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Systematic Review
Revisão Sistemática

Cochrane method for systematic review and meta-analysis of interventions to prevent occupational noise-induced hearing loss – abridged

Revisão sistemática e metanálise Cochrane de intervenções para prevenção de perda auditiva ocupacional induzida por ruído – abreviada

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Keywords

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Occupational Noise
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ABSTRACT

Purpose: Assess the effect of non-pharmaceutical interventions at work on noise exposure or occupational hearing loss compared to no or alternative interventions. **Research strategies:** Pubmed, Embase, Web of Science, OSHupdate, Cochrane Central and Cumulative Index to Nursing and Allied Health Literature (CINAHL) were searched. **Selection criteria:** Randomized Controlled Trials (RCT), Controlled Before-After studies (CBA) and Interrupted Time-Series studies (ITS) evaluating engineering controls, administrative controls, personal hearing protection devices, and hearing surveillance were included. Case studies of engineering controls were collected. **Data analysis:** Cochrane methods for systematic reviews, including meta-analysis, were followed. **Results:** 29 studies were included. Stricter legislation can reduce noise levels by 4.5 dB(A) (very low-quality evidence). Engineering controls can immediately reduce noise (107 cases). Eleven RCTs and CBA studies (3725 participants) were evaluated through Hearing Protection Devices (HPDs). Training of earplug insertion reduces noise exposure at short term follow-up (moderate quality evidence). Earmuffs might perform better than earplugs in high noise levels but worse in low noise levels (very low-quality evidence). HPDs might reduce hearing loss at very long-term follow-up (very low-quality evidence). Seventeen studies (84028 participants) evaluated hearing loss prevention programs. Better use of HPDs might reduce hearing loss but other components not (very low-quality evidence). **Conclusion:** Hearing loss prevention and interventions modestly reduce noise exposure and hearing loss. Better quality studies and better implementation of noise control measures and HPDs is needed.

Descritores

Perda Auditiva Provocada por Ruído
Ruído Ocupacional
Dispositivos de Proteção Auditiva
Revisão Sistemática
Metanálise

RESUMO

Objetivo: Avaliar o efeito de intervenções no trabalho sobre a exposição ao ruído ou a perda auditiva em comparação com ausência ou intervenções alternativas. **Estratégia de pesquisa:** Buscas em Pubmed, Embase, Web of Science, OSHupdate, Cochrane Central e CINAHL. **Critérios de seleção:** Incluídos ensaios clínicos randomizados (ECR), estudos controlados pré/pós-intervenção (ECPPI) e estudos de séries temporais interrompidas (SIT) avaliando controles de engenharia, administrativos, equipamentos de proteção auditiva (EPAs) e vigilância auditiva. Coletados estudos de caso de engenharia. **Análise dos dados:** Cochrane para revisões sistemáticas, incluindo metanálise. **Resultados:** Foram incluídos 29 estudos. Legislação mais rigorosa pode reduzir níveis de ruído em 4,5 dB(A) (evidência de qualidade muito baixa). Controles de engenharia podem reduzir imediatamente o ruído (107 casos). Onze ECR e ECPPI (3.725 participantes) avaliaram EPAs. Treinamento para inserção do EPA reduz a exposição ao ruído no acompanhamento de curto prazo (evidência de qualidade moderada). Protetores tipo concha podem ter desempenho melhor do que protetores de inserção em níveis altos de ruído, mas piores em níveis mais baixos (evidência de qualidade muito baixa). EPAs podem reduzir a perda auditiva no acompanhamento de muito longo prazo (evidência de qualidade muito baixa). Dezessete estudos (84.028 participantes) avaliaram programas de prevenção de perdas auditivas. Um melhor uso do EPA pode reduzir a perda auditiva, mas outros componentes não (evidência de qualidade muito baixa). **Conclusão:** As intervenções para prevenção da perda auditiva reduzem modestamente a exposição ao ruído e a perda auditiva. Estudos de melhor qualidade e melhor implementação de medidas de controle de ruído e EPA são necessários.

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INTRODUCTION

Worldwide millions of workers are exposed to noise levels that increase their risk of hearing disorders[1]. While hearing loss prevention programs (HLPPs) are mandatory in many countries, the reportedly continuing high rate of occupational noise-induced hearing loss (NIHL) casts doubt upon their effectiveness[2]. Moreover, the broad range of interventions included in HLPPs makes it difficult to appraise the most effective strategy. A systematic review of studies that evaluated interventions to reduce occupational exposure to noise or to decrease occupationally induced hearing loss is therefore warranted. This paper summarizes the main results of the second update of the Cochrane review originally published in 2009.

Purpose

To assess the effectiveness of non-pharmaceutical interventions for preventing occupational noise exposure or occupational hearing loss compared to no or alternative interventions.

Research strategy

This is an abridged version of the second update of a Cochrane Review originally published in 2009 based on the methods originally described in the review protocol[3]. Systematic searches were conducted combining search words for the occupational setting, exposure, interventions, and effects on noise or hearing loss. No restrictions on language were used, publication year or publication status and were searched Pubmed, Embase, Web of Science, OSHupdate, Cochrane Central and Cumulative Index to Nursing and Allied Health Literature (CINAHL) databases up until September 2016 (search history in Appendix 1 and Appendix 2). To determine which studies fulfilled the inclusion criteria, pairs of the review authors independently scanned the titles and abstracts of every record retrieved from the databases. Full articles were retrieved for further eligibility assessment.

Data were independently extracted for each included study and resolved discrepancies by discussion. A standard form to extract information about was used: study design, randomisation methods, setting, participants, interventions, outcome measures, follow-up, and adverse events. To assess whether HLPPs are as good as not being exposed, it had to be made an assumption about the minimal clinically relevant hearing loss. Hearing loss was associated with exposure to 85 dB(A) as the minimum amount of damage that should be avoided by the interventions. Based on International Organization for Standardization (ISO) 1990[4], the amount of hearing loss after five years of exposure to 85 dB(A) was calculated for the median, 10th and 90th percentile would be 4.2 dB, 2.1 dB and 6.1 dB, respectively. This is equivalent to a mean of 4.2 dB hearing loss and represents clinically relevant hearing loss[5]. This means, the 95% CI from meta-analysis results on hearing loss can include zero, but not 4.2 to assure that the protected and non-exposed groups are equivalent[6].

Selection criteria

We included studies that 1) used a randomised controlled, controlled before-after, or interrupted time-series study design, 2) included workers exposed to noise levels greater than 80 dB(A), 3) concerned interventions aimed at reduction of noise exposure to prevent NIHL, and 4) used noise exposure or NIHL as an outcome. Case studies on the effects of engineering control interventions without a control group could be included. The results of case studies for the conclusions of the review, as the study design did not fulfil our inclusion criteria, were not used.

Data analysis

Eight authors of recent studies were contacted regarding missing or unclear information and were obtained additional data from three[7-9].

When authors reported results separately for participant groups[10,11] we combined these following the Cochrane Handbook for Systematic Reviews of Interventions guidance[12]. In two studies, multiple interventions were compared with one control group. To avoid using the same control group data more than once, the control group was split into three[13] or two[14] equal subgroups that were subsequently combined in the meta-analysis.

To evaluate the risk of bias, the quality criteria presented by Ramsay et al.[15] for ITS studies was used. For RCTs and cohort studies, the internal validity items by Downs and Black[16] were used that are mostly congruent with the Cochrane 'Risk of bias' tool[17]. We defined studies' overall risk of bias as low if they scored more than 50% of the maximum score.

Sufficiently homogeneous studies, regarding interventions, participants, settings and outcomes in a meta-analysis, were combined. When results were statistically heterogeneous according to the I^2 statistic, a random-effects model for the meta-analysis was used. A sensitivity analysis to assess the influence of risk of bias on the pooled effect sizes was conducted.

We deemed change in hearing level at 4 kHz and Standard Threshold Shifts (STS) as similar outcome measures for hearing effects and calculated Standardized Mean Differences (SMD) to enable combination of both measures in the meta-analysis[18]. For easing interpretation, we transformed the pooled SMDs back to a mean change in hearing level in dB using the median standard deviation of the included studies.

The Grading of Recommendation, Assessment, Development and Evaluation (GRADE) approach to rate the quality of the evidence for each outcome was followed. The grading is based on study design, risk of bias, consistency, directness (generalisability), precision and publication bias across all studies[19]. Overall quality is considered high for RCTs and low for observational studies and can be further reduced or upgraded[20] (Table 1).

Ratings are interpreted as: 1) high-quality evidence is unlikely to change, moderate-quality evidence; 2) further research is likely to have an impact and may change estimates, low-quality evidence; 3) further research is very likely to have an important impact, and very low-quality evidence provides very uncertain effects estimates.

Table 1. Assessment of quality of evidence (GRADE)

Comparison	N Studies	1. RoB?	2. Inconsistent?	3. Indirect?	4. Imprecise?	5. Pub bias?	6. Large ES?	7. DR?	8. Opp Conf	Quality[a]
					Outcome noise					
Legislation vs no legislation	1 ITS	yes	1 study	no	no	1 study	yes	no	no	very low[(1)]
One HPD vs another HPD	1 RCT 4 CBA	2 yes	no	no	no	not shown	no	no	no	low[(1)]
HPD+Instruction vs HPD-instruction	2 RCT	2 no	no	no	yes	not shown	na	na	na	moderate[(7)]
Information vs no information	1 RCT (2 arms)	1 yes	1 study	no	yes	1 study	na	na	na	low[(1,7)]
					Outcome hearing loss					
One HPD vs another HPD (TTS)	2 CBA									no data
Earmuffs vs Earplugs	2 CBA	2 yes	no	no	yes	not shown	no	no	no	very low[(1,7)]
Frequent HPD vs less frequent use	1 CBA	1 yes	1 study	no	yes	1 study	no	no	no	very low[(1)]
HLPP vs audiometry	1 RCT	1 yes	1 study	no	no	1 study	na	na	na	moderate[(1)]
HLPP+exposure information vs HLPP-information	1 CBA	1 yes	1 study	no	yes	1 study	no	no	no	very low[(1,7)]
Frequent HPD in HLPP vs less	5 CBA	5 yes	no	no	yes	not shown	no	no	no	very low[(1,7)]
HLPP vs no exposure	7 CBA	7 yes	no	no	yes	not shown	no	no	no	very low[(1,7)]
Follow-up vs no follow-up	1 CBA	1 yes	1 study	no	yes	1 study	no	no	no	very low[(1,7)]
HLPP+long shifts vs HLPP normal	1 CBA	1 yes	1 study	no	yes	1 study	no	no	no	very low[(1,7)]

1-5 Reasons for downgrading: 1. Risk of bias/Limitations in study design; 2. Inconsistency between studies; 3. Indirectness of PICO; 4. Imprecision of the results; 5. Publication bias; **6-8** Reasons for upgrading: 6. Large effect size. 7. Dose-response relationship 8. Confounding opposes the direction of the effect; [a]Final grading of quality of evidence, between brackets domain that led to down/upgrading the quality; **Caption:** N = number of; ITS = interrupted timeseries analysis; RCT = randomized controlled trial; CBA = controlled before after study; na= not applicable; 1 study = only one study available and impossible to assess consistency or publication bias

The results for the most important comparisons in 'Summary of Findings' (SoF) were presented tables.

RESULTS

29 studies (Figure 1, Table 2, Appendix 1, Appendix 2)[7-11,13,14,21-42] were included. One study evaluated legislation to reduce noise exposure in a 12-year ITS analysis. Thirteen studies with 3725 participants evaluated effects of personal HPDs (three RCTs and ten CBAs). Fifteen studies with 84,028 participants evaluated effects of HLPPs (two RCTs and thirteen CBAs).

While the participants in all studies were described as being exposed to noise at work, these descriptions were often based on measurement methods that were not clearly described. We assumed that the noise exposure was higher than 80 dB(A).

Noise-exposed participants worked in construction, mining, manufacturing, agriculture, forestry, military, an orchestra, unspecified company or in various workplaces. One study did not describe workplaces[40].

In most studies, only men were included or there were mostly male workers at the workplaces studied.

Most studies scored poorly on all aspects of the risk of bias checklist (Figure 2) and only six studies scored an overall low risk of bias[13,22,28,29,37,40].

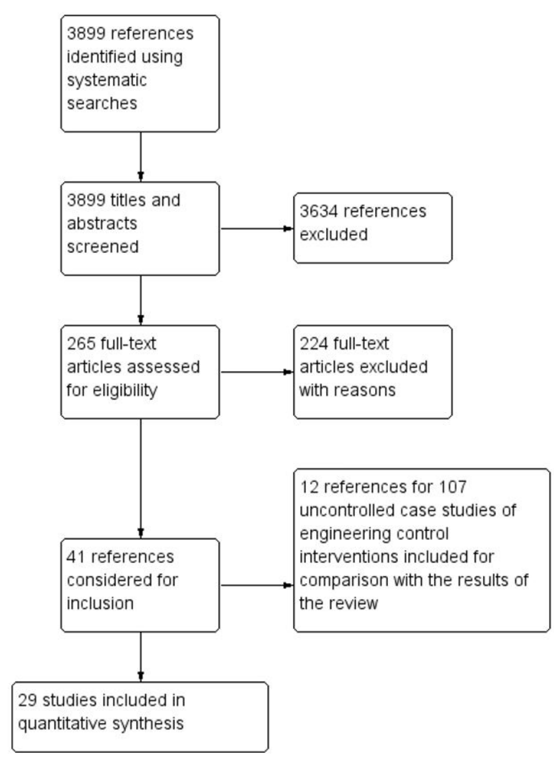

Figure 1. Study flow diagram

Table 2. Overview of study characteristics

Study ID	Design	Participants	Intervention	Outcomes	Follow-up
Forouzanfar et al. (2016)[1] and Adera (1993)[21]	CBA	Various occupations, Military, USA	HLPP	HL	Long-term
Adera et al. (2000)[11]	CBA	Various occupations, n = 19,640, 1 company, USA	HLPP	HL	Long-term
Berg et al. (2009)[22]	RCT	Agricultural students involved in farm work, n = 753, 34 schools, USA	HLPP	HL	Long-term
Brink et al. (2002)[23]	CBA	Automobile workers, n = 264, 1 company, USA	HPD	HL	Long-term
Davies et al. (2008)[7]	CBA	Lumber mills workers, n = 22,376, Canada, British Columbia	HLPP	HL	Long-term
Erlandsson et al. (1980)[24]	CBA	Shipyard workers, n = 40, 1 shipyard, Sweden	HPD	HL	Long-term
Gosztonyi (1975)[25]	CBA	Various occupations in 1 company, n = 142, USA	HLPP	HL	Long-term
Hager et al. (1982)[26]	CBA	Various workers, n = 43, 1 company, USA	HLPP	HL	Long-term
Heyer et al. (2011)[27]	CBA	Workers, n = 6483, 2 automotive plants, 1 food-processing plant, USA	HLPP	HL	Long-term
Horie (2002)[28]	CBA	Steel industry quality check workers, n = 12, 1 company, Japan	HPD	HL	Immediate
Huttunen et al. (2011)[29]	CBA	Orchestra, n = 10, Finland	HPD	NE	Immediate
Joy and Middendorf (2007)[8]	ITS	Coal mines, Workplace measurements n = 142,735 Whole mining branch, USA	Legislation	NE	Long-term
Lee-Feldstein (1993)[30]	CBA	Automobile workers, n = 11,435, 1 company, USA	HLPP	HL	Long-term
Meyer and Wirth (1993)[31]	CBA	Various occupations, n = 1377, Military, USA	HLPP	HL	Long-term
Moshammer et al. 2015[32]	CBA	Fitters and welders, n = 125, steel factory, Austria	HPD	HL	Immediate
Muhr et al. (2006)[13]	CBA	Army conscripts, n = 885, Military, Sweden	HPD	HL	Short term
Muhr et al. (2016)[33]	CBA	Army conscripts, n= 1234, Military, Sweden	HLPP	HL	Short term
Nilsson (1980)[34]	CBA	Ship builders, n = 231, Sweden, 1 shipyard	HPD	HL	Long-term
Pääkkönen et al. (1998)[35]	CBA	Shooter, n=5, Military, Finland	HPD	NE	Immediate
Pääkkönen et al. (2001)[36]	CBA	Air combat plane, n = 2, Military, Finland	HPD	NE	Immediate
Park and Casali (1991) instruction[37]	RCT	Various workers, n = 40, several companies, USA	HPD	HL	Immediate
Park and Casali (1991) protection[37]	RCT	Various workers, n = 40, several companies, USA	HPD	HL	Immediate
Pell (1973)[10]	CBA	Various workers, n = 1572, 1 company, USA	HLPP	HL	Long-term
Rabinowitz et al. 2011[9]	CBA /ITS	Various workers of an aluminium smelter, n = 312	HLPP	NE, HL	Long-term
Reynolds et al. (1990)[38]	CBA	Workers, n = 852, 1 company in the chemical industry, USA	HLPP	HL	Long-term
Royster (1980)[39]	CBA	Workers, n = 70, various occupations, USA	HPD	HL	Immediate
Salmani et al. (2014)[40]	RCT	Workers, n = 150, Iran	HPD	NE	Immediate
Seixas et al. (2011)[14]	RCT	Construction workers, n = 176, USA	HPD	NE	Short term
Simpson et al. (1994)[41]	CBA	Various occupations, n = 13283, 21 companies, USA	HLPP	HL	Long-term

Caption: CBA = controlled before after study, ITS = interrupted time series analysis, RCT = randomised controlled trial, HL = hearing loss, NE = noise exposure, HPD = hearing protection device, HLPP = hearing loss prevention program; n = number

The effect of engineering interventions (following legislation) on noise exposure was evaluated in one ITS study. The study[8] found that new legislation in the mining industry reduced the median personal noise exposure dose in underground coal mining by 27.7 percentage points (95% Confidence Interval (CI) -36.1 to -19.3 percentage points) immediately after the implementation of stricter legislation (Table 3). This roughly translates to a 4.5 dB(A) decrease in noise level. The intervention was associated with a favourable but statistically non-significant downward trend in time of the noise dose of -2.1 percentage points per year (95% CI -4.9 to 0.7, four-year follow-up, very low-quality evidence).

Additionally, 12 case studies were collected reporting on 107 uncontrolled studies of engineering control interventions[43-54]. In most cases[41], authors evaluated design changes, followed by installing damping material and silencers[21], purchasing new equipment[17], using enclosures[15], installing acoustic panels and curtains[13], and maintenance only[7]. Types of jobs, when reported, included operating machines and driving vehicles. The effect of the intervention was measured as change in absolute noise levels in 87 of the 107 cases and as personal noise exposure for workers in 27 cases.

Studies showed immediate reductions in noise levels of machinery ranging from 11.1 to 19.7 dB(A) as a result of purchasing new equipment, segregating noise sources or installing panels or curtains around sources. However, studies lacked long-term follow-up, a control group, and in some cases the outcome was evaluated by an acoustical consultant or an employee at the firm where the intervention was evaluated and a conflict of interest was apparent (14 cases).

	14. Blinding (subjects)	15. Blinding (outcome assessors)	16. Retrospective unplanned subgroup analyses	17. Follow-up	18. Statistical tests	19. Compliance	20. Outcome measures	21. Selection bias (population)	22. Selection bias (time)	23. Randomization	24. Allocation concealment	25. Adjustment for confounding	26. Incomplete outcome data
Adera 1993	-	-	+	+	+	?	+	?	-	-	?	+	?
Adera 2000	-	-	+	+	+	?	?	-	?	-	?	+	?
Berg 2009	-	?	+	+	+	+	+	+	+	?	?	+	+
Brink 2002	-	-	+	?	+	+	+	+	+	-	?	?	?
Davies 2008	-	-	+	+	+	?	?	+	-	-	?	+	?
Erlandsson 1980	-	-	+	+	?	?	+	+	+	-	?	?	?
Gosztonyi 1975	-	-	+	+	+	?	+	+	+	-	?	?	+
Hager 1982	-	-	+	+	+	?	?	+	?	-	?	?	+
Heyer 2011	-	+	+	+	+	?	+	?	?	-	?	+	?
Horie 2002	-	-	+	+	+	?	-	?	+	?	?	+	+
Huttunen 2011	-	-	+	+	?	+	+	+	+	-	-	+	+
Joy 2007													
Lee-Feldstein 1993	-	-	+	+	?	?	+	+	+	-	?	+	?
Meyer 1993	-	-	+	+	+	-	?	+	+	-	?	?	?
Moshammer 2015	-	?	-	+	+	?	+	+	+	-	-	+	-
Muhr 2006	-	-	+	+	+	+	+	+	+	-	?	+	+
Muhr 2016	-	-	+	?	+	?	+	+	-	-	-	+	?
Nilsson 1980	-	-	+	+	?	?	+	-	?	-	?	-	?
Pääkkönen 1998	-	-	+	?	-	+	+	?	+	-	?	?	?
Pääkkönen 2001	-	-	+	+	-	+	+	+	+	-	?	?	?
Park 1991a instructions	-	-	+	+	+	+	+	+	+	+	?	?	+
Park 1991b protection	-	-	+	+	+	+	+	+	+	+	?	?	+
Pell 1973	-	-	+	+	-	?	+	+	+	-	?	-	?
Rabinowitz 2011													
Reynolds 1990a	-	-	+	+	-	?	?	+	?	-	?	?	?
Royster 1980	-	-	+	+	+	?	+	+	+	-	-	+	+
Salmani 2014	?	+	+	+	?	+	+	+	+	?	?	+	+
Seixas 2011	-	?	+	+	?	+	+	+	+	?	?	+	-
Simpson 1994	-	-	+	+	?	?	?	-	?	-	?	?	?

Caption: Adera 1993: Forouzanfar et al.[1] and Adera[21], Adera 2000: Adera et al.[11]; Berg 2009: Berg et al.[22]; Brink 2002: Brink et al. [23]; Davis 2008: Davies et al.[7]; Erlandsson 1980: Erlandsson et al.[24], Gosztonyi 1975: Gosztonyi[25]; Hager 1982: Hager et al.[26]; Heyer 2011: Heyer et al.[27]; Horie 2002: Horie[28]; Huttunen 2011: Huttunen et al.[29]; Joy 2007: Joy & Middendorf[8]; Lee-Feldstein 1993: Lee-Feldstein[30]; Meyer 1933: Meyer & Wirth[31]; Moshammer 2015: Moshammer et al.[32]; Muhr 2006: Muhr et al.[13]; Muhr 2016: Muhr et al.[33]; Nilsson 1980: Nilsson[34]; Pääkkönen 1998: Pääkkönen et al.[35]; Pääkkönen 2001: Pääkkönen et al.[36]; Park 1991a instructions: Park & Casali [37]; Park 1991b protection: Park & Casali [37]; Pell 1973: Pell[10]; Rabinowitz 2011: Rabinowitz et al.[9]; Reynolds 1990: Reynolds et al.[38]; Royster 1980: Royster[39]; Salmani 2014: Salmani et al.[40]; Seixas 2011: Seixas et al.[14]; Simpson 1994: Simpson et al.[41]; (+) = low risk of bias; (-) = high risk of bias; (?) = unknown risk of bias

Figure 2. Risk of bias summary for included studies

The review found no effects for administrative controls on environmental noise exposure. On-site training sessions giving instructions for HPD use and noise control techniques (sound barriers and distance) did not have an effect on personal environmental noise-exposure levels compared to information only in one cluster-RCT after four months' follow-up (Mean Difference (MD) 0.14 dB; 95% CI -2.66 to 2.38). Another arm of the same study found that personal noise exposure information had no effect on noise levels (MD 0.30 dB(A), 95% CI -2.31 to 2.91) compared to no such information (176 participants, low-quality evidence) (Table 4).

HPDs reduced noise exposure on average over various frequencies measured by about 20 dB(A) in one RCT and three CBAs (57 participants, low-quality evidence). There was moderate-quality evidence that personal instructions for inserting earplugs into the ear canal have a considerable effect on the noise attenuation of the devices with an 8.6 dB (95% CI 6.9 to 10.3) higher protection averaged across frequencies (two RCTs[37,40], 140 participants) (Table 5).

The effects of HPDs on hearing loss were measured in short and long-term follow-up studies. Authors of two studies compared different devices and measured temporary threshold shifts at short-term follow-up but reported insufficient data for analysis. In two CBA studies, the authors found no difference in hearing loss from noise exposure above 89 dB (A) between earmuffs and earplugs at long-term follow-up (Odds Ratio

Table 3. SoF table – Stricter legislation (noise exposure)

Stricter legislation compared with existing legislation for noise exposure Patient or population: workers with noise exposure Settings: coal mines Intervention: stricter legislation Comparison: existing legislation					
Outcomes	Illustrative comparative risks* (95% CI)		No of observations (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk			
	Existing legislation	Stricter legislation			
Immediate change in level in year 2000 (noise level at work as PEL dose in dB(A); range 0 to 6400, log scale) 1 year	The mean noise levels during pre-intervention years were 56.9 PEL dose	The mean noise exposure level after introduction was 27.70 PEL dose lower (36.1 lower to 19.3 lower PEL dose)	14 years pre-intervention and 4-years post-intervention (1 ITS)	⊕⊝⊝⊝ **very low1**	The reduction of 27.7 PEL dose translates to about 4.5 dB(A)
Change in slope after introduction (noise level at work as PEL dose in dB(A); range 0 to 6400, log scale) 4 years	The mean noise levels during pre-intervention years were 56.9 PEL dose	The mean change in level of noise exposure per year after introduction was 2.10 PEL dose lower (4.90 lower to 0.70 PEL dose higher)	14 years pre-intervention and 4 years post-intervention (1 ITS)	⊕⊝⊝⊝ **very low**[1]	

GRADE Working Group grades of evidence. High quality: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate quality: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; Low quality: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low quality: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the assumed ris**k** (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the absolute effect of the intervention (and its 95% CI); [1]We downgraded by one level from low to very low because there is only one study and it has a high risk of bias
Caption: CI: Confidence interval; **PEL**: permissible exposure level; **ITS:** interrupted time series analysis

Table 4. SoF table – Training plus exposure information versus training (noise exposure)

Exposure information compared with training as usual for noise exposure **Patient or population:** workers exposed to noise **Settings:** construction industry **Intervention:** provision of noise level indicator **Comparison:** safety training as usual					
Outcomes	Illustrative comparative risks* (95% CI)		No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk			
	Training as usual	Plus noise level indicator			
Change in noise levels at 4 months' follow-up (dB(A))	The mean noise level in the control group ranged from 87.1 to 89 dB(A)	The mean noise level in the intervention groups was 0.3 dB(A) higher (2.31 dB(A) lower to 2.91 dB(A) higher	176 (1 RCT)	⊕⊕⊝⊝ **low**[1]	

GRADE Working Group grades of evidence. High quality: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate quality: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; Low quality: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low quality: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI); [1]We downgraded by two levels from high to low because of high risk of bias and imprecision
Caption: CI: Confidence interval; **RCT**: randomized controlled trial

(OR) 0.8, 95% CI 0.63 to 1.03, very low-quality evidence) (Table 6). The long-term evaluation of the effect of earmuffs versus earplugs on hearing loss showed that earmuffs might perform better than earplugs in high noise levels, but worse in low noise levels (very low-quality evidence).

Authors of another CBA study found that wearing HPDs more often resulted in less hearing loss at very long-term follow-up (very low-quality evidence).

Studies also evaluated the effects of the combination of interventions in a hearing loss prevention programmes on noise exposure and hearing loss. One RCT found no significant effect in lowering noise level with the use of noise level indicators plus basic information or plus intensive information compared to basic information only at two- and four-months follow-up. The noise level decreased 0.32 dB more in the control group at two months (95% CI -2.44, 3.08) but 0.14 dB more in the intervention group at four months (95%CI -2.66 to 2.38). Neither were statistically significant. Also, the comparison of intensive versus basic information showed no significant differences in noise levels at two (-1.7dB, 95% CI -1.24 to 4.64) and four months (0.3 dB, 95% CI -2.31 to 2.91).

One cluster-RCT found no difference in hearing loss at three- or 16-year follow-up between an intensive HLPP for agricultural students and audiometry only (moderate-quality evidence) (Table 7). One CBA study found no reduction of the rate of hearing loss (MD -0.82 dB per year (95% CI -1.86 to 0.22) for a HLPP that provided regular personal noise exposure information compared to a program that did not provide such information (Table 8).

There was very low-quality evidence in four long-term studies, that better use of HPDs as part of a HLPP decreased the risk of hearing loss compared to less well used HPDs in HLPPs (OR 0.40, 95% CI 0.23 to 0.69) (Table 9).This could not be shown for worker training, audiometry alone or noise monitoring by very low- and moderate-quality evidences. More individualized information on daily noise exposure as part of a HLPP showed favourable but non-significant effects on hearing loss in one study.

Table 5. SoF table – Earplugs with instruction versus no instruction (noise exposure)

Earplugs with instruction compared with no instruction for noise reduction					
Patient or population: workers with exposure to noise **Settings:** industrial **Intervention:** instruction on how to insert earplugs **Comparison:** no instruction					
Outcomes	Illustrative comparative risks* (95% CI)		No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk			
	Without instruction	With instruction			
Mean noise attenuation over 0.5, 1, 2, 3, 4, 6, 8 kHz (dB) Immediate follow-up	The mean noise attenuation ranged across frequencies from 5.5 to 25.9 dB	The mean noise attenuation in the intervention groups was 8.59 dB higher (6.92 dB higher to 10.25 dB higher)	140 participants (2 RCTs)	⊕⊕⊕⊝ **moderate**[1]	

GRADE Working Group grades of evidence. High quality: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate quality: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; Low quality: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low quality: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI); [1]We downgraded from high quality by one level because of imprecision due to small number of participants

Caption: CI: Confidence interval; **RCT**: randomized controlled trial; **RCTs**: randomized controlled trials

Table 6. SoF table – Earmuffs versus earplugs (hearing loss)

Earmuffs compared with earplugs for noise-induced hearing loss (NIHL)						
Patient or population: workers exposed to 88-94 dB(A) **Settings**: shipyard **Intervention**: most wearing earmuffs **Comparison**: most wearing earplugs						
Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Earplugs	Earmuffs				
Hearing loss change over 3 years (4 kHz/STS) 2 to 3 years' follow-up	**High risk population**		OR 0.8 (0.63 to 1.03)	3242 (2 CBA studies)	⊕⊝⊝⊝ **very low**[1]	At lower exposures the results were too heterogeneous to be combined
	42 per 1000	**34 per 1000** (26 to 43)				

GRADE Working Group grades of evidence. High quality: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate quality: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; Low quality: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low quality: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI), [1]We downgraded from low quality to very low quality because of high risk of bias in both studies; **Caption: CI:** Confidence interval; **OR:** Odds Ratio; **STS**: standard threshold shift; **CBA**: controlled before after study.

Table 7. SoF table - HLPP versus audiometry (hearing loss)

Hearing loss prevention programme (HLPP) compared to audiometric testing						
Patient or population: agricultural students without hearing loss **Settings:** agricultural schools **Intervention:** HLPP with information **Comparison:** audiometric testing only						
Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Audiometric testing only	HLPP with information				
Hearing loss STS ≥ 10 dB loss average over 2, 3, 4 kHz in either ear Follow-up: mean three years	**21 per 1000**	**18 per 1000** (6 to 49)	**OR 0.85** (0.29 to 2.44)	687 (1 study, RCT)	⊕⊕⊕⊝ **moderate**[1]	
Hearing loss STS ≥ 10 dB hearing loss average over 2, 3, 4 kHz in either ear Follow-up: mean 16 years	**149 per 1000**	**141 per 1000** (74 to 250)	**OR 0.94** (0.46 to 1.91)	355 (1 study, RCT)	⊕⊕⊕⊝ **moderate**[1]	

GRADE Working Group grades of evidence. High quality: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate quality: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; Low quality: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low quality: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI); [1]We downgraded one level from high to moderate due to lack of information on randomisation and allocation concealment

Caption: CI: Confidence interval; **HLPP**; hearing loss prevention programme; **OR:** Odds ratio; **STS**: standard threshold shift; **RCT**: randomized controlled trial

Table 8. SoF table - HLPP with exposure information versus HLPP without (hearing loss)

HLPP with exposure information compared with HLPP without exposure information for noise-induced hearing loss (NIHL)					
Patient or population: workers exposed to noise **Settings:** aluminium smelter **Intervention:** exposure information as part of HLPP **Comparison:** no such information					
Outcomes	Illustrative comparative risks* (95% CI)		No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk			
	Without exposure info	With exposure info			
Annual increase in hearing threshold (dB/year at 2,3 and 4 kHz) 4-year follow-up	The mean hearing loss rate in the control group was 1.0 dB per year	The mean hearing loss rate in the intervention groups was 0.82 dB/year lower (1.86 lower to 0.22 higher)	312 (1 CBA study)	⊕⊝⊝⊝ **very low**[1]	Matched for age, gender, baseline hearing loss and baseline hearing

GRADE Working Group grades of evidence. High quality: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate quality: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; Low quality: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low quality: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI); We downgraded by one level from low to very low because of high risk of bias

Caption: CI: Confidence interval; **HLPP**: hearing loss prevention programme; **CBA**: controlled before after study

In the meta-analysis of four long-term CBA studies the difference in mean changes in hearing level at 4 kHz was 0.53 dB (95%CI -0.53 to 1.68)[10,25,26,30]. We performed a sensitivity-analysis and left out one study[10] that had a high risk of bias due to a 10-year age difference between the intervention and the non-exposed group, which could explain a difference of 7dB hearing thresholds (calculated based on ISO 1990[4]). Sensitivity analysis results showed workers in a HLPP had a statistically non-significant 1.8 dB (95% CI -0.6 to 4.2) greater hearing loss at 4 kHz than non-exposed workers (very low-quality evidence, Table 10). The confidence interval includes a possible hearing loss of 4.2 dB which is similar to the level of hearing loss resulting from five years of exposure to 85 dB(A), which means workers might still be at risk of a clinically relevant hearing loss.

In addition, out of three other CBA studies that could not be included in the meta-analysis, two showed an increased risk of hearing loss in spite of the protection of a HLPP compared to non-exposed workers[13,38] and one CBA did not[33].

Table 9. SoF table - Better implemented versus less well-implemented HLPP (hearing loss)

Well-implemented hearing loss prevention programme (HLPP) compared to less well-implemented HLPP for hearing loss						
Patient or population: workers **Settings:** exposure to noise **Intervention:** well-implemented HLPP **Comparison:** less well-implemented HLPP						
Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Less well-implemented HLPP	Well-implemented HLPP				
Hearing loss STS > 10 dB change average over 2, 3 and 4 kHz[1]; Follow-up: mean 9.3 years	**86 per 1000**	**36 per 1000** (21 to 61)[2]	**OR 0.40** (0.23 to 0.69)[3]	16,301 (3 studies[4])	⊕⊖⊖⊖ **very low**[5]	SMD 0.26 (0.14 to 0.47)

GRADE Working Group grades of evidence. High quality: we are very confident that the true effect lies close to that of the estimate of the effect; Moderate quality: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; Low quality: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; Very low quality: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the assumed risk (e.g. the median control group risk across studies) is provided in footnotes. The corresponding risk (and its 95% confidence interval) is based on the assumed risk in the comparison group and the relative effect of the intervention (and its 95% CI); [1]STS used in two studies, change of mean 4 kHz threshold in one study; [2]Number of events based on median event rate in included studies; [3]Result from the meta-analysis of three studies; [4]One extra study provided similar evidence but could not be combined in the meta-analysis; [5]We downgraded by one level from low to very low because of risk of bias due to lack of adjustment for age and hearing loss
Caption: CI: Confidence interval; **HLPP**: hearing loss prevention programme; **OR:** Odds ratio; **STS**: standard threshold shift; **SMD**: standardized mean difference

Table 10. SoF table - HLPP versus non-exposed workers (hearing loss)

Hearing loss prevention programme (HLPP) compared to non-exposed workers						
Patient or population: workers **Settings:** exposure to noise **Intervention:** HLPP **Comparison:** non-exposed workers						
Outcomes	Illustrative comparative risks* (95% CI)		Relative effect (95% CI)	No of participants (studies)	Quality of the evidence (GRADE)	Comments
	Assumed risk	Corresponding risk				
	Non-exposed workers	HLPP				
Hearing loss Change in hearing threshold at 4 kHz in dB; Follow-up: mean 5 years	The mean hearing loss in the control groups was **3.6 dB at 4 kHz**[1]	The mean hearing loss in the intervention groups was **1.8 dB higher** (0.6 lower to 4.2 higher)		1846 (3 studies[2])	⊕⊖⊖⊖ **very low**[3,4]	pooled effect size 0.17 (95% CI -0.06 to 0.40) recalculated into dBs

GRADE Working Group grades of evidence. **High quality**: we are very confident that the true effect lies close to that of the estimate of the effect; **Moderate quality**: we are moderately confident in the effect estimate; the true effect is likely to be close to the estimate of effect, but there is a possibility that it is substantially different; **Low quality**: our confidence in the effect estimate is limited; the true effect may be substantially different from the estimate of the effect; **Very low quality**: we have very little confidence in the effect estimate; the true effect is likely to be substantially different from the estimate of effect; *The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% confidence interval) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI); Assumed increase of hearing threshold: median of three studies with respectively 3.4, 3.6 and 5.2 dB increase in hearing threshold at 4 kHz after five years' follow-up; [2]Results from three of five studies were included in sensitivity analysis because one study was at serious risk of bias and one other study showed that in spite of hearing protection workers were still more at risk than non-exposed workers; [3]We downgraded by one level from low to very low because three studies did not adjust for age and hearing loss at baseline; [4]We would have downgraded by one more level because the confidence interval does not exclude a risk of hearing loss similar to exposure to 85 dB(A) but we had already reached a rating of very low quality evidence
Caption: CI: Confidence interval; **HLPP**: hearing loss prevention programme

DISCUSSION

We could not find any controlled studies, in which technical measures to reduce workers' noise exposures were evaluated at the company level. Some argue that control groups are not necessary because the effect can be measured immediately[(55)]. On the other hand, the measurement of noise levels in real working life can be biased by many operational and environmental factors. To address this issue, we systematically collected case studies. The immediate results of those studies are similar to those of HPDs. Noise control can potentially make HPDs in workplaces unnecessary, along with other components of hearing conservation programs. However, for most case studies, it was unclear if the measured reductions also effected personal noise level exposure. Other case studies measured personal noise exposure of workers but did not report measurement protocols and the personal effect remains uncertain. Moreover, long-term follow-up is missing and it is unclear if these are lasting solutions. Many potential biases in the uncontrolled studies would be remediated by the use of control groups, better reporting of noise measurement protocols and long-term follow-up measurements.

No studies evaluated the effectiveness of recommendations from occupational health services, national agencies or occupational health professionals to reduce noise levels. Regulations regarding noise at work can make it difficult to challenge current practice in experiments.

For immediate effects of HPDs, we restricted our inclusion criteria to field studies among workers and excluded studies that made use of volunteers or were carried out in the laboratory. All excluded studies showed a benefit of extra instruction compared to less or no instruction(56-59). The increase in attenuation was similar to that found in our review. We only included studies that compared different devices worn by the same workers because the evaluation depends to a great extent on the wearer. That criterion excluded a great number of studies that evaluated different devices worn by different workers, but provided us with more reliable results.

Researchers who intended to evaluate a HLPP did not clearly define its implementation, which is especially important in studies comparing HLPPs. It is unclear if the results are applicable in other settings and what measures were taken in addition to HPDs (e.g. training).

The risk of bias was high (especially for long-term evaluation studies) because most studies were set up retrospectively and it is difficult to control confounders. Individual factors, such as skills necessary to correctly use HPDs or age, have an important effect on the outcome but only some studies used randomisation to ensure no baseline differences. Consequently, there is a need for better quality evidence. It has often been argued that randomisation of workers or workplaces is not possible but two studies that evaluated a HLPP (or components thereof) showed that randomisation was feasible, even in difficult sectors such as construction(14,22). Evidence from more RCTs would eventually yield much higher-quality information on the effectiveness of hearing loss prevention programs.

Even though, we made significant efforts to search databases that would contain grey literature seeing that we did not go through conference proceedings. It is therefore possible that we missed retrospective cohort studies or controlled noise-reduction studies.

Publication bias could play a role in the results of the evaluation studies of HLPPs, with four of the studies being funded or carried out by people employed by the company responsible for the intervention, who could possibly have an interest in publishing studies demonstrating a preventative effect of HLPPs(13,33).

Other authors drew similar conclusions to our review but mostly applied less systematic approaches.

One review located 22 studies that evaluated the field performance of many different types of HPDs worn by different workers(60,61). The inclusion criteria of these studies were essentially different from ours because only studies comparing devices among the same subjects were included. However, the conclusions from all these studies are in agreement: under field conditions the noise attenuation of HPDs is much less than under laboratory conditions.

Another review concluded that the evidence from long-term evaluation studies does not support HLPPs' effectiveness(62), but the search for studies was not systematic. The review included five studies, of which four were also included in this review. His conclusions for the effectiveness of HLPPs are similar to ours.

Authors from other studies reviewed occupational NIHL data(63), evaluated the quality of HLPPs in companies(64), or performed a narrative review directed at the mining sector alone(65). All studies concluded either that HLPPs are ineffective, or programs are commonly incomplete and miss noise control interventions.

There is very low-quality evidence that implementation of stricter legislation can reduce noise levels in workplaces. Case studies showed promising effects of engineering control on noise reduction at immediate follow-up but controlled studies and evaluation of the long-term effects are missing. It is unclear if results can be replicated in other workplaces and what the long-term effects are.

Under field conditions the average noise reduction of HPDs is lower than indicated ratings provided by the manufacturers. There is moderate-quality evidence that training of proper insertion of earplugs significantly reduces noise exposure at short-term follow-up but long-term follow-up is still needed.

There is very low-quality evidence that the better use of HPDs as part of HLPPs reduces the risk of hearing loss, whereas for other program components of HLPP we found no effect. The absence of conclusive evidence should not be interpreted as evidence of lack of effectiveness. Rather, it means that further research is very likely to have an important impact.

Future studies should use randomised design for HPDs or comparisons of different HLPPs or single programme components, or different levels of implementation in a cluster-randomised design. The ITS design has potential for evaluating HLPPs because much data is collected routinely.

CONCLUSION

Hearing loss prevention interventions modestly reduce noise exposure and hearing loss. Better quality studies and better implementation of noise control measures and HPDs is needed.

Disclaimer

The findings and conclusions in this report are those of the author(s) and do not necessarily represent the views of the National Institute for Occupational Safety and Health.

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REFERENCES

1. Forouzanfar MH, Afshin A, Alexander LT, Anderson HR, Bhutta ZA, Biryukov S, et al. Global, regional, and national comparative risk assessment of 79 behavioural, environmental and occupational, and metabolic risks or clusters of risks, 1990-2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet. 2016;388(10053):1659-724. http://dx.doi.org/10.1016/S0140-6736(16)31679-8. PMid:27733284.
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. PMid:16299704.
3. Kateman E, Verbeek JH, Morata T, Coolsma B, Dreschler W, Sorgdrager B. Interventions to prevent occupational noise-induced hearing loss. Cochrane Database Syst Rev. 2017;7:CD006396. http://dx.doi.org/10.1002/14651858.CD006396.pub4.
4. ISO: International Organization for Standardization. ISO 4869-1: Acoustics - Hearing Protectors - Part 1: Subjective method for the measurement of sound attenuation. Geneva: ISO; 1990.
5. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range and the size of a sample. BMC Medical Research Methodology. 2005;5:1-13. http://dx.doi.org/10.1186/1471-2288-5-13.
6. Piaggio G, Elbourne DR, Altman DG, Pocock SJ, Evans SJ, CONSORT Group. Reporting of non-inferiority and equivalence randomised trials. JAMA. 2006;295(10):1152-60. http://dx.doi.org/10.1001/jama.295.10.1152. PMid:16522836.
7. Davies H, Marion S, Teschke K. The impact of hearing conservation programs on incidence of noise-induced hearing loss in Canadian workers. Am J Ind Med. 2008;51(12):923-31. http://dx.doi.org/10.1002/ajim.20634. PMid:18726988.
8. Joy G, Middendorf PJ. Noise exposure and hearing conservation in US coal mines, a surveillance report. J Occup Environ Hyg. 2007;4(1):26-35. http://dx.doi.org/10.1080/15459620601067209. PMid:17162478.
9. Rabinowitz PM, Galusha D, Kirsche SR, Cullen MR, Slade MD, Dixon-Ernst C. Effect of daily noise exposure monitoring on annual rates of hearing loss in industrial workers. Occup Environ Med. 2011;68(6):414-8. http://dx.doi.org/10.1136/oem.2010.055905. PMid:21193566.
10. Pell S. An evaluation of hearing conservation program - a five-year longitudinal study. Am Ind Hyg Assoc J. 1973;34(2):82-91. http://dx.doi.org/10.1080/0002889738506811. PMid:4715098.
11. Adera T, Amir C, Anderson L. Use of comparison populations for evaluating the effectiveness of hearing loss prevention programs. Am Ind Hyg Assoc J. 2000;61(1):11-5. http://dx.doi.org/10.1202/0002-8894(2000)061<0011:UOCPFE>2.0.CO;2. PMid:10772609.
12. Deeks JJ, Higgins JPT, Altman DG. Analysing data and undertaking meta-analyses. In: Higgins JPT, Green S, editors. Cochrane handbook for systematic reviews of interventions version 5.1.0 [Internet]. United Kingdom: The Cochrane Collaboration; 2011. Chapter 9 [cited 2019 May 26]. Available from: handbookcochraneorg
13. Muhr P, Månsson B, Hellström PA. A study of hearing changes among military conscripts in the Swedish army. Int J Audiol. 2006;45(4):247-51. http://dx.doi.org/10.1080/14992020500190052. PMid:16684706.
14. Seixas NS, Neitzel R, Stover B, Sheppard L, Daniell B, Edelson J, et al. A multi-component intervention to promote hearing protector use among construction workers. Int J Audiol. 2011;50(Suppl 1):s46-56. http://dx.doi.org/10.3109/14992027.2010.525754. PMid:21091403.
15. Ramsay CR, Matowe L, Grilli R, Grimshaw JM, Thomas RE. Interrupted time series designs in health technology assessment: lessons from two systematic reviews of behavior change strategies. Int J Technol Assess Health Care. 2003;19(4):613-23. http://dx.doi.org/10.1017/S0266462303000576. PMid:15095767.
16. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. J Epidemiol Community Health. 1998;52(6):377-84. http://dx.doi.org/10.1136/jech.52.6.377. PMid:9764259.
17. Higgins JPT, Altman DG, Sterne JAC. Assessing risk of bias in included studies. In: Higgins JPT, Green S, editors. Cochrane handbook for systematic reviews of interventions version 5.1.0 [Internet]. United Kingdom: The Cochrane Collaboration; 2011. Chapter 8 [cited 2019 May 26]. Available from: handbookcochraneorg
18. Chinn S. A simple method for converting an odds ratio to effect size for use in meta-analysis. Stat Med. 2000;19(22):3127-31. http://dx.doi.org/10.1002/1097-0258(20001130)19:22<3127::AID-SIM784>3.0.CO;2-M. PMid:11113947.
19. Balshem H, Helfand M, Schünemann HJ, Oxman AD, Kunz R, Brozek J, et al. GRADE guidelines: 3. Rating the quality of evidence. J Clin Epidemiol. 2011;64(4):401-6. http://dx.doi.org/10.1016/j.jclinepi.2010.07.015. PMid:21208779.
20. Cuello-Garcia CA, Morgan RL, Brozek J, Santesso N, Verbeek J, Thayer K, et al. A scoping review and survey provides the rationale, perceptions, and preferences for the integration of randomized and nonrandomized studies in evidence syntheses and GRADE assessments. J Clin Epidemiol. 2018;98:33-40. http://dx.doi.org/10.1016/j.jclinepi.2018.01.010. PMid:29452221.
21. Adera T, Donahue AM, Malit BD, Gaydos JC. An epidemiologic method for assessing the effectiveness of hearing conservation programs using audiometric data. Mil Med. 1993;158(11):698-701. http://dx.doi.org/10.1093/milmed/158.11.698. PMid:8284053.
22. Berg RL, Pickett W, Fitz-Randolph M, Broste SK, Knobloch MJ, Wood DJ, et al. Hearing conservation program for agricultural students: short-term outcomes from a cluster-randomised trial with planned long-term follow-up. Prev Med. 2009;49(6):546-52. http://dx.doi.org/10.1016/j.ypmed.2009.09.020. PMid:19800914.
23. Brink LL, Talbott EO, Burks JA, Palmer CV. Changes over time in audiometric thresholds in a group of automobile stamping and assembly workers with a hearing conservation program. Am Ind Hyg Assoc J. 2002;63(4):482-7. http://dx.doi.org/10.1080/15428110208984737. PMid:12486782.
24. Erlandsson B, Hakanson H, Ivarsson A, Nilsson P. The difference in protection efficiency between earplugs and earmuffs. An investigation performed at a workplace. Scand Audiol. 1980;9(4):215-21. http://dx.doi.org/10.3109/01050398009076356. PMid:7466283.
25. Gosztonyi RE Jr. The effectiveness of hearing protective devices. J Occup Med. 1975;17(9):569-80. PMid:1165499.
26. Hager WL, Hoyle ER, Hermann0 ER. Efficacy of enforcement in an industrial hearing conservation program. Am Ind Hyg Assoc J. 1982;43(6):455-65. http://dx.doi.org/10.1080/15298668291410035. PMid:7113926.
27. Heyer N, Morata TC, Pinkerton LE, Brueck SE, Stancescu D, Panaccio MP, et al. Use of historical data and a novel metric in the evaluation of the effectiveness of hearing conservation program components. Occup Environ Med. 2011;68(7):510-7. http://dx.doi.org/10.1136/oem.2009.053801. PMid:21059594.
28. Horie S. Improvement of occupational noise-induced temporary threshold shift by active noise control earmuff and bone conduction microphone. J Occup Health. 2002;44(6):414-20. http://dx.doi.org/10.1539/joh.44.414.
29. Huttunen KH, Sivonen VP, Poykko VT. Symphony orchestra musicians' use of hearing protection and attenuation of custom-made hearing protectors as measured with two different real-ear attenuation at threshold methods. Noise Health. 2011;13(51):176-88. http://dx.doi.org/10.4103/1463-1741.77210. PMid:21368443.
30. Lee-Feldstein A. Five-year follow-up study of hearing loss at several locations within a large automobile company. Am J Ind Med. 1993;24(1):41-54. http://dx.doi.org/10.1002/ajim.4700240105. PMid:8352292.
31. Meyer GD, Wirth DB. An evaluation of the U.S. Air Force's detailed follow-up audiometric examination program. Mil Med. 1993;158(9):603-5. http://dx.doi.org/10.1093/milmed/158.9.603. PMid:8232998.
32. Moshammer H, Kundi M, Wallner P, Herbst A, Feuerstein A, Hutter HP. Early prognosis of noise-induced hearing loss. Occup Environ Med. 2015;72(2):85-9. http://dx.doi.org/10.1136/oemed-2014-102200. PMid:25063775.
33. Muhr P, Johnson AC, Skoog B, Rosenhall U. A demonstrated positive effect of a hearing conservation program in the Swedish armed forces. Int J Audiol. 2016;55(3):168-72. http://dx.doi.org/10.3109/14992027.2015.1117662. PMid:26754548.

34. Nilsson R, Lindgren F. The effect of long term use of hearing protectors in industrial noise. Scand Audiol Suppl. 1980;(Suppl 12):204-11. PMid:6939090.

35. Pääkkönen R, Lehtomaki K, Savolainen S. Noise attenuation of communication hearing protectors against impulses from assault rifle. Mil Med. 1998;163(1):40-3. http://dx.doi.org/10.1093/milmed/163.1.40. PMid:9465571.

36. Pääkkönen R, Kuronen P, Korteoja M. Active noise reduction in aviation helmets during a military jet trainer test flight. Scand Audiol Suppl. 2001;52(52):177-9. http://dx.doi.org/10.1080/010503901300007452. PMid:11318460.

37. Park MY, Casali JG. A controlled investigation of in-field attenuation performance of selected insert, earmuff, and canal cap hearing protectors. Hum Factors. 1991;33(6):693-714. http://dx.doi.org/10.1177/001872089103300606. PMid:1800294.

38. Reynolds JL, Royster LH, Pearson RG. Hearing conservation programs (HCPs): the effectiveness of one company's HCP in a 12-hr work shift environment. Am Ind Hyg Assoc J. 1990;51(8):437-46. http://dx.doi.org/10.1080/15298669091369907. PMid:2392973.

39. Royster LH. An evaluation of the effectiveness of two different insert types of ear protection in preventing TTS in an industrial environment. Am Ind Hyg Assoc J. 1980;41(3):161-9. http://dx.doi.org/10.1080/15298668091424546. PMid:7395724.

40. Salmani Nodoushan M, Mehrparvar AH, Torab Jahromi M, Safaei S, Mollasadeghi A. Training in using earplugs or using earplugs with a higher than necessary noise reduction rating? A randomized clinical trial. Int J Occup Environ Med. 2014;5(4):187-93. PMid:25270008.

41. Simpson TH, Stewart M, Kaltenbach JA. Early indicators of hearing conservation program performance. J Am Acad Audiol. 1994;5(5):300-6. PMid:7987019.

42. Moshammer H, Kundi M, Wallner P, Herbst A, Feuerstein A, Hutter HP. Author response: comments on TTS as a predictor of noise-induced hearing loss. Occup Environ Med. 2015;72(2):160-1. http://dx.doi.org/10.1136/oemed-2014-102644. PMid:25406475.

43. Azman AS, Yantek DS, Alcorn LA. Evaluations of a noise control for roof bolting machines. Min Eng. 2012;64(12):64-70. PMid:26251555.

44. Caillet J, Marrot F, Unia Y, Aubourg PA. Comprehensive approach for noise reduction in helicopter cabins. Aerosp Sci Technol. 2012;23(1):17-25. http://dx.doi.org/10.1016/j.ast.2012.03.004.

45. Cockrell TW Jr, Balanay JAG, Dawkins W. Engineering control of noise from 4-roll calender operations in tire manufacturing. J Occup Environ Hyg. 2015;12(9):D193-200. http://dx.doi.org/10.1080/15459624.2015.1043053. PMid:25921237.

46. Golmohammadi R, Giahi O, Aliabadi M, Darvishi E. An intervention for noise control of blast furnace in steel industry. J Res Health Sci. 2014;14(4):287-90. PMid:25503285.

47. HSE: Health and Safety Executive. Sound solutions for the food and drink industries: reducing noise in food and drink manufacture. USA: HSE; 2013. 77 p. HSG232.

48. Küpper T, Jansing P, Schöffl V, Van Der Giet S. Does modern helicopter construction reduce noise exposure in helicopter rescue operations? Ann Occup Hyg. 2013;57(1):34-42. PMid:23006816.

49. Maling GC Jr, Wood EW, Lotz G, Lang WW. Reducing employee noise exposure in manufacturing: best practices, innovative techniques, and the workplace of the future. USA: Institute of Noise Control Engineering; 2016.

50. Morata T, Hayden C, Driscoll D, Stephenson CM, Clegg PM, Afanuh S. Preventing hazardous noise and hearing loss during project design and operation. Workplace design solutions. USA: National Institute for Occupational Safety and Health; 2015.

51. Pan J, Paurobally R, Qiu XJ. Active noise control in workplaces. Acoust Aust. 2016;44(1):45-50. http://dx.doi.org/10.1007/s40857-015-0035-2.

52. Thompson JK. Noise control of large mining machines. In: 44th International Congress and Exposition on Noise Control Engineering – INTERNOISE; 2015 Aug 9-12; San Francisco, California. Proceedings. Reston: Institute of Noise Control Engineering; 2015.

53. Wilson P. Top 10 noise control techniques: 2015. Acoust Aust. 2016;44(1):33-43. http://dx.doi.org/10.1007/s40857-015-0039-y.

54. HSE: Health and Safety Executive. A recipe for safety: health and safety in food and drink manufacture. USA: HSE; 2015. HSG252.

55. Glasziou P, Chalmers I, Rawlins M, McCulloch P. When are randomised trials unnecessary? Picking signal from noise. BMJ. 2007;334(7589):349-51. http://dx.doi.org/10.1136/bmj.39070.527986.68. PMid:17303884.

56. Franks JR, Murphy WJ, Johnson JL, Harris DA. Four earplugs in search of a rating system. Ear Hear. 2000;21(3):218-26. http://dx.doi.org/10.1097/00003446-200006000-00005. PMid:10890730.

57. Merry CJ, Sizemore CW, Franks JR. The effect of fitting procedure on hearing protector attenuation. Ear Hear. 1992;13(1):11-8. http://dx.doi.org/10.1097/00003446-199202000-00005. PMid:1541368.

58. Toivonen M, Pääkkönen R, Savolainen S, Lehtomäki K. Noise attenuation and proper insertion of earplugs into ear canals. Ann Occup Hyg. 2002;46(6):527-30. PMid:12176767.

59. Williams W. Instruction and the improvement of hearing protector performance. Noise Health. 2004;7(25):41-7. PMid:15703148.

60. Berger EH, Franks JR, Behar A, Casali JG, Dixon-Ernst C, Kieper RW, et al. Development of a new standard laboratory protocol for estimating the field attenuation of hearing protection devices. Part III. The validity of subject-fit data. J Acoust Soc Am. 1998;103(2):665-72. http://dx.doi.org/10.1121/1.423236. PMid:9479749.

61. Berger EH, Franks JR, Lindgren F. International review of feld studies of hearing protector attenuation. In: Axelsson A, Borchgrevink HM, Hamernik RP, Hellstrom P-A, Henderson D, Salvi RJ, editors. Scientific basis of noise-induced hearing loss. USA: George Thieme Verlag; 1996. p. 361-77.

62. Dobie RA. Prevention of noise-induced hearing loss. Arch Otolaryngol Head Neck Surg. 1995;121(4):385-91. http://dx.doi.org/10.1001/archotol.1995.01890040011002. PMid:7702811.

63. Borchgrevink HM. Does health promotion work in relation to noise? Noise Health. 2003;5(18):25-30. PMid:12631433.

64. Daniell WE, Swan SS, McDaniel MM, Camp JE, Cohen MA, Stebbins JG. Noise exposure and hearing loss prevention programmes after 20 years of regulations in the United States. Occup Environ Med. 2006;63(5):343-51. http://dx.doi.org/10.1136/oem.2005.024588. PMid:16551755.

65. McBride DI. Noise-induced hearing loss and hearing conservation in mining. Occup Med (Lond). 2004;54(5):290-6. http://dx.doi.org/10.1093/occmed/kqh075. PMid:15289584.

Author contributions

CT participated in searching, eligibility screening, quality assessment, data extraction, data analysis, writing and update of the text, comment on drafts of protocol and review and is the guarantor of this review; JV participated in protocol development, searching, eligibility screening, quality assessment, data extraction, data analysis, writing and update of the text, comment on drafts of protocol and review; EK participated in protocol development, searching for trials, eligibility screening, quality assessment of studies, data extraction, review development, comment on drafts of protocol and review; TCM participated in searching for studies, eligibility screening, data extraction, update of the text, comment on drafts of protocol and review, and review of translation into Portuguese; WD participated in eligibility screening, data extraction, comment on drafts of protocol and review. SF participated in eligibility screening, data extraction, comment on drafts of protocol and review, translation into Portuguese.

Appendix 1. Search strategy for CENTRAL

#1 MeSH descriptor Noise, Occupational explode all trees with qualifier: PC
#2 noise AND (reduction OR abatement OR diminishment OR elimination OR "engineering controls" OR "administrative controls")
#3 "hearing loss prevention" OR "hearing conservation" OR "hearing surveillance"
#4 "ear protective device" OR "ear protective devices" OR "hearing protective device" OR "hearing protective devices" OR "hearing protector" OR "hearing protectors" OR "hearing protection" OR "ear muffs" OR "ear plugs" OR "ear defenders"
#5 ("noise reduction" AND "protective equipment")
#6 MeSH descriptor Noise, Occupational explode all trees
#7 "protective equipment"
#8 (#6 AND #7)
#9 (#1 OR #2 OR #3 OR #4 OR #5 OR #8)
2016
#10 (#9) limited to publication year from 2008

Appendix 2. Search strategies for other databases

PubMed	Embase	CINAHL
2009 #1 noise [tiab] AND (reduction [tiab] OR abatement [tiab] OR diminishment [tiab] OR elimination [tiab] OR "engineering controls" [tiab] OR "administrative controls"[tiab]) #2 "hearing loss prevention" [tiab] OR "hearing conservation" [tiab] OR "hearing surveillance" [tiab] #3 "ear protective device" [tiab] OR "ear protective devices" [tiab] OR "hearing protective device" [tiab] OR "hearing protective devices" [tiab] OR "hearing protector" [tiab] OR "hearing protectors" [tiab] OR "hearing protection" [tiab] OR "ear muffs" [tiab] OR "ear plugs" [tiab] OR "ear defenders" [tiab] #4 ("noise reduction" [tiab] AND "protective equipment" [tiab]) #5 "Noise, Occupational/prevention and control"[Mesh] #6 "Noise, Occupational"[Mesh] #7 "protective equipment" [tiab] #8 #6 AND #7 #9 #1 OR #2 OR #3 OR #4 OR #5 OR #8 #10 (effect*[tiab] OR control*[tiab] OR evaluation*[tiab] OR program*[tiab]) AND (work*[tiab] OR worker*[tiab] OR workplace*[tiab] OR occupation*[tiab] OR prevention*[tiab] OR protect*[tiab]) #11 #9 AND #10 **2012** #12 2008:2012[dp] #13 #11 AND #12 **2015** #12 "2012"[Date - Publication]: "3000"[Date - Publication] #13 #11 AND #12 **2016** #12 "2015/08/21"[Date - Publication]: "3000"[Date - Publication] #13 #11 AND #12	**2009** 1 industrial noise/ 2 (protective adj equipment).tw. 3 1 and 2 4 (noise and (reduction or abatement or diminishment or elimination or (engineering adj controls) or (administrative adj controls))).tw. 5 ((hearing adj loss adj prevention) or (hearing adj conservation) or (hearing adj surveillance)).tw. 6 ((ear adj protective adj device) or (ear adj protective adj devices) or (hearing adj protective adj device) or (hearing adj protective adj devices) or (hearing adj protecto) or (hearing adj protectors) or (hearing adj protection) or (ear adj muffs) or (ear adj plugs) or (ear adj defenders)).tw. 7 ((noise adj reduction) and (protective adj equipment)).tw 8 6 or 4 or 3 or 7 or 5 9 ((effect* or control* or evaluation* or program*) and (work or worker* or workplace* or working or occupation* or prevention* or protect*)).tw. 10 8 and 9 11 10 **2012** #1 'industrial noise':de AND [2008-2012]/py #2 protective NEAR/3 equipment AND [2008-2012]/py #3 #1 AND #2 AND [2008-2012]/py #4 noise AND (reduction OR abatement OR diminishment OR elimination OR 'engineering controls' OR 'administrative controls') AND [2008-2012]/py #5 noise:ab,ti AND (reduction:ab,ti OR abatement:ab,ti OR diminishment:ab,ti OR elimination:ab,ti OR 'engineering controls':ab,ti OR 'administrative controls':ab,ti) AND [2008-2012]/py #6 'hearing loss' NEAR/5 prevention AND [2008-2012]/py #7 hearing NEAR/5 conservation AND [2008-2012]/py #8 'hearing surveillance' AND [2008-2012]/py #9 #6 OR #7 OR #8 AND [2008-2012]/py #10 ear NEAR/5 protective AND device* AND [2008-2012]/py #11 hearing NEAR/3 protect* AND [2008-2012]/py #12 ear NEAR/1 muff* AND [2008-2012]/py #13 ear NEAR/1 plug* AND [2008-2012]/py #14 ear NEAR/1 defender* AND [2008-2012]/py #15 #10 OR #11 OR #12 OR #13 OR #14 AND [2008-2012]/py #16 noise NEAR/1 reduct* AND protect* NEAR/1 equipm* AND [2008-2012]/py #17 #3 OR #4 OR #9 OR #15 OR #16 AND [2008-2012]/py #18 effect* OR control* OR evaluation* OR program* AND (work OR worker* OR workplace* OR working OR occupation* OR prevention* OR protect*) AND [2008-2012]/py #19 #17 AND #18 AND [2008-2012]/py #20 #19 AND [embase]/lim AND [2008-2012]/py #21 #20 NOT [medline]/lim AND [2008-2012]/py **2015** same search as in 2012; except change of time span [2008-2012]/py to [2012-2015]/py **2016** same search as in 2012; except change of time span [2012-2015]/py to [2015-2016]/py	**2009** #1 (noise AND (reduction OR abatement OR diminishment OR elimination OR "engineering controls" OR "administrative controls")) OR "hearing loss prevention" OR "hearing conservation" OR "hearing surveillance" #2 "ear protective device" OR "ear protective devices" OR "hearing protective device" OR "hearing protective devices" OR "hearing protector" OR "hearing protectors" OR "hearing protection" OR "ear muffs" OR "ear plugs" OR "ear defenders" #3 (noise(mh) AND "protective equipment") OR ("noise reduction" AND "protective equipment") #4 (effect* OR control* OR evaluation* OR program*) AND (work* OR worker* OR workplace* OR working OR occupation* OR prevention* OR protect*) #5 (#1 OR #2 OR #3) #6 (#4 AND #5) **2015** same strategy, #7 (#6) results limited to date of publication Jan 2012 - October 2016

Appendix 2. Continued...

BIOSIS/CAB Abstracts	Web of Science	NIOSHTIC/OSH UPDATE
2009 1 (noise and (reduction or abatement or diminishment or elimination or (engineering adj controls) or (administrative adj controls))).tw. 2 ((hearing adj loss adj prevention) or (hearing adj conservation) or (hearing adj surveillance)).tw. 3 ((ear adj protective adj device) or (ear adj protective adj devices) or (hearing adj protective adj device) or (hearing adj protective adj devices) or (hearing adj protecto) or (hearing adj protectors) or (hearing adj protection) or (ear adj muffs) or (ear adj plugs) or (ear adj defenders)).tw. 4 ((noise adj reduction) and (protective adj equipment)).tw 5 ((effect* or control* or evaluation* or program*) and (work or worker* or workplace* or working or occupation* or prevention* or protect*)).tw. 6 4 or 1 or 3 or 2 7 6 and 5	**2009** #1 TS=(noise AND (reduction OR abatement OR diminishment OR elimination OR "engineering controls" OR "administrative controls")) #2 TS=("hearing loss prevention" OR "hearing conservation" OR "hearing surveillance") #3 TS=("ear protective device" OR "ear protective devices" OR "hearing protective device" OR "hearing protective devices" OR "hearing protector" OR "hearing protectors" OR "hearing protection" OR "ear muffs" OR "ear plugs" OR "ear defenders") #4 #3 OR #2 OR #1 #5 TS=((effect* OR control* OR evaluation* OR program*) AND (work* OR worker* OR workplace* OR working OR occupation* OR prevention* OR protect*)) #6 #5 AND #4 **2012** same as search in 2009, added time span 2008-2012 **2016** same as search in 2009, added time span 2012-2016 #7 (#6) refined by: WEB OF SCIENCE CATEGORIES: (PUBLIC ENVIRONMENTAL OCCUPATIONAL HEALTH OR ACOUSTICS OR ENGINEERING MECHANICAL OR METALLURGY METALLURGICAL ENGINEERING OR ENGINEERING ENVIRONMENTAL OR MECHANICS OR ENGINEERING MANUFACTURING OR CONSTRUCTION BUILDING TECHNOLOGY OR ENGINEERING MULTIDISCIPLINARY OR TRANSPORTATION OR GEOSCIENCES MULTIDISCIPLINARY OR MEDICINE GENERAL INTERNAL OR OPERATIONS RESEARCH MANAGEMENT SCIENCE OR BEHAVIORAL SCIENCES OR ENGINEERING INDUSTRIAL OR ENGINEERING AEROSPACE OR MEDICINE RESEARCH EXPERIMENTAL OR AGRICULTURE MULTIDISCIPLINARY)	**2009 NIOSHTIC** (noise AND (induced OR hearing)) **2012 OSH UPDATE** time span 01-2008 to 01-2012 Searched in bibliographic databases: International bibliographic, CISDOC, HSELINE, IRRST, NIOSHTIC, NIOSHTIC-2, RILOSH #1 DC{OUBIB OR OUCISD OR OUHSEL OR OUISST OR OUNIOC OR OUNIOS OR OURILO #2 GW{noise} #3 GW{induced OR hearing} #4 #2 AND #3 #5 #1 AND #4 #6 PY{2008 OR 2009 OR 2010 OR 2011 OR 2012} #7 #5 AND #6 **2015 OSHupdate** strategy same as in 2012, change of time span: # 6 PY{2012 OR 2013 OR 2014 OR 2015} **2016 OSHupdate** all databases, strategy same as 2012, change of time span: #6 PY{2015 OR 2016}