been more exposed to chemicals than the reference groups. For the other factors we have no reason to believe that they would influence the results since we doubt that they have a different prevalence among the workers compared with the controls.

Most of the maintenance workers went through a health examination before they were employed, and a severe hearing loss would normally have been regarded as a disqualification preventing employment. One may therefore expect some selection at recruitment. The requirements regarding hearing acuity are not very strict, however, and identical for the maintenance workers and the control group of railway workers. We therefore believe that selection factors are of minor importance.

We are lacking information of years of employment for the maintenance workers and even for the office workers. Most of the train- and track maintenance workers, however, are recruited at an early age and are quite stable with only a small turnover. The same is the case for the office personnel. We cannot rule out the possibility that these groups have had a previous job with occupational noise exposure, but we assess the possibility for this to influence the results to be unlikely.

Before we conducted this study, there was a general perception that train and track maintenance workers are at risk for getting noise induced hearing loss. Based on individual assessments of workers and their audiograms and using the diagnostic guidelines of the Norwegian Labor Inspection Authority, 70 to 76 percent were suspected to have NIHL. The prevalence according to these criteria was 63 percent in the internal control group with office workers. This indicates that the use of these criteria has strong limitations with respect to the validity of predicting noise induced hearing loss.

To distinguish between noise induced and age related hearing loss based solely on audiograms is problematic. Some indications of differences may be given by audiometric notches, but they are also present in workers without any noise exposure as shown in the present and other studies[19 20] .

The results might be valid for male railway maintenance workers in other countries with similar type of work, noise exposure and legislation.

In conclusion, this cross-sectional study has detected a small average hearing loss among the older part of the 4627 male train and track maintenance workers compared with non-exposed workers in the same company and reference values from ISO 1999: 2013.

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Figure legends

Figure 1: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 50 percentile.

Figure 2: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 90 percentile.

What this paper adds:

- Previous studies have suggested that railway maintenance workers are at risk for the development of noise induced hearing loss (NIHL).
- This study has detected only small hearing loss among older maintenance workers compared to reference values.
- Hearing loss meeting national criteria for NIHL and audiometric notches are highly prevalent among workers not exposed to noise and are therefore of limited use in the diagnosis of NIHL.

Acknowledgement

Per Frode Hove, Ingvill M. Hornkjøl and the rest of the staff at the Norwegian State Railways (NSB) Occupational Health Service are greatly acknowledged for providing exposure data, data from the medical records, and for valuable criticism and advice

Contributorship statement

Arve Lie and Marit Skogstad have written the first draft of manuscript. Bo Engdahl and Kristian Tambs have given valuable advice on the manuscript and statistics. Torstein Seip Johnsen has provided the data from the OHS and has also been involved in the forming of the manuscript.

All the authors have given substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting and revising of the article and final approval of the version to be published.

Competing Interests

There are no competing interests

Data Sharing Statement

No additional data are available

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Abstract

Background

Railway workers performing maintenance work of trains and tracks could be at an increased risk of developing noise induced hearing loss, since they are exposed to noise levels of 75- 90 dB(A) with peak exposures of 130-140 dB(C).

Objective

To study hearing thresholds among train and track maintenance workers and to compare the results with reference groups not exposed to noise.

Methods

The most recent audiogram from a total of 1897 male train and 2730 track maintenance workers were obtained from the medical records of the occupational health service of the Norwegian State Railways (NSB), the largest Norwegian railway company. The results were compared with audiograms from a control group of 2872 male railway traffic controllers and office workers not exposed to noise and with reference values from the ISO 1999:2013. The frequencies from 0.5 to 8 kHz of the better ear and the prevalence of audiometric notches ~~(> 25 dB (A) at 4 kHz)~~(Coles notch) were used for comparison.

Results

The train and track maintenance workers 45 years or older had a small mean hearing loss in the 3-6 kHz area of 3-5 dB. The hearing loss was smaller among workers younger than 45 years. ~~and a higher~~The prevalence of audiometric notches ~~(25% vs. 17%)~~was slightly more prevalent among the noise exposed (59-64%) compared to the controls (49%). ~~The hearing loss was smaller among workers younger than 45 years.~~

Conclusion

Train and track maintenance workers 45 years or older on average have a slightly ~~stronger~~ greater hearing loss and more audiometric notches compared to reference groups not exposed to noise. Younger (<45 years) workers have hearing thresholds comparable to the reference groups.

Strengths and limitations of the study

Strengths:

- The size of the study with close to 100% participation rate
- The use of two groups for comparison
- High quality of the audiometric data and exposure assessment

Limitations:

- Cross sectional study with only the most recent audiogram from the participants

Introduction

Noise induced hearing loss (NIHL) accounts for more than 60 percents of occupational disorders reported to the Norwegian Labor Inspection Authority [1]. Age is, however, the main cause for hearing loss [2] . Heritability, gender, smoking, high blood pressure, diabetes, high cholesterol level, the use of ototoxic medication and exposure to ototoxic chemicals may also affect the hearing and so may leisure time noise, first and foremost from the use of firearms [3-5].

Train and track maintenance workers are occupationally exposed to noise. Noise measurements in the railway companies that we have studied reveal average 8 hour noise exposure levels of 75-90 dB(A) in both groups with peak exposures reaching 130-140 dB(C).

In studies of train and track maintenance workers, noise induced hearing loss has been described by Virokannas [6], but the exposure levels were much higher than in our study. In the US National Health Interview Survey, railroad employees had the highest prevalence of hearing difficulties among the occupational groups examined, but the study did not present audiometric data, only self reported symptoms [7] ~~-~~.

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The aim of this cross-sectional study was to assess the risk of noise induced hearing loss among train and track maintenance workers by comparing their audiograms with audiograms from a reference group of railway workers not exposed to noise and a Norwegian reference population (HUNT) [10] which recently has been included in the 2013 revision of the ISO 1999 reference data base [11] .

Methods

Exposure assessment

As a part of the risk assessment of the train and track maintenance workers, the occupational hygienists of the ~~OH~~ occupational health service (OHS) ha~~s~~ve conducted an extensive programme of measurements of the noise exposure by dosimetry and peak noise measurements. The exposure shows ~~a~~ high variability, depending on the type of work being done. On an 8 hour average level the exposure varies from 75 dB(A) up to 90 dB(A), averaging 85-86 dBA, and with peak exposures up to 130 dB(C) - 140 dB(C). Since the workers should wear hearing protection when the exposure exceeds 85 dB(A), the actual exposure to the ear will become somewhat lower.

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Finally, the prevalence of hearing loss meeting the Norwegian NIHL criteria, a hearing loss of 25 dB or more at either 3, 4 or 6 kHz or 20 dB ~~or more~~ for all of 3, 4 and 6 kHz, worse ear, was computed and compared to the reference group.

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	35-44	330	529	692	
	45-54	555	801	738	
	55-64	669	839	809	
	Total	1897	2730	2872	
Occupational noise exposure (dB(A))		75-90 + peak	75-90 + peak	< 70	

[a]) ANOVA

The average age and the distribution of age were similar in the 3 groups. The noise exposure of the train and track maintenance workers is in the order of 75-90 dB(A). In addition there may be peak exposures of 130-140 dB(C). Hearing protection in terms of ear muffs or ear plugs is to be used when the noise exposure exceeds 80 dB(A).

Figure 1 shows the grouped median values of the hearing thresholds of the maintenance workers, the internal control group and the ISO 1999. The largest difference between the noise exposed and the control groups, 2-7 dB for 3 kHz and 4 kHz, was found for the age groups 45 years or older compared with the control groups. The grouped 90 percentile (figure 2) of the hearing thresholds reveals similar findings with an elevated hearing threshold of 6-10 dB in the same age groups of the noise exposed workers compared to the control groups. In the younger age groups (25-44 years) there are only minor differences between those with noise exposure compared to the internal control group and ISO-standards.

The hearing loss, the prevalences of audiometric notches and NIHL criteria in the maintenance workers compared with the internal control group are shown in table 2.

Table 2: Hearing loss (better ear) and prevalence of audiometric notches (worse ear) and NIHL (worse ear) in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Hearing loss compared to the internal reference, mean 3,4 and 6 kHz, better ear (95% CI)					
	-24	2.3(0.8-3.7)	1.1(-0.1-2.3)[b]	0 (Ref)	
	25-34	0.8(-0.5-2.1)	0.0(-1.2-1.3)	0 (Ref)	
	35-44	1.8(0.3-3.3)	1.1(-0.2-2.4)	0 (Ref)	
	45-54	3.3(1.6-5.0)	3.1(1.5-4.6))	0 (Ref)	
	55-64	4.6(2.5-6.6)	4.9(2.9-6.8)	0 (Ref)	
	~~Total~~	~~4.6(3.5-5.6)~~	~~3.2(2.3-4.2)~~	~~0 (Ref)~~	
Coles ~~A~~audiometric notch, prevalence, worse ear (%)					
	-24	~~3~~50	~~3~~56	~~3~~39	<0.001~~0.96~~[e]
	25-34	~~10~~50	~~9~~53	~~7~~39	<0.001~~0.26~~
	35-44	~~21~~59	~~19~~62	~~13~~50	<0.001~~0.002~~
	45-54	~~29~~65	~~33~~71	~~20~~55	<0.001
	55-64	~~36~~60	~~35~~66	~~22~~52	<0.001
	Total	~~25~~59	~~25~~64	~~16~~49	<0.001
NIHL criteria hearing loss, prevalence, worse ear, (%)					
	-24	26	21	20	0.432[a]
	25-34	36	29	28	0.116
	35-44	63	56	50	<0.001
	45-54	87	85	74	<0.001
	55-64	95	95	92	0.005
	Total	76	70	63	<0.001

[a]) ANOVA [b]) ANOVA, Bonferroni post hoc [c]) Chi- square test

From the age of 45 there is a significant hearing loss among the maintenance workers of 3-5 dB compared to the controls. In the younger age groups the hearing is comparable to that of the controls group.

An increase in audiometric notches in all groups with ~~-~~increasing age up to the age of 54and then declining is revealed with a significant higher prevalence in the exposed groups compared with the control group ~~from the age of 35~~for all age groups. ~~In the younger age groups the hearing and prevalence of notches is comparable to that of the controls group.~~

The prevalence of the Norwegian criteria for NIHL is in line with the audiometric notches found in the present study (table 2). The prevalence of audiometric NIHL criteria is almost as high in the reference group (6~~4~~3%) as in the train- and track maintenance workers (70-76%).

The results indicate that there is only a small, but significant noise induced hearing loss in the noise sensitive area (3-6 kHz) in the exposed workers from the age of 35.

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Discussion

This cross-sectional study of 4627 male train- and track maintenance workers demonstrates hearing thresholds similar to that of the non-exposed groups, but the oldest workers have a small, but significantly greater hearing loss with more notched audiograms than the control group. This indicates a small noise induced hearing loss (NIHL) in the noise exposed groups. The magnitude of the hearing loss of the noise sensitive area (3-6 kHz) is in the order of 5 dB or less, which is about as expected. According to ISO 1999[11] an unprotected noise exposure of 85 and 90 dB(A) at an 8 hour daily basis will lead to a median expected hearing loss of 4 dB and 9 dB, respectively, after 10 years of exposure.

The hearing of the younger workers is close to normal. This is probably due to shorter time of noise exposure, better preventive measures, such as the use of noise protection and the use of hearing protection, during the last years and in line with studies of similar noise-exposed groups in the developed world[16-18] . The workers 45 years or older, however, had a small noise-induced hearing loss. This could be due to a longer time of noise exposure and former high levels of workplace noise. This finding is also in line with previous studies showing that railroad workers are at risk of getting NIHL[6 7].

~~This present study has some strengths~~The strengths of the present study include~~.~~ ~~The~~ a large number of maintenance workers ~~is large~~ and ~~so are the~~large control groups. We also assess the audiometric measurements to be of good quality. Since audiometric testing is mandatory for most of the workers, we assume that the participation rate is close to100 %. The use of two comparison groups strengthens the study. The results from the two comparison groups are very similar. Furthermore, the internal control group of office workers was examined by the same OHS professionals and with the same audiometric equipment as were the train and track maintenance workers.

There are, however, also some limitations of this study.

This cross sectional assessment is based on only one audiogram from each of the participants, the most recent measurement. Longitudinal data would be favorable in such a study, because selective drop-out may have occurred. Since selection in and selection out of work due to hearing loss is quite uncommon, we believe that the limitation of using cross-sectional data in this study is of ~~limited~~ minor importance.

Information of factors other than noise that may modify hearing loss such as smoking, high blood pressure, metabolic syndrome, diabetes, exposure to ototoxic medication or chemicals, leisure time noise exposure etc were not available. Thus possible confounders were not assessed. The maintenance workers have probably been more exposed to chemicals than the reference groups. For the other factors we have no reason to believe that they would influence the results since we doubt that they have a different prevalence among the workers compared with the controls.

Most of the maintenance workers went through a health examination before they were employed, and a severe hearing loss would normally have been regarded as a disqualification preventing employment. One may therefore expect some selection at recruitment. The requirements regarding hearing acuity are not very strict, however, and identical for the maintenance workers and the control group of railway workers. ~~Selection would be expected to result in superior hearing in the~~

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~~maintenance workers compared to the control groups in the youngest age groups, but this is not the case in our study.~~ We therefore believe that selection factors are of minor importance.

We are lacking information of years of employment ~~-~~for the maintenance workers and even for the office workers. Most of the train- and track maintenance workers, however, are recruited at an early age and are quite stable with only a small turnover. The same is the case for the office personnel. We cannot rule out the possibility that these groups have had a previous job with occupational noise exposure, but we assess the possibility for this to influence the results ~~to a significant degree~~ to be unlikely.

Before we conducted this study, there was a general understanding that train and track maintenance workers are at risk for getting noise induced hearing loss. Based on individual assessments of workers and their audiograms and using the diagnostic guidelines of the Norwegian Labor Inspection Authority, 70 to 76 percent were suspected to have NIHL. The prevalence according to these criteria was 63 percent in the internal control group with office workers. This indicates that the use of these criteria has strong limitations with respect to the ~~validly~~ validity ~~diagnosing~~ of predicting noise induced hearing loss.

To distinguish between noise induced and age related hearing loss based solely on audiograms ~~only~~ is problematic. Some indications of differences may be given by audiometric notches, but they are also present in workers without any noise exposure as shown in the present and other studies[19 20].

The results might be valid for railway maintenance workers in other countries with similar type of work, noise exposure and legislation.

In conclusion, this cross-sectional study has detected a small average hearing loss among the older part of the 4627 male train and track maintenance workers compared with non-exposed workers in the same company and reference values from ISO 1999: 2013.

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Figure legends

Figure 1: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 50 percentile.

Figure 2: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 90 percentile.

What this paper adds:

- Previous studies have suggested that railway maintenance workers are at risk for the development of noise induced hearing loss (NIHL).
- This study has detected only small hearing loss among older maintenance workers compared to reference values.
- Hearing loss meeting national criteria for NIHL and audiometric notches are highly prevalent among workers not exposed to noise and are therefore of limited use in the diagnosis of NIHL.

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Contributorship statement

Arve Lie and Marit Skogstad have written the first draft of manuscript. Bo Engdahl and Kristian Tambs have given valuable advice on the manuscript and statistics. Torstein Seip Johnsen has provided the data from the OHS and has also been involved in the forming of the manuscript.

All the authors have given substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting and revising of the article and final approval of the version to be published.

Competing Interests

There are no competing interests

Data Sharing Statement

No additional data are available

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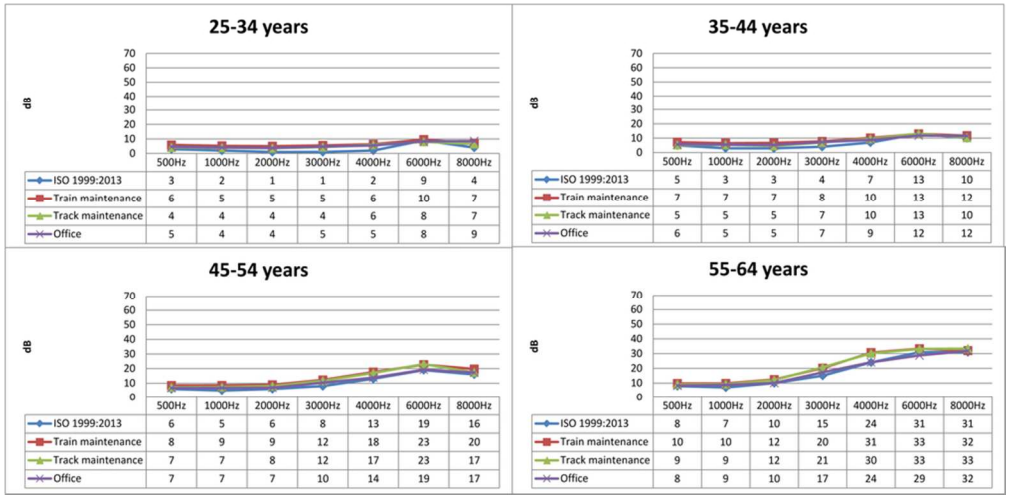

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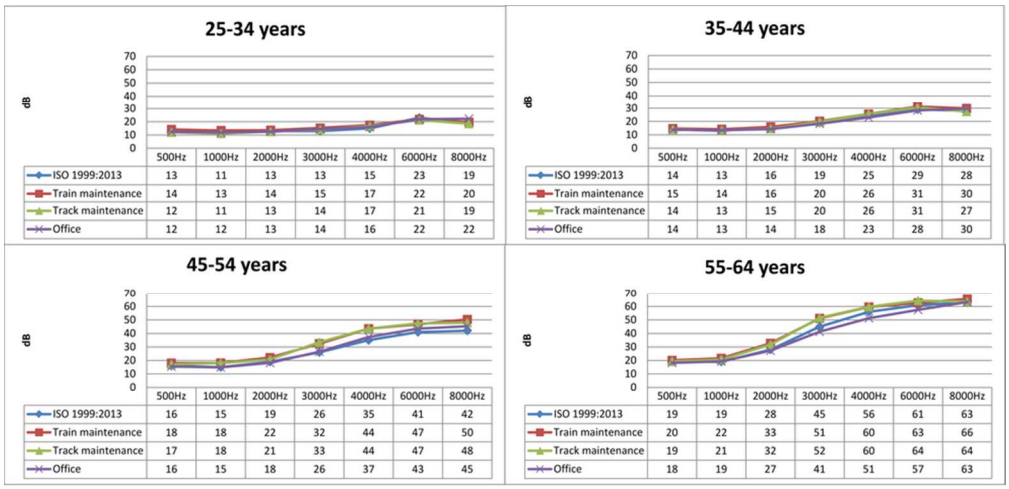

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4,5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5,6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	-
Outcome data	15*	Report numbers of outcome events or summary measures	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7
		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	7,8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8,9
Generalisability	21	Discuss the generalisability (external validity) of the study results	9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	6

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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A cross-sectional study of hearing thresholds among 4627 Norwegian train and track maintenance workers

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A cross-sectional study of hearing thresholds among 4627 Norwegian train and track maintenance workers

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Abstract

Objective

Railway workers performing maintenance work of trains and tracks could be at risk of developing noise induced hearing loss, since they are exposed to noise levels of 75- 90 dB(A) with peak exposures of 130-140 dB(C). The objective was to make a risk assessment by comparing the hearing thresholds among train and track maintenance workers with a reference group not exposed to noise and reference values from the ISO 1999.

Design

Cross sectional

Setting

A major Norwegian railway company.

Participants

1897 male train and 2730 male track maintenance workers, all exposed to noise, and 2872 male railway traffic controllers and office workers not exposed to noise.

Outcome measures

The primary outcome was the hearing threshold (pure tone audiometry, frequencies from 0.5 to 8 kHz) and the secondary the prevalence of audiometric notches (Coles notch) of the most recent audiogram.

Results

The train and track maintenance workers 45 years or older had a small mean hearing loss in the 3-6 kHz area of 3-5 dB. The hearing loss was smaller among workers younger than 45 years. Audiometric notches were slightly more prevalent among the noise exposed (59-64%) compared to the controls (49%) for all age groups. Audiometric notches may therefore be a sensitive measure in disclosing an early hearing loss at a group level.

Conclusion

Train and track maintenance workers 45 years or older on average have a slightly greater hearing loss and more audiometric notches compared to reference groups not exposed to noise. Younger (<45 years) workers have hearing thresholds comparable to the controls.

Strengths and limitations of the study

Strengths:

- The size of the study with close to 100% participation rate
- The use of two groups for comparison
- High quality of the audiometric data and exposure assessment

Limitations:

- Cross sectional study with only the most recent audiogram from the participants

Introduction

Noise induced hearing loss (NIHL) accounts for more than 60 percents of occupational disorders reported to the Norwegian Labor Inspection Authority [1]. Age is, however, the main cause for hearing loss[2] . Heritability, gender, smoking, high blood pressure, diabetes, high cholesterol level, the use of ototoxic medication and exposure to ototoxic chemicals may also affect the hearing and so may leisure time noise, first and foremost from the use of firearms[3-5].

Train and track maintenance workers are occupationally exposed to noise. Noise measurements in the railway companies that we have studied reveal average 8 hour noise exposure levels of 75-90 dB(A) in both groups with peak exposures reaching 130-140 dB(C).

In studies of train and track maintenance workers, noise induced hearing loss has been described by Virokannas[6], but the exposure levels were much higher than in our study. In the US National Health Interview Survey, railroad employees had the highest prevalence of hearing difficulties among the occupational groups examined, but the study did not present audiometric data, only self reported symptoms[7].

Norwegian physicians are legally obliged to report occupational diseases, such as NIHL, to the Norwegian Labour Inspection Authority. More than 70 percents of the male 20-64 year old workers that we have studied, have an audiogram meeting the national criteria for NIHL, namely a sufficiently strong noise exposure and a hearing loss of 25 dB or more at either 3, 4 or 6 kHz, worse ear, or 20 dB for all of 3, 4 and 6 kHz, worse ear, not adjusted for age or sex[8] .

A recent study of hearing status among train drivers and train conductors in the Norwegian State Railways showed normal mean hearing threshold for their age[9]. Still many of them, just like the maintenance workers that we have studied, had audiograms compatible with the Norwegian criteria for NIHL.

The aim of this cross-sectional study was to assess the risk of noise induced hearing loss among train and track maintenance workers by comparing their audiograms with audiograms from a reference group of railway workers not exposed to noise and a Norwegian reference population (HUNT)[10] which recently has been included in the 2013 revision of the ISO 1999 reference data base[11] .

Methods

Exposure assessment

As a part of the risk assessment of the train and track maintenance workers, the occupational hygienists of the occupational health service (OHS) have conducted an extensive programme of measurements of the noise exposure by dosimetry and peak noise measurements. The exposure shows high variability, depending on the type of work being done. On an 8 hour average level the exposure varies from 75 dB(A) up to 90 dB(A), averaging 85-86 dB(A), and with peak exposures up to 130 dB(C) - 140 dB(C). Since the workers should wear hearing protection when the exposure exceeds 85 dB(A), the actual exposure to the ear will become somewhat lower.

The study group

Most of the train and track maintenance workers have to perform an audiometric test as a part of a mandatory health assessment due to national and European Union regulations for railway safety personnel in order to be certified. The test is to be done before employment and later, depending on age, with 1-5 year intervals. All the tests are conducted by the occupational health service (OHS) of the Norwegian state railways (NSB).

The most recent available audiograms of the participating subjects, recorded during the period 1994-2011, were obtained from the electronic medical records along with age, sex and type of job information. Since there were only a few female maintenance workers, only male workers were used in the analysis.

Audiograms from the train and track maintenance workers were compared with those of a control group of non-exposed male railway office workers, mainly doing traffic controlling, and with a similar social and educational background and salary as the maintenance workers. The study population was also compared with external reference data from the ISO 1999: 2013, annex B, table 2, based on a Norwegian reference population[11].

Hearing examination

Madsen Xeta Otometrics pure tone audiometric testing using a TDH-39P earphone headset in a soundproof booth at frequencies of 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz was performed by trained nurses. The audiometric test was done in line with standard procedures according to the Norwegian Labour Inspection Authority[8] . The audiometer was calibrated every second year according to the requirements of the equipment provider.

Since grouped median and percentile values from the better ear are used in the ISO 1990: 2013, the same values of the hearing threshold of frequencies from 0.5- 8 kHz were computed and compared to the values from reference groups.

The prevalence of notches was calculated since audiometric notches are regarded as an indicator of NIHL[12]. The Coles notch was used. It is defined as hearing thresholds at 3, 4 or 6 kHz of 10 dB or more compared to that at 1 or 2 kHz and 8 kHz [13]. The criteria established by Coles et al. have been proven to correlate well with clinical assessments [14]

Finally, the prevalence of hearing loss meeting the Norwegian NIHL criteria, a hearing loss of 25 dB or more at either 3, 4 or 6 kHz or 20 dB for all of 3, 4 and 6 kHz, worse ear, was computed and compared to the reference group.

Ethical considerations

The audiograms have been obtained as a part of regular occupational health services work. Risk assessment of NIHL is a part of the OHS tasks. Therefore an application to the regional ethical committee is not necessary according to Norwegian regulations.

Statistics

Descriptive statistics were used in this study. Groups were compared using chi-square tests for categorical variables and ANOVA for continuous variables. The data analysis was performed using

SPSS (IBM SPSS Statistics Version 20) with percentile values estimated by the FREQUENCIES /GROUPED command[15]. A significance level of 5% was chosen.

Competing interests

None declared. The study did not receive any funding.

Results

Audiograms from 1897 train- and 2730 track maintenance workers, all males, were compared to audiograms from 2872 male railway office workers working as traffic controllers or in other types of jobs without any significant noise exposure.

An overview of age distribution in the train- and track maintenance workers and non-exposed office workers is shown in table 1.

Table 1: Background data and noise exposure in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Age, mean (SD)		47.6 (11.9)	46.2 (13.0)	45.7 (11.8)	<0.001[a]
Age, N=	-24	118	286	129	
	25-34	225	275	504	
	35-44	330	529	692	
	45-54	555	801	738	
	55-64	669	839	809	
	Total	1897	2730	2872	
Occupational noise exposure (dB(A))		75-90 + peak	75-90 + peak	< 70	

[a]) ANOVA

The average age and the distribution of age were similar in the 3 groups. The noise exposure of the train and track maintenance workers is in the order of 75-90 dB(A). In addition there may be peak exposures of 130-140 dB(C). Hearing protection in terms of ear muffs or ear plugs is to be used when the noise exposure exceeds 80 dB(A).

Figure 1 shows the grouped median values of the hearing thresholds of the maintenance workers, the internal control group and the ISO 1999. The largest difference between the noise exposed and the control groups, 2-7 dB for 3 kHz and 4 kHz, was found for the age groups 45 years or older compared with the control groups. The grouped 90 percentile (figure 2) of the hearing thresholds reveals similar findings with an elevated hearing threshold of 6-10 dB in the same age groups of the noise exposed workers compared to the control groups. In the younger age groups (25-44 years) there are only minor differences between those with noise exposure compared to the internal control group and ISO-standards.

The hearing loss, the prevalences of audiometric notches and NIHL criteria in the maintenance workers compared with the internal control group are shown in table 2.

Table 2: Hearing loss (better ear) and prevalence of audiometric notches (worse ear) and NIHL (worse ear) in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Hearing loss compared to the internal reference, mean 3,4 and 6 kHz, better ear (95% CI)					
	-24	2.3(0.8-3.7)	1.1(-0.1-2.3)[b]	0 (Ref)	
	25-34	0.8(-0.5-2.1)	0.0(-1.2-1.3)	0 (Ref)	
	35-44	1.8(0.3-3.3)	1.1(-0.2-2.4)	0 (Ref)	
	45-54	3.3(1.6-5.0)	3.1(1.5-4.6))	0 (Ref)	
	55-64	4.6(2.5-6.6)	4.9(2.9-6.8)	0 (Ref)	
Coles audiometric notch, prevalence, worse ear (%)					
	-24	50	56	39	<0.001[c]
	25-34	50	53	39	<0.001
	35-44	59	62	50	<0.001
	45-54	65	71	55	<0.001
	55-64	60	66	52	<0.001
	Total	59	64	49	<0.001
NIHL criteria hearing loss[d], prevalence, worse ear, (%)					
	-24	26	21	20	0.432[a]
	25-34	36	29	28	0.116
	35-44	63	56	50	<0.001
	45-54	87	85	74	<0.001
	55-64	95	95	92	0.005
	Total	76	70	63	<0.001

[a]) ANOVA [b]) ANOVA, Bonferroni post hoc [c]) Chi- square test [d]) a hearing threshold of 25 dB or more at either 3, 4 or 6 kHz, worse ear, or 20 dB for all of 3, 4 and 6 kHz, worse ear.

From the age of 45 there is a significant hearing loss among the maintenance workers of 3-5 dB compared to the controls. In the younger age groups the hearing is comparable to that of the controls group.

An increase in audiometric notches in all groups with increasing age up to the age of 54 and then declining, is revealed with significantly higher prevalences in the exposed groups compared with the control group for all age groups.

The prevalence of the Norwegian criteria for NIHL is in line with the audiometric notches found in the present study (table 2), but is only significant for exposed workers compared to controls above 35 years. The prevalence of audiometric NIHL criteria is almost as high in the reference group (63%) as in the train- and track maintenance workers (70-76%).

The results indicate that there is only a small, but significant noise induced hearing loss in the noise sensitive area (3-6 kHz) in the exposed workers from the age of 35.

Discussion

This cross-sectional study of 4627 male train- and track maintenance workers demonstrates hearing thresholds similar to that of the non-exposed groups, but the oldest workers have a small, but significantly greater hearing loss with more notched audiograms than the control group. This indicates a small noise induced hearing loss (NIHL) in the noise exposed groups. The magnitude of the hearing loss of the noise sensitive area (3-6 kHz) is in the order of 5 dB or less, which is about as expected. According to ISO 1999[11] an unprotected noise exposure of 85 and 90 dB(A) at an 8 hour daily basis will lead to a median expected hearing loss of 4 dB and 9 dB, respectively, after 10 years of exposure.

The hearing of the younger workers is close to normal. This is probably due to shorter time of noise exposure, better preventive measures, such as the use of noise protection and the use of hearing protection, during the last years and in line with studies of similar noise-exposed groups in the developed world[16-18]. The workers 45 years or older, however, had a small noise-induced hearing loss. This could be due to a longer time of noise exposure and former high levels of workplace noise. This finding is also in line with previous studies showing that railroad workers are at risk of getting NIHL[6 7].

The prevalences of notched audiograms are statistically significantly higher among noise exposed workers compared to controls for all age groups but only for workers above 35 for the prevalence of the Norwegian NIHL criteria. This may indicate that a notched audiogram is more sensitive than the NIHL criteria in disclosing an early NIHL at a group level. The main problem with both the notched audiograms and the NIHL criteria, however, is the almost as high prevalence of these finding among the controls compared to the exposed. This means that the specificity is low, and these diagnostic criteria for NIHL are therefore of limited value at an individual level.

The strengths of the present study include a large number of maintenance workers and large control groups. We also assess the audiometric measurements to be of good quality. Since audiometric testing is mandatory for most of the workers, we assume that the participation rate is close to100 %. The use of two comparison groups strengthens the study. The results from the two comparison groups are very similar. Furthermore, the internal control group of office workers was examined by the same OHS professionals and with the same audiometric equipment as were the train and track maintenance workers.

There are, however, also some limitations of this study.

This cross sectional assessment is based on only one audiogram from each of the participants, the most recent measurement. Longitudinal data would be favorable in such a study, because selective drop-out may have occurred. Since selection in and selection out of work due to hearing loss is quite uncommon, we believe that the limitation of using cross-sectional data in this study is of minor importance.

Information of factors other than noise that may modify hearing loss such as smoking, high blood pressure, metabolic syndrome, diabetes, exposure to ototoxic medication or chemicals, leisure time noise exposure etc were not available. Thus possible confounders were not assessed. The maintenance workers have probably been more exposed to chemicals than the reference groups. For the other factors we have no reason to believe that they would influence the results since we doubt that they have a different prevalence among the workers compared with the controls.

Most of the maintenance workers went through a health examination before they were employed, and a severe hearing loss would normally have been regarded as a disqualification preventing employment. One may therefore expect some selection at recruitment. The requirements regarding hearing acuity are not very strict, however, and identical for the maintenance workers and the control group of railway workers. We therefore believe that selection factors are of minor importance.

We are lacking information of years of employment for the maintenance workers and even for the office workers. Most of the train- and track maintenance workers, however, are recruited at an early age and are quite stable with only a small turnover. The same is the case for the office personnel. We cannot rule out the possibility that these groups have had a previous job with occupational noise exposure, but we assess the possibility for this to influence the results to be unlikely.

Before we conducted this study, there was a general perception that train and track maintenance workers are at risk for getting noise induced hearing loss. Based on individual assessments of workers and their audiograms and using the diagnostic guidelines of the Norwegian Labor Inspection Authority, 70 to 76 percent were suspected to have NIHL. The prevalence according to these criteria was 63 percent in the internal control group with office workers. This indicates that the use of these criteria has strong limitations with respect to the validity of predicting noise induced hearing loss.

To distinguish between noise induced and age related hearing loss based solely on audiograms is problematic. Some indications of differences may be given by audiometric notches, but they are also present in workers without any noise exposure as shown in the present and other studies[19 20] .

The results might be valid for male railway maintenance workers in other countries with similar type of work, noise exposure and legislation.

In conclusion, this cross-sectional study has detected a small average hearing loss among the older part of the 4627 male train and track maintenance workers compared with non-exposed workers in the same company and reference values from ISO 1999: 2013.

What this paper adds:

- Previous studies have suggested that railway maintenance workers are at risk for the development of noise induced hearing loss (NIHL).
- This study has detected only small hearing loss among older maintenance workers compared to reference values.
- Hearing loss meeting national criteria for NIHL and audiometric notches are highly prevalent among workers not exposed to noise and are therefore of limited use in the diagnosis of NIHL.

Acknowledgement

Per Frode Hove, Ingvill M. Hornkjøl and the rest of the staff at the Norwegian State Railways (NSB) Occupational Health Service are greatly acknowledged for providing exposure data, data from the medical records, and for valuable criticism and advice

Contributorship statement

Arve Lie and Marit Skogstad have written the first draft of manuscript. Bo Engdahl and Kristian Tambs have given valuable advice on the manuscript and statistics. Torstein Seip Johnsen has provided the data from the OHS and has also been involved in the forming of the manuscript.

All the authors have given substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting and revising of the article and final approval of the version to be published.

Competing Interests

There are no competing interests

Data Sharing Statement

No additional data are available

Figure legends

Figure 1: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 50 percentile.

Figure 2: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 90 percentile.

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A cross-sectional study of hearing thresholds among 4627 Norwegian train and track maintenance workers

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Abstract

Objective

Railway workers performing maintenance work of trains and tracks could be at risk of developing noise induced hearing loss, since they are exposed to noise levels of 75- 90 dB(A) with peak exposures of 130-140 dB(C). The objective was to make a risk assessment by comparing the hearing thresholds among train and track maintenance workers with a reference group not exposed to noise and reference values from the ISO 1999.

Design

Cross sectional

Setting

A major Norwegian railway company.

Participants

1897 male train and 2730 male track maintenance workers, all exposed to noise, and 2872 male railway traffic controllers and office workers not exposed to noise.

Outcome measures

The primary outcome was the hearing threshold (pure tone audiometry, frequencies from 0.5 to 8 kHz) and the secondary the prevalence of audiometric notches (Coles notch) of the most recent audiogram.

Results

The train and track maintenance workers 45 years or older had a small mean hearing loss in the 3-6 kHz area of 3-5 dB. The hearing loss was smaller among workers younger than 45 years. Audiometric notches were slightly more prevalent among the noise exposed (59-64%) compared to the controls (49%) for all age groups. Audiometric notches may therefore be a sensitive measure in disclosing an early hearing loss at a group level.

Conclusion

Train and track maintenance workers 45 years or older on average have a slightly greater hearing loss and more audiometric notches compared to reference groups not exposed to noise. Younger (<45 years) workers have hearing thresholds comparable to the controls.

Strengths and limitations of the study

Strengths:

- The size of the study with close to 100% participation rate
- The use of two groups for comparison
- High quality of the audiometric data and exposure assessment

Limitations:

- Cross sectional study with only the most recent audiogram from the participants

Introduction

Noise induced hearing loss (NIHL) accounts for more than 60 percents of occupational disorders reported to the Norwegian Labor Inspection Authority [1]. Age is, however, the main cause for hearing loss[2] . Heritability, gender, smoking, high blood pressure, diabetes, high cholesterol level, the use of ototoxic medication and exposure to ototoxic chemicals may also affect the hearing and so may leisure time noise, first and foremost from the use of firearms[3-5].

Train and track maintenance workers are occupationally exposed to noise. Noise measurements in the railway companies that we have studied reveal average 8 hour noise exposure levels of 75-90 dB(A) in both groups with peak exposures reaching 130-140 dB(C).

In studies of train and track maintenance workers, noise induced hearing loss has been described by Virokannas[6], but the exposure levels were much higher than in our study. In the US National Health Interview Survey, railroad employees had the highest prevalence of hearing difficulties among the occupational groups examined, but the study did not present audiometric data, only self reported symptoms[7].

Norwegian physicians are legally obliged to report occupational diseases, such as NIHL, to the Norwegian Labour Inspection Authority. More than 70 percents of the male 20-64 year old workers that we have studied, have an audiogram meeting the national criteria for NIHL, namely a sufficiently strong noise exposure and a hearing loss of 25 dB or more at either 3, 4 or 6 kHz, worse ear, or 20 dB for all of 3, 4 and 6 kHz, worse ear, not adjusted for age or sex[8] .

A recent study of hearing status among train drivers and train conductors in the Norwegian State Railways showed normal mean hearing threshold for their age[9]. Still many of them, just like the maintenance workers that we have studied, had audiograms compatible with the Norwegian criteria for NIHL.

The aim of this cross-sectional study was to assess the risk of noise induced hearing loss among train and track maintenance workers by comparing their audiograms with audiograms from a reference group of railway workers not exposed to noise and a Norwegian reference population (HUNT)[10] which recently has been included in the 2013 revision of the ISO 1999 reference data base[11] .

Methods

Exposure assessment

As a part of the risk assessment of the train and track maintenance workers, the occupational hygienists of the occupational health service (OHS) have conducted an extensive programme of measurements of the noise exposure by dosimetry and peak noise measurements. The exposure shows high variability, depending on the type of work being done. On an 8 hour average level the exposure varies from 75 dB(A) up to 90 dB(A), averaging 85-86 dB(A), and with peak exposures up to 130 dB(C) - 140 dB(C). Since the workers should wear hearing protection when the exposure exceeds 85 dB(A), the actual exposure to the ear will become somewhat lower.

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Most of the train and track maintenance workers have to perform an audiometric test as a part of a mandatory health assessment due to national and European Union regulations for railway safety personnel in order to be certified. The test is to be done before employment and later, depending on age, with 1-5 year intervals. All the tests are conducted by the occupational health service (OHS) of the Norwegian state railways (NSB).

The most recent available audiograms of the participating subjects, recorded during the period 1994-2011, were obtained from the electronic medical records along with age, sex and type of job information. Since there were only a few female maintenance workers, only male workers were used in the analysis.

Audiograms from the train and track maintenance workers were compared with those of a control group of non-exposed male railway office workers, mainly doing traffic controlling, and with a similar social and educational background and salary as the maintenance workers. The study population was also compared with external reference data from the ISO 1999: 2013, annex B, table 2, based on a Norwegian reference population[11].

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Hearing examination

Madsen Xeta Otometrics pure tone audiometric testing using a TDH-39P earphone headset in a soundproof booth at frequencies of 0.25, 0.5, 1, 2, 3, 4, 6 and 8 kHz was performed by trained nurses. The audiometric test was done in line with standard procedures according to the Norwegian Labour Inspection Authority[8] . The audiometer was calibrated every second year according to the requirements of the equipment provider.

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Since grouped median and percentile values from the better ear are used in the ISO 1990: 2013, the same values of the hearing threshold of frequencies from 0.5- 8 kHz were computed and compared to the values from reference groups.

The prevalence of notches was calculated since audiometric notches are regarded as an indicator of NIHL[12]. The Coles notch was used. It is defined as hearing thresholds at 3, 4 or 6 kHz of 10 dB or more compared to that at 1 or 2 kHz and 8 kHz [13]. The criteria established by Coles et al. have been proven to correlate well with clinical assessments [14]

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Finally, the prevalence of hearing loss meeting the Norwegian NIHL criteria, a hearing loss of 25 dB or more at either 3, 4 or 6 kHz or 20 dB for all of 3, 4 and 6 kHz, worse ear, was computed and compared to the reference group.

Ethical considerations

The audiograms have been obtained as a part of regular occupational health services work. Risk assessment of NIHL is a part of the OHS tasks. Therefore an application to the regional ethical committee is not necessary according to Norwegian regulations.

Statistics

Descriptive statistics were used in this study. Groups were compared using chi-square tests for categorical variables and ANOVA for continuous variables. The data analysis was performed using

SPSS (IBM SPSS Statistics Version 20) with percentile values estimated by the FREQUENCIES /GROUPED command[15]. A significance level of 5% was chosen.

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Competing interests

None declared. The study did not receive any funding.

Results

Audiograms from 1897 train- and 2730 track maintenance workers, all males, were compared to audiograms from 2872 male railway office workers working as traffic controllers or in other types of jobs without any significant noise exposure.

An overview of age distribution in the train- and track maintenance workers and non-exposed office workers is shown in table 1.

Table 1: Background data and noise exposure in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Age, mean (SD)		47.6 (11.9)	46.2 (13.0)	45.7 (11.8)	<0.001[a]
Age, N=	-24	118	286	129	
	25-34	225	275	504	
	35-44	330	529	692	
	45-54	555	801	738	
	55-64	669	839	809	
	Total	1897	2730	2872	
Occupational noise exposure (dB(A))		75-90 + peak	75-90 + peak	< 70	

[a]) ANOVA

The average age and the distribution of age were similar in the 3 groups. The noise exposure of the train and track maintenance workers is in the order of 75-90 dB(A). In addition there may be peak exposures of 130-140 dB(C). Hearing protection in terms of ear muffs or ear plugs is to be used when the noise exposure exceeds 80 dB(A).

Figure 1 shows the grouped median values of the hearing thresholds of the maintenance workers, the internal control group and the ISO 1999. The largest difference between the noise exposed and the control groups, 2-7 dB for 3 kHz and 4 kHz, was found for the age groups 45 years or older compared with the control groups. The grouped 90 percentile (figure 2) of the hearing thresholds reveals similar findings with an elevated hearing threshold of 6-10 dB in the same age groups of the noise exposed workers compared to the control groups. In the younger age groups (25-44 years) there are only minor differences between those with noise exposure compared to the internal control group and ISO-standards.

The hearing loss, the prevalences of audiometric notches and NIHL criteria in the maintenance workers compared with the internal control group are shown in table 2.

Table 2: Hearing loss (better ear) and prevalence of audiometric notches (worse ear) and NIHL (worse ear) in male train and track maintenance workers compared to an internal male non noise exposed reference group.

	Age	Train maintenance	Track maintenance	Internal ref.	P
Hearing loss compared to the internal reference, mean 3,4 and 6 kHz, better ear (95% CI)					
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	25-34	0.8(-0.5-2.1)	0.0(-1.2-1.3)	0 (Ref)	
	35-44	1.8(0.3-3.3)	1.1(-0.2-2.4)	0 (Ref)	
	45-54	3.3(1.6-5.0)	3.1(1.5-4.6))	0 (Ref)	
	55-64	4.6(2.5-6.6)	4.9(2.9-6.8)	0 (Ref)	
Coles audiometric notch, prevalence, worse ear (%)					
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[a]) ANOVA [b]) ANOVA, Bonferroni post hoc [c]) Chi- square test [d]) a hearing threshold of 25 dB or more at either 3, 4 or 6 kHz, worse ear, or 20 dB for all of 3, 4 and 6 kHz, worse ear.

From the age of 45 there is a significant hearing loss among the maintenance workers of 3-5 dB compared to the controls. In the younger age groups the hearing is comparable to that of the controls group.

An increase in audiometric notches in all groups with increasing age up to the age of 54 and then declining, is revealed with a significant higher prevalences in the exposed groups compared with the control group for all age groups.

The prevalence of the Norwegian criteria for NIHL is in line with the audiometric notches found in the present study (table 2), but is only significant for exposed workers compared to controls above 35 years. The prevalence of audiometric NIHL criteria is almost as high in the reference group (63%) as in the train- and track maintenance workers (70-76%).

The results indicate that there is only a small, but significant noise induced hearing loss in the noise sensitive area (3-6 kHz) in the exposed workers from the age of 35.

Discussion

This cross-sectional study of 4627 male train- and track maintenance workers demonstrates hearing thresholds similar to that of the non-exposed groups, but the oldest workers have a small, but significantly greater hearing loss with more notched audiograms than the control group. This indicates a small noise induced hearing loss (NIHL) in the noise exposed groups. The magnitude of the hearing loss of the noise sensitive area (3-6 kHz) is in the order of 5 dB or less, which is about as expected. According to ISO 1999[11] an unprotected noise exposure of 85 and 90 dB(A) at an 8 hour daily basis will lead to a median expected hearing loss of 4 dB and 9 dB, respectively, after 10 years of exposure.

The hearing of the younger workers is close to normal. This is probably due to shorter time of noise exposure, better preventive measures, such as the use of noise protection and the use of hearing protection, during the last years and in line with studies of similar noise-exposed groups in the developed world[16-18] . The workers 45 years or older, however, had a small noise-induced hearing loss. This could be due to a longer time of noise exposure and former high levels of workplace noise. This finding is also in line with previous studies showing that railroad workers are at risk of getting NIHL[6 7].

The prevalences of notched audiograms are statistically significantly higher among noise exposed workers compared to controls for all age groups but only for workers above 35 for the prevalence of the Norwegian NIHL criteria. This may indicate that a notched audiogram is more sensitive than the NIHL criteria in disclosing an early NIHL at a group level. The main problem with both the notched audiograms and the NIHL criteria, however, is the almost as high prevalence of these finding among the controls compared to the exposed. This means that the specificity is low, and these diagnostic criteria for NIHL are therefore of limited value at an individual level.

The strengths of the present study include a large number of maintenance workers and large control groups. We also assess the audiometric measurements to be of good quality. Since audiometric testing is mandatory for most of the workers, we assume that the participation rate is close to100 %. The use of two comparison groups strengthens the study. The results from the two comparison groups are very similar. Furthermore, the internal control group of office workers was examined by the same OHS professionals and with the same audiometric equipment as were the train and track maintenance workers.

There are, however, also some limitations of this study.

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Information of factors other than noise that may modify hearing loss such as smoking, high blood pressure, metabolic syndrome, diabetes, exposure to ototoxic medication or chemicals, leisure time noise exposure etc were not available. Thus possible confounders were not assessed. The maintenance workers have probably been more exposed to chemicals than the reference groups. For the other factors we have no reason to believe that they would influence the results since we doubt that they have a different prevalence among the workers compared with the controls.

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To distinguish between noise induced and age related hearing loss based solely on audiograms is problematic. Some indications of differences may be given by audiometric notches, but they are also present in workers without any noise exposure as shown in the present and other studies[19 20] .

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The results might be valid for male railway maintenance workers in other countries with similar type of work, noise exposure and legislation.

In conclusion, this cross-sectional study has detected a small average hearing loss among the older part of the 4627 male train and track maintenance workers compared with non-exposed workers in the same company and reference values from ISO 1999: 2013.

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Figure legends

Figure 1: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 50 percentile.

Figure 2: Hearing threshold of male train and track maintenance workers compared to ISO 1999:2013 and an internal reference group of office workers. 90 percentile.

What this paper adds:

- Previous studies have suggested that railway maintenance workers are at risk for the development of noise induced hearing loss (NIHL).
- This study has detected only small hearing loss among older maintenance workers compared to reference values.
- Hearing loss meeting national criteria for NIHL and audiometric notches are highly prevalent among workers not exposed to noise and are therefore of limited use in the diagnosis of NIHL.

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Contributorship statement

Arve Lie and Marit Skogstad have written the first draft of manuscript. Bo Engdahl and Kristian Tambs have given valuable advice on the manuscript and statistics. Torstein Seip Johnsen has provided the data from the OHS and has also been involved in the forming of the manuscript.

All the authors have given substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, drafting and revising of the article and final approval of the version to be published.

Competing Interests

There are no competing interests

Data Sharing Statement

No additional data are available

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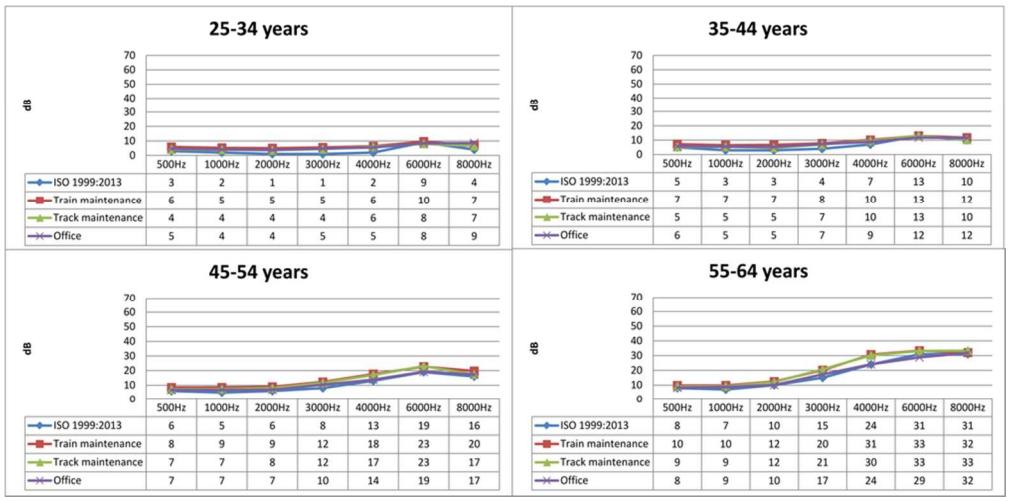

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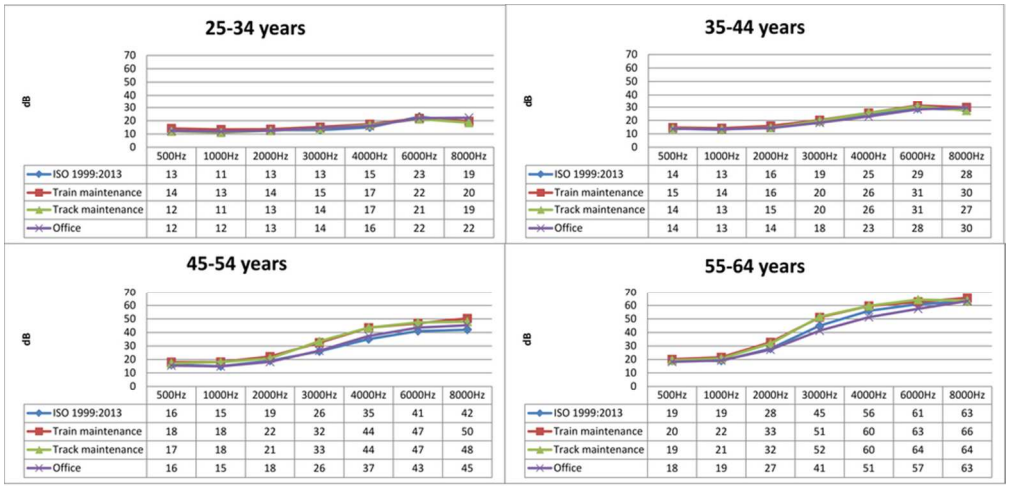

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STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1,2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4,5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	5
Bias	9	Describe any efforts to address potential sources of bias	5
Study size	10	Explain how the study size was arrived at	5,6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5,6
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	-
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	-
		(*e*) Describe any sensitivity analyses	-
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	-
		(c) Consider use of a flow diagram	-
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	-
Outcome data	15*	Report numbers of outcome events or summary measures	7
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	7
		(*b*) Report category boundaries when continuous variables were categorized	7
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	7
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	-
Discussion			
Key results	18	Summarise key results with reference to study objectives	7,8
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	8
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	8,9
Generalisability	21	Discuss the generalisability (external validity) of the study results	9
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	6

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.