International Journal of Occupational Medicine and Environmental Health 2016;29(6):991–999
http://dx.doi.org/10.13075/ijomeh.1896.00714

SIMPLIFIED RISK ASSESSMENT OF NOISE INDUCED HEARING LOSS BY MEANS OF 2 SPREADSHEET MODELS

ARVE LIE[1], BO ENGDAHL[2], and KRISTIAN TAMBS[2]

[1] National Institute of Occupational Health, Oslo, Norway
Department of Occupational Medicine and Epidemiology
[2] Norwegian Institute of Public Health, Oslo, Norway

Abstract
Objectives: The objective of this study has been to test 2 spreadsheet models to compare the observed with the expected hearing loss for a Norwegian reference population. **Material and Methods:** The prevalence rates of the Norwegian and the National Institute for Occupational Safety and Health (NIOSH) definitions of hearing outcomes were calculated in terms of sex and age, 20–64 years old, for a screened (with no occupational noise exposure) (N = 18 858) and unscreened (N = 38 333) Norwegian reference population from the Nord-Trøndelag Hearing Loss Study (NTHLS). Based on the prevalence rates, 2 different spreadsheet models were constructed in order to compare the prevalence rates of various groups of workers with the expected rates. The spreadsheets were then tested on 10 different occupational groups with varying degrees of hearing loss as compared to a reference population. **Results:** Hearing of office workers, train drivers, conductors and teachers differed little from the screened reference values based on the Norwegian and the NIOSH criterion. The construction workers, miners, farmers and military had an impaired hearing and railway maintenance workers and bus drivers had a mildly impaired hearing. The spreadsheet models give a valid assessment of the hearing loss. **Conclusions:** The use of spreadsheet models to compare hearing in occupational groups with that of a reference population is a simple and quick method. The results are in line with comparable hearing thresholds, and allow for significance testing. The method is believed to be useful for occupational health services in the assessment of risk of noise induced hearing loss (NIHL) and the preventive potential in groups of noise-exposed workers. Int J Occup Med Environ Health 2016;29(6):991–999

Key words:
Method, Risk assessment, Occupational health services, Noise induced hearing loss, Spread sheet, Reference data ISO

INTRODUCTION

Noise induced hearing loss (NIHL) is one of the most highly reported disorders among all the work-related disorders [1–4]. It accounts for more than 60% of the cases of occupational diseases reported to the Norwegian Labour Inspection Authority. Most of the cases of the NIHL (85%) are reported by the occupational health services (OHS). In the period from 2005 to 2009, a total of 7888 NIHL cases were reported to be corresponding to an annual incidence of 66/100 000 workers [5]. Noise induced hearing loss is a difficult diagnosis to make, partly because the expected hearing loss due to noise is usually small as compared to the age-related loss [6,7], and partly because the audiometric notch, which has been used as a diagnostic criterion for the NIHL, also commonly occurs in non noise-exposed ones [8,9]. The national hearing loss criteria used for diagnosis purposes vary from nation to nation, which is regarded as a major problem because it makes it difficult to compare results [10].

Received: June 18, 2015. Accepted: January 4, 2016.
Corresponding author: A. Lie, National Institute of Occupational Health, Department of Occupational Medicine and Epidemiology, P.O. Box 8149 Dep, N-0033 Oslo, Norway (e-mail: arve.lie@stami.no).

In Norway, a hearing loss exceeding 25 dB at either ear in the frequency range of 3–6 kHz or 20 dB at all 3 frequencies should, according to the Labour Inspection Authority, be considered as a possible NIHL if the noise exposure is sufficient [11]. The National Institute for Occupational Safety and Health (NIOSH) criterion is a hearing loss of > 25 dB (pure-tone hearing threshold average for both ears frequencies 1 kHz, 2 kHz, 3 kHz and 4 kHz) [3], while the World Health Organization (WHO) operates with a fence of 25 dB for frequencies 0.5 kHz, 1 kHz, 2 kHz and 4 kHz for the best ear [3].

It is necessary to compare hearing in an occupational population with a reference population to make a risk assessment of the NIHL [12]. The International Organization for Standardization document ISO 1999 [7] has for many years had reference data on hearing. The newly revised version of the ISO 1999 has 3 different reference materials for comparison: a Swedish one with averages of both ears as a reference value, a Norwegian one and an American one based on hearing in the better ear. The Swedish and Norwegian ones are screened for noise exposure, while the US is unscreened. The 3 materials demonstrate the grouped percentiles (10th, 50th and 90th percentile) for men and women for hearing thresholds from 0.5 kHz to 8 kHz in the age groups 25–34, 35–44, 45–54, 55–64 and 65–74 years old.

The ISO 1999 has been used extensively for research purposes [13–15] but has probably been used less in working life in general, such as in the case of the OHS, for the purpose of comparing hearing. The comparison of hearing in a group of workers with the grouped percentiles of the ISO 1999 normally requires access to statistical methods and skills that are rarely available in the case of the OHS, and the use of grouped percentiles, such as in the case of the ISO 1999, makes significance testing difficult. Graphic plots of the observed vs. reference hearing thresholds therefore normally are used without any testing of statistical significance.

In order to make it easier for the OHS to assess hearing, we have created a spreadsheet method for the comparison of hearing outcomes with reference values at a group level. Such a simplified method for comparison of hearing may be an important step towards a better risk assessment regarding the NIHL. The aim of this study is to describe and test this method.

MATERIAL AND METHODS

We have used data from the Nord-Trøndelag Hearing Loss Study (NTHLS) to calculate reference prevalence rates of hearing loss according to the Norwegian criterion and the NIOSH criterion of the age groups of 20–29, 30–39, 40–49, 50–59 years old and 60–64 years old for men and women in a screened and unscreened population. In the screened population (4345 men and 14 513 women) all the subjects with any occupational noise exposure have been omitted while they are included in the unscreened population (18 086 men and 20 242 women). The NTHLS material originates from a population study from Norway during the period from 1996 to 1998 that is a part of the Nord-Trøndelag Health Study (Helseundersøkelsen i Nord-Trøndelag – HUNT 2) [16]. The screened NTHLS data is a part of the recently revised ISO 1999 [7]. Using this data, we have created 2 spreadsheets in the Excel computer programme that makes it simple to compare the observed with the sex-and-age adjusted expected prevalences of hearing loss in a working population.

One spreadsheet is based on the Norwegian definition of hearing loss: class 1 – hearing loss ≥ 25 dB at either 3 kHz, 4 kHz or 6 kHz on either the right or left ear or hearing loss = 20 dB at all frequencies; class 2 – hearing loss ≥ 45 dB at 3 kHz, 4 kHz or 6 kHz, and ≤ 20 dB at 2 kHz; class 3 – hearing loss ≥ 45 dB at 3 kHz, 4 kHz or 6 kHz, and > 20 dB at 2 kHz. It is the hearing of the worse ear that applies. A class 1 – hearing loss on the right ear and class 3 of the left one qualify for a class 3 hearing loss in total.

The second spreadsheet is based on the NIOSH criterion > 25 dB for an average of 1 kHz, 2 kHz, 3 kHz and 4 kHz for both ears. We used both the screened and unscreened reference populations in the spreadsheets since there are disagreements whether one should compare hearing of an occupationally exposed group of workers with a screened or unscreened reference material [17]. The ISO 1999 therefore uses both unscreened and screened reference data [7]. We then tested the spreadsheets by using audiometric findings from various occupational groups of railway employees in Norway and occupational groups from the NTHLS. These data materials have been discussed in previous studies [6,18,19]. The railway material consists of the latest audiogram for the period of the years 1994–2011 for 1567 train drivers, 1565 train conductors, 4884 maintenance workers, 4039 office employees, and 2116 bus drivers. The typical 8 h equivalent noise exposure level was 70–85 dB (A) for the train drivers and conductors, < 80 dB (A) for the bus drivers, 85–90 dB (A) for the maintenance workers and < 70 dB (A) for the office workers. The use of hearing protection makes the actual daily noise exposure level somewhat lower for the maintenance workers. For the other occupational groups hearing protection is not in regular use.

The NTHLS material consists of 1311 teachers, 567 construction workers, 156 miners, 4372 farmers and 422 ones from the military [6]. We only had self reported noise exposure data from the NTHLS but this data and the audiometric findings suggest a rather high noise exposure for the miners and construction workers.

The expected numbers of hearing loss of the various occupational groups were calculated in the Excel spreadsheet by multiplying the age and sex specific prevalence rates of the screened and unscreened reference population of the NTHLS by the number of subjects in the age groups of 20–29, 30–39, 40–49, 50–59 years old and 60–64 years old for men and women separately. The sum of the age and sex specific expected numbers is the total expected number calculated by the spreadsheet and so is a bar diagram and a significance testing of the findings.

Statistics

The audiometric data from the NTHLS and railway was processed by using SPSS version 21. Age-and-sex adjustment of hearing was done by means of the analysis of covariance (using SPSS with the UNIANOVA, EMMEANS command). The Excel spreadsheet was based on Microsoft Office 2007, and the significance testing in the Excel spreadsheet was a Chi^2 test.

Ethics

The data from the railway employees was anonymized and therefore no ethics committee application is necessary according to the Norwegian regulation. The data from the NTHLS has been approved by The National Committee for Medical and Health Research Ethics and the Norwegian Data Inspectorate. None of the authors has declared any conflicts of interest.

RESULTS

The Table 1 shows the groups we have studied, 5 from the NTHLS and 5 from the railway population. Age and gender distribution vary considerably from group to group. Hearing (binaural average of 3 kHz, 4 kHz and 6 kHz and of 1 kHz, 2 kHz, 3 kHz and 4 kHz) was therefore age-and-gender adjusted. As compared with office workers (the reference railway), hearing was similar for train drivers, conductors, and slightly worse for maintenance workers and bus drivers. The construction workers, miners, farmers and military all had a hearing loss compared with the teachers (the reference NTHLS). Hearing thresholds for the railway workers and the NTHLS are not comparable because the train data has an adjusted age of 44.5 years old and the female percentage share of 17%, while the adjusted age in the NTHLS is slightly lower (42.8 years old) and the proportion of women is much higher (52.9%). Hearing thresholds are therefore only comparable within the NTHLS sample and within the railway sample.

The Table 2 shows the prevalences of hearing loss class 1–3 according to the Norwegian criterion for age and sex for

Table 1. Background data in Norwegian occupational groups from the Norwegian Railway and the Nord-Trøndelag Hearing Loss Study

Occupation	Respondents (N = 20 999)		Age [years] (M±SD)	Hearing threshold* [dB] (M)			
	total (men and women) [n]	women [%]		3, 4 and 6 kHz	p	1, 2, 3 and 4 kHz	p
Railway							
office workers	4 039	28.9	43.6±12.0	19.0	reference	13.3	reference
train drivers	1 567	7.7	45.5±12.4	19.9	n.s.	12.9	n.s.
train conductors	1 565	40.3	38.0±11.6	20.0	< 0.050	13.2	n.s.
train and track maintenace workers	4 884	5.3	46.4±12.7	22.3	< 0.001	15.5	< 0.001
bus drivers	2 116	8.0	46.0±10.1	21.2	< 0.001	15.0	< 0.001
The Nord-Trøndelag Hearing Loss Study (NTHLS)							
teachers	1 311	58.9	49.3±7.1	14.6	reference	9.8	reference
construction workers	567	1.6	44.3±10.5	22.5	< 0.001	15.6	< 0.001
miners	156	5.1	46.8±10.2	22.6	< 0.001	14.8	< 0.001
farmers	4 372	33.9	46.6±11.1	18.3	< 0.001	12.3	< 0.001
military	422	1.9	39.4±9.9	17.4	< 0.001	11.8	< 0.001

M – mean binaural hearing; SD – standard deviation; n.s. – not statistically significant.
* Railway: age-and-sex adjusted to 44.5 years old, women – 17%; NTHLS: age-and-sex adjusted to 42.8 years old, women – 52.9%.

Table 2. Prevalence of class 1–3 hearing loss (Norwegian definition) in a screened and unscreened Norwegian population (The Nord Trøndelag Hearing Loss Study – NTHLS)

Age [years]	Prevalence of hearing loss [%]					
	screened (N = 18 858)			unscreened (N = 38 328)		
	class 1	class 2	class 3	class 1	class 2	class 3
Men						
20–29	22.4	3.0	1.8	25.5	5.8	2.3
30–39	35.2	6.0	4.7	36.9	9.7	4.8
40–49	47.0	14.5	6.3	44.6	20.2	10.3
50–59	45.6	27.3	16.5	35.3	30.8	25.3
60–64	24.8	36.8	34.8	17.8	30.0	49.9
Women						
20–29	20.3	1.3	1.7	20.6	1.3	1.6
30–39	31.4	2.2	2.2	31.2	2.4	2.3
40–49	42.5	3.9	4.5	42.2	4.3	4.5
50–59	52.7	9.4	11.2	52.4	9.7	11.6
60–64	48.8	17.0	23.3	46.7	16.3	25.1

Table 3. Prevalence of hearing loss (The National Institute for Occupational Safety and Health (NIOSH) definition) in a screened and unscreened Norwegian population (The Nord-Trøndelag Hearing Loss Study – NTHLS)

Age [years]	Prevalence of hearing loss [%]	
	screened (N = 18 858)	unscreened (N = 38 328)
Men		
20–29	1.5	2.1
30–39	4.2	5.3
40–49	6.0	12.2
50–59	18.4	31.7
60–64	41.6	59.9
Women		
20–29	1.6	1.6
30–39	1.9	2.1
40–49	4.4	4.5
50–59	11.2	11.8
60–64	22.7	24.9

a screened and unscreened population in the NTHLS. The prevalences increase sharply with age and are higher for men than for women. Most of the oldest workers have a class 1–3 hearing loss. Hearing loss was, as expected, slightly more prevalent in the unscreened as compared with the screened material.

The Table 3 shows the prevalences of hearing loss according to the NIOSH criterion. The prevalence is much lower than for the Norwegian definition and increases sharply with increasing age and is higher for men than women. Hearing loss according to the NIOSH criterion is rare for people < 40 years of age. The prevalence of the NIOSH criterion for hearing loss is slightly higher than the prevalence of class 3 hearing loss but shows the same with prevalences which are low before the age of 40 years old and rapidly increase from the age of 40 years old.

Spreadsheets

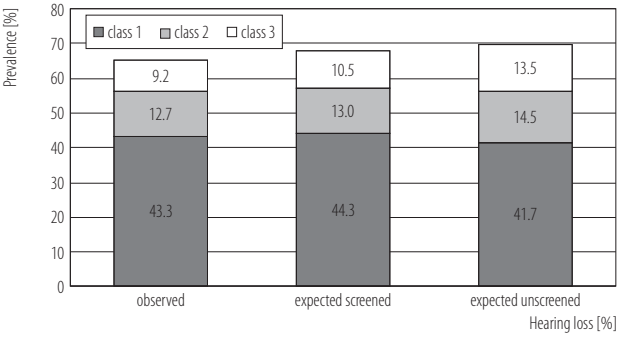
Based on prevalence rates, a spreadsheet was created. The numbers of men and women in different age groups and the numbers of persons with the class 1, 2 and 3 hearing loss are entered into the spreadsheet. The expected numbers are computed in terms of the age and sex-specific prevalence rates of the screened and unscreened reference data from the NTHLS and a diagram with significance testing is automatically generated.

The Figure 1 shows data of 1311 teachers from the NTHLS material. The teachers were among the ones with the best hearing in the NTHLS. The figure shows that teachers hear a little better than the unscreened NTHLS, while the difference as compared to the screened NTHLS is not statistically significant.

The Figure 2 shows hearing of teachers vs. expected one based on the NIOSH criterion. Again we see that teachers hear a little better than the unscreened NTHLS, while the difference as compared to the screened NTHLS is not statistically significant.

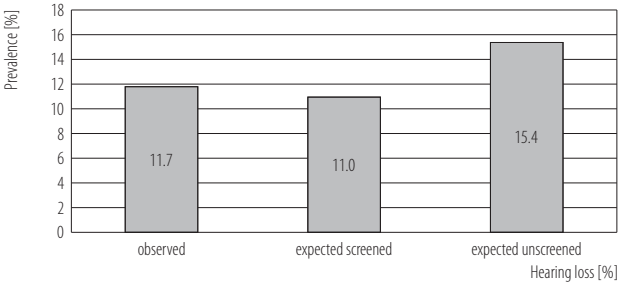
In the Table 4 we have made similar estimates of the selected professions from the NTHLS and from the railway by means of the spreadsheet model.

The table shows that among the railway employees, the office workers, the train drivers and the conductors



P for Chi² observed vs. screened = 0.140, observed vs. unscreened = 0.000.

Fig. 1. Observed vs. expected hearing loss for Norwegian teachers – Norwegian class 1–3 criteria



NIOSH > 25 dB.
P for Chi² observed vs. expected screened = 0.449,
observed vs. expected unscreened = 0.000.

Fig. 2. Observed vs. expected hearing loss for Norwegian teachers – The National Institute for Occupational Safety and Health (NIOSH) criterion

have a hearing which is slightly better than expected as compared with a screened and unscreened population. The maintenance workers and bus drivers have a slightly worse hearing as compared with the screened but better than the unscreened population. The findings are in good agreement with the sex-and-age-adjusted hearing loss for these groups of 2–3 dB as shown in the Table 1.

Among the NTHLS occupational groups we find the same tendency. Teachers have a hearing which is at about the same level as the screened reference group, while military employees and farmers have a little hearing loss and construction workers and miners have a somewhat greater hearing loss. The findings agree well with the sex and age-adjusted hearing loss for these groups as shown in the Table 1.

The Table 5 shows the prevalences of hearing loss according to the NIOSH criterion for the same occupational groups. Office workers, train drivers, and conductors have a hearing which is slightly better than both screened and

Table 4. Prevalence of observed class 1–3 hearing loss compared to expected values from a screened and unscreened Norwegian population

Occupation	Prevalence of hearing loss (Norwegian classification) [%]									p (Chi², df = 3)	
	observed (O)			expected screened (E1)*			expected unscreened (E2)*			O vs. E1	O vs. E2
	class 1	class 2	class 3	class 1	class 2	class 3	class 1	class 2	class 3		
Railway											
office workers	33.5	12.2	8.4	37.3	14.7	10.9	34.5	16.3	15.1	< 0.001	< 0.001
train drivers	37.3	15.8	9.3	37.3	18.2	13.0	33.5	20.1	18.7	< 0.001	< 0.001
train conductors	31.1	9.2	5.0	35.0	9.7	6.8	33.5	11.8	9.2	< 0.001	< 0.001
train and track maintenance workers	35.2	20.3	15.5	37.8	19.5	13.2	33.3	21.5	20.1	< 0.001	< 0.001
bus drivers	42.0	18.2	13.8	40.4	17.7	11.7	36.4	20.5	16.9	< 0.001	< 0.001
NTHLS											
teachers	43.3	12.7	9.2	44.3	13.0	10.5	41.7	14.5	13.5	n.s.	< 0.001
construction workers	34.6	24.0	21.3	39.2	16.0	10.6	36.3	19.2	15.2	< 0.001	< 0.001
miners	29.5	21.8	25.6	39.6	18.7	12.8	35.5	21.1	18.6	< 0.001	n.s.
farmers	37.7	17.9	15.6	40.5	14.5	11.2	37.8	16.4	15.0	< 0.001	< 0.010
military	32.5	15.6	11.8	34.8	10.8	7.7	34.5	13.8	10.3	< 0.001	n.s.

NTHLS – The Nord-Trøndelag Hearing Loss Study; n.s. – not statistically significant.
* Calculated by the spreadsheet model.

Table 5. Prevalence of observed hearing loss (The National Institute for Occupational Safety and Health (NIOSH) criterion) as compared to expected values from a screened and unscreened Norwegian population

Occupation	Prevalence of hearing loss (NIOSH criterion) [%]			p (Chi², df = 1)	
	observed (O)	expected screened (E1)*	expected unscreened (E2)*	O vs. E1	O vs. E2
Railway					
office workers	10.7	11.9	17.9	< 0.050	< 0.001
train drivers	11.6	14.5	22.5	< 0.010	< 0.001
train conductors	5.9	7.1	10.7	n.s.	< 0.001
train and track maintenace workers	20.2	15.4	24.2	< 0.001	< 0.001
bus drivers	16.5	12.2	20.4	< 0.001	< 0.001
NTHLS					
teachers	11.7	11.0	15.4	n.s.	< 0.001
construction workers	26.8	11.4	18.2	< 0.001	< 0.001
miners	28.2	14.2	23.4	< 0.001	n.s.
farmers	18.2	11.9	17.4	< 0.001	n.s.
military	13.5	8.0	12.0	< 0.001	n.s.

NTHLS – The Nord-Trøndelag Hearing Loss Study; n.s. – not statistically significant.
* Calculated by the spreadsheet model.

unscreened referents, while maintenance workers and bus drivers have significantly worse hearing than screened and better hearing than unscreened reference.

Teachers have a hearing similar to the screened NTHLS. Construction workers, miners, farmers and military employees have a significant hearing loss as compared with screened NTHLS.

The findings in the Table 5 show the same pattern as the Norwegian class 1–3 hearing loss (Table 4). Both spreadsheets manage to capture the difference in hearing thresholds among the occupational groups. A closer analysis shows that an increase in the observed vs. expected hearing loss of 10% (i.e., 22% vs. expected 12%) of class 3 hearing loss corresponds to an increased hearing threshold at about 5 dB for an average of 3 kHz, 4 kHz and 6 kHz binaurally. A similar increase for the NIOSH criterion corresponds to an increased hearing threshold of 3–4 dB for an average of 1 kHz, 2 kHz, 3 kHz and 4 kHz binaurally. This suggests that the use of spreadsheets for the purpose of the comparison of hearing in a group of workers to a reference population may provide a valid picture of hearing. The spreadsheet method also gives a good picture of the prevention potential and might be a simple way for the longitudinal follow up of groups of exposed workers as a part of a hearing conservation program.

DISCUSSION

When examining hearing of a group of noise exposed workers, it is necessary to compare it with reference values, such as the ISO 1999. In this study we have found that the use of a simple spreadsheet method has given results that are comparable to the traditional method by comparing median hearing from the ISO with median hearing in the exposed groups. The traditional way is time consuming

and requires access to statistical tools that many OHS do not have. Significance testing is also difficult when using the traditional methods. Most OHS therefore refrain from such testing.

The spreadsheet method makes the comparison easy. One only needs to enter the number of men and women in various age groups and the prevalence of hearing loss by the NIOSH or Norwegian definition to get the answer with a Chi^2 significance test. Many electronic medical records (EMR) in Norway automatically encode hearing in accordance with the Norwegian class 1–3 system, meaning that all the data needed for the spreadsheet is readily available. Preliminary testing of the Norwegian spreadsheet model shows that most OHS find it is simple to use.

The graphic presentation of the spreadsheet showing the observed vs. expected prevalences of hearing loss also gives a good picture of the normal prevalence of hearing loss and the prevention potential. The fact that the method is easy to use makes it suitable for monitoring the development of hearing in a group of workers over time to assess the effectiveness of preventive measures.

The spreadsheet model may also be used on subgroups, such as women or men or special age groups.

The strength of the study is the use of a large reference material from the NTHLS as the screened data has been included in the 2013 revised version of the ISO 1999 recently. We have used various groups of workers to test the spreadsheet model. The variation in the hearing threshold in relation to what is expected is quite large for the 10 occupational groups.

The study has some limitations. We have only specified 2 outcome measures; the Norwegian and the NIOSH definitions of hearing loss. The Norwegian outcome is hardly used anywhere else in the world. The NIOSH outcome is in common use. The NIOSH criterion for hearing loss gives a low prevalence among people < 40 years old. That could mean that the sensitivity using this outcome may be too poor to capture a hearing loss among younger workers. Several other outcome measures are in common use internationally, such as the Occupational Safety and Health Administration (OSHA) or the WHO classification. It is simple to create spreadsheets provided you have the access to reference data, such as the NTHLS or any other reference data found suitable.

The spreadsheet method does not allow for adjustment due to possible confounding with age and sex. This may be important if you only compare with a screened reference population since occupational noise exposure is significantly associated with educational level, leisure time and firearm noise, and smoking which all may have an impact on hearing [17]. Since the spreadsheets used in this study are compared with both a screened and unscreened population, we believe that the lack of control for confounding is of minor importance.

Based on experience, the spreadsheet models should be used with caution for groups of workers smaller than 50. The Chi^2 test in the spreadsheet may be of use in interpreting the results, in particular in the case of small groups.

CONCLUSIONS

The use of a spreadsheet model to compare hearing in various occupational groups with a reference material is a simple and quick method. The results are in line with traditional methods of comparing hearing threshold, and allows for significance testing of deviations from normative data. We believe that the method is useful for occupational health services in the risk assessment of groups of noise-exposed workers with regard to the NIHL and the potential for prevention.

REFERENCES

1. European Agency for Safety and Health at Work. Noise in figures. Report. Luxembourg: Office for Official Publications of the European Communities; 2005.
2. Nelson DI, Nelson RY, Concha-Barrientos M, Fingerhut M. The global burden of occupational noise-induced hearing loss.

Am J Ind Med. 2005;48(6):446–58, http://dx.doi.org/10.1002/ajim.20223.

3. World Health Organization. Occupational noise: Assessing the burden of disease from work-related hearing impairment at national and local levels. Geneva: The Organization; 2004.
4. Dobie RA. The burdens of age-related and occupational noise-induced hearing loss in the United States. Ear Hear. 2008;29(4):565–77, http://dx.doi.org/10.1097/AUD.0b013e31817349ec.
5. Samant Y, Lysberg K, Landrø M, Eriksen T, Wergeland E. [Doctors report of noise induced hearing loss]. Tidsskr Nor Laegeforen. 2014;134(20):1950–4, http://dx.doi.org/10.4045/tidsskr.13.1321. Norwegian.
6. Engdahl B, Tambs K. Occupation and the risk of hearing impairment – Results from the Nord-Trøndelag study on hearing loss. Scand J Work Environ Health. 2010;36(3):250–7, http://dx.doi.org/10.5271/sjweh.2887.
7. ISO 1999:2013. Acoustics – Estimation of noise-induced hearing loss. Geneva: International Organization for Standardization; 2013
8. Nondahl DM, Shi X, Cruickshanks KJ, Dalton DS, Tweed TS, Wiley TL, et al. Notched audiograms and noise exposure history in older adults. Ear Hear. 2009;30(6):696–703, http://dx.doi.org/10.1097/AUD.0b013e3181b1d418.
9. Osei-Lah V, Yeoh L. High frequency audiometric notch: An outpatient clinic survey. Int J Audiol. 2010;49(2):95–8, http://dx.doi.org/10.3109/14992020903300423.
10. Rabinowitz PM. The public health significance of noise-induced hearing loss. In: Le Prell CG, Henderson D, Fay RR, Popper AN, editors. Noise-induced hearing loss. New York: Springer New York; 2012. p. 13–25, http://dx.doi.org/10.1007/978-1-4419-9523-0_2.
11. Labour Inspection Authority. [Hearing assessment in noise exposed workers] [Internet]. Trondheim: Arbeidstilsynet; 2013 [cited 2015 Jun 10]. Available from: http://www.arbeidstilsynet.no/binfil/download2.php?tid=77943. Norwegian.
12. Adera T, Amir C, Anderson L. Use of comparison populations for evaluating the effectiveness of hearing loss prevention programs. AIHAJ. 2000;61(1):11–5.
13. Leensen MCJ, Duivenbooden JC, Dreschler WA. A retrospective analysis of noise-induced hearing loss in the Dutch construction industry. Int Arch Occup Environ Health. 2011;84(5):577–90, http://dx.doi.org/10.1007/s00420-010-0606-3.
14. Clark WW, Bohl CD. Hearing levels of firefighters: Risk of occupational noise-induced hearing loss assessed by cross-sectional and longitudinal data. Ear Hear. 2005;26(3):327–40, http://dx.doi.org/10.1097/00003446-200506000-00008.
15. Guest M, Boggess M, Attia J. Relative risk of elevated hearing threshold compared to ISO 1999 normative populations for Royal Australian Air Force male personnel. Hear Res. 2012;285(1–2):65–76, http://dx.doi.org/10.1016/j.heares.2012.01.007.
16. Engdahl B, Tambs K, Borchgrevink HM, Hoffman HJ. Screened and unscreened hearing threshold levels for the adult population: Results from the Nord-Trøndelag Hearing Loss Study. Int J Audiol. 2005;44(4):213–30, http://dx.doi.org/10.1080/14992020500057731.
17. Lie A, Skogstad M, Johnsen TS, Engdahl B, Tambs K. Hearing status among Norwegian train drivers and train conductors. Occup Med (Lond). 2013;63(8):544–8, http://dx.doi.org/10.1093/occmed/kqt114.
18. Lie A, Skogstad M, Johnsen TS, Engdahl B, Tambs K. A cross-sectional study of hearing thresholds among 4627 Norwegian train and track maintenance workers. BMJ Open. 2014;4(10):e005529, http://dx.doi.org/10.1136/bmjopen-2014-005529.
19. Agrawal Y, Niparko JK, Dobie RA. Estimating the effect of occupational noise exposure on hearing thresholds: The importance of adjusting for confounding variables. Ear Hear. 2010;31(2):234–7, http://dx.doi.org/10.1097/AUD.0b013e3181c6b9fd.