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REVIEW ARTICLE

A scoping review to identify strategies that work to prevent four important occupational diseases

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Abstract

Background: Despite being largely preventable, many occupational diseases continue to be highly prevalent and extremely costly. Effective strategies are required to reduce their human, economic, and social impacts.

Methods: To better understand which approaches are most likely to lead to progress in preventing noise-related hearing loss, occupational contact dermatitis, occupational cancers, and occupational asthma, we undertook a scoping review and consulted with a number of key informants.

Results: We examined a total of 404 articles and found that various types of interventions are reported to contribute to occupational disease prevention but each has its limitations and each is often insufficient on its own. Our principal findings included: legislation and regulations can be an effective means of primary prevention, but their impact depends on both the nature of the regulations and the degree of enforcement; measures across the hierarchy of controls can reduce the risk of some of these diseases and reduce exposures; monitoring, surveillance, and screening are effective prevention tools and for evaluating the impact of legislative/policy change; the effect of education and training is context-dependent and influenced by the manner of delivery; and, multifaceted interventions are often more effective than ones consisting of a single activity.

Conclusions: This scoping review identifies occupational disease prevention strategies worthy of further exploration by decisionmakers and stakeholders and of future systematic evaluation by researchers. It also identified important gaps, including a lack of studies of precarious workers and the need for more studies that rigorously evaluate the effectiveness of interventions.

KEYWORDS
noise-induced hearing loss, occupational asthma, occupational cancer, occupational contact dermatitis, occupational disease, primary prevention

1 | INTRODUCTION

The International Labour Organization estimates that occupational diseases kill six times as many people each year as occupational injuries[1]; Canadian studies suggest a much higher ratio.[2,3] Despite being largely preventable, the human, societal, and economic impacts of these diseases are enormous and include, for example, the impoverishment of workers and their families, reduced productivity and work capacity, workers' compensation benefits, and healthcare expenditures.[1,4-14] Researchers in Quebec recently estimated that the annual cost of all occupational diseases in that province accepted for compensation during 2005 to 2007 was $C834 million (average cost per case: $C161 000) and occupational disease-related deaths accounted for $C128 million (average cost per case: $C1.7 million).[12] Compensation figures such as these substantially under-represent the real burden of occupational diseases and are inadequate as a basis for research or as a guide for public policy.[15-22]

This article aims to address the impact of prevention in four diseases: noise-induced hearing loss, contact dermatitis, occupational asthma (OA), and occupational cancers associated with four specific work exposures (asbestos, diesel exhaust, silica, and shiftwork). While not the only occupational diseases and sources of carcinogen exposure in Canada and elsewhere, these diseases are major contributors to fatalities and a high burden of illness. They are also diverse in terms of latency periods, populations affected (both currently and in the past) and the history of prevention initiatives. The four carcinogens selected were, and continue to be, key exposures in many workplaces (CAREX Canada estimates that over 3.33 million Canadian workers had exposure to these agents in 2006) and were responsible for between 42% and 49% of the cancers diagnosed in Canada in 2011.[14]

The burden of work-related noise-induced hearing loss (NIHL) is considerable[12] and there is evidence that occupational noise exposure also contributes to "nonauditory" problems such as heart attack and hypertension.[23] The hearing conservation program (HCP) paradigm, which is held up as a model approach, is widely applied throughout North America and in other countries. However, despite widespread implementation and millions of audiograms collected over several decades, noise and NIHL are still not well controlled and relatively few systematic evaluations of HCP's effectiveness exist.[24,25] Indeed, some experts have concluded that annual audiograms "merely document the hearing loss occurring"[26] and HCPs have been accused of being their own self-serving industry, a "black box" that involves the risk that they endanger workers by encouraging them to trust that their hearing is being protected in the absence of evidence that this is the case.[27]

Occupational contact dermatitis (OCD) resulting from workplace exposure to either irritants or allergens has significant impact on function, employment, quality of life, and costs.[28,29] In many jurisdictions, OCD is one of the most common occupational diseases[30] and in some high-risk industries, up to 20 to 40% of workers have been found to have hand dermatitis.[31,32] Prevention of OCD focuses on avoidance of exposure, the use of appropriate personal protective equipment, and skin care.[29] The earlier the diagnosis, the better the outcome; so, early detection, definitive diagnosis, and effective management are crucial.[33,34] Recent systematic reviews have noted the limited number of high-quality studies on OCD prevention programs and have recommended further evaluation of existing programs.[35-38]

Despite persistent under-reporting,[15,20] the number of occupational cancer fatalities in Canada has increased steadily over time and now surpasses the annual number of workplace traumatic fatalities.[2] Exposure to known or suspected carcinogens at work is widespread, with recent studies estimating that over 15 million Canadians alive in 2011 had been exposed to at least one carcinogen in the workplace between 1961 and 2001.[14,39] Of the approximately 252 000 cancers diagnosed in Canada in 2011, approximately 10 000 can be attributed to past occupational exposure to 13 carcinogens: arsenic, asbestos, benzene, chromium (VI) compounds, diesel engine exhaust, second-hand smoke, nickel compounds, polycyclic aromatic hydrocarbons (PAHs), radon, night shift work, silica (crystalline), solar ultraviolet radiation, and welding fumes.[14] Three recent studies estimated the economic burden to Canadian society in 2011 of newly diagnosed asbestos-related cancers (ie, mesothelioma and lung cancer),[11] bladder cancers,[40] and non-melanoma skin cancers.[41] In the asbestos study, the economic burden was estimated to be $C2.3 billion—with direct (eg, healthcare) and indirect (eg, lost productivity) costs accounting for $C831 million and quality of life costs accounting for $C1.5 billion.[11] The estimated per-case cost was approximately $C1.1 million and $C1.0 million for mesothelioma and lung cancer, respectively.[11]

OA, which is known to be caused by more than 300 compounds, is reported to be "the most common chronic occupational lung disease in industrialized regions" and is estimated to contribute to about 10% of adult-onset asthma.[42,43] While primary prevention measures have been outlined for asthma in the workplace and improved outcomes have been associated with programs that combine medical surveillance with occupational hygiene measures and worker education,[42] few programs have been evaluated for efficacy and many have methodological limitations.[44] Some success has been documented with efforts to prevent occupational exposure to natural latex and to reduce exposure to diisocyanates, but ongoing barriers have been identified to early diagnosis, particularly among workers with lower education levels and lower incomes.[42]

This article presents the findings of a scoping review undertaken to identify strategies and programs to reduce the risk of the four occupational diseases of interest. Despite widespread interest and concern, there continues to be a lack of awareness of these occupational diseases among workers, employers, healthcare professionals, and other frontline groups. In Canada and elsewhere, cases of these occupational diseases continue to be underdiagnosed by clinicians, under-reported to government and to workers' compensation authorities, and under-compensated. Effective prevention strategies are essential to reduce the

incidence and the high economic, social, and human costs of occupational disease.

2 | METHODS

2.1 | Study design

The project utilized scoping review methods[45-48] to identify, abstract, and synthesize the evidence on what is known about the effectiveness of primary prevention strategies for each of the diseases of interest and for "occupational disease" more generally. Carrying out a scoping review, as opposed to a systematic review, allowed for a broader range of questions to be considered with available resources. The study design was based on the 5-stage Arksey and O'Malley scoping review framework (ie, identifying the research question; identifying relevant studies; selecting studies; charting the data; and, collating, summarizing, and reporting the results).[45] Because one of our objectives was to engage with key stakeholders in occupational health and safety (OHS) prevention across Canada on the findings emerging from the scoping review, we also incorporated a consultation exercise (which took the form of key informant interviews and conference workshops). This study design was deemed exempt from formal ethics review at each of the authors' affiliated Research Ethics Boards.

2.2 | Research question

Our overarching research question was: what is known in the peer-reviewed and the gray literature about the effectiveness of primary prevention programs in reducing occupational disease in the workplace? Our specific questions were: what is known about preventing noise-induced hearing loss, OCD, OA, and occupational cancer associated with exposure to asbestos, diesel exhaust, silica, and shiftwork? We focused our review on primary prevention (ie, the attempt to prevent injury or disease *before* it occurs) rather than secondary or tertiary prevention. Primary prevention activities may involve single interventions or a combination of different interventions, they may focus on a specific hazard or disease, or they may intervene at different or multiple levels ranging from the worker or the worksite to the regulation of work environments. Although secondary prevention (ie, the *early* identification of a health problem to prevent the occurrence of disease) was technically outside the scope of our project, some secondary prevention initiatives were included because they can play a key role in primary prevention when the documentation of symptoms and illness is accompanied by a feedback loop to interventions to reduce exposures.[49-51] In addition to the overarching and specific research questions noted above, the project also had the following key objectives: to assess whether the strategies identified are applicable in the Canadian OHS context (including small and medium enterprises, vulnerably situated workers, and those that are precariously employed); and, to involve key stakeholders in OHS disease prevention across Canada as members of the team, through key informant discussions and broader consultations.

2.3 | Search strategy

Health sciences librarians at each of the four Canadian research institutions engaged in the project assisted the research team to develop and define the search criteria, to identify the most useful bibliographic databases; and to identify natural language keywords and database-specific controlled vocabulary search terms, in both English and French. These terms were combined with disease-specific and work-related keywords in various permutations to create database-specific search strings built around the problem, the intervention, and the outcome (Table 1). Some search strings needed to be customized for specific databases and for specific diseases.

Searches were conducted iteratively. Electronic databases of the peer-reviewed literature were targeted first. The findings of these searches were used to inform searches of the gray literature. To increase capture of relevant information, a snowballing technique was used to identify promising programs and strategies from the reference lists of key studies. In total, 12 bibliographic databases of peer-reviewed and gray literature were searched (Table 2). All searches were limited to articles in English and French, published between 1996 and 2016. This 20-year time period was selected for pragmatic reasons (ie, to allow for project completion within its 1-year funding period) and to identify interventions of relevance to current working environments.

2.4 | Selection of articles for inclusion in the review

Five research assistants and a postdoctoral fellow carried out the disease-specific literature searches and performed the reviews in consultation with their supervisor. To filter out articles that were beyond the scope of the project, a stepwise and iterative screening approach was developed and implemented. Articles were mainly restricted to those focusing on primary prevention programs or strategies for occupational disease implemented in Canada, the United States, the European Union (EU), and Australia. Of particular interest were programs or strategies that: (a) had been implemented in the field, rather than under experimental conditions; (b) paid attention to changing industry structures and labor force dynamics; (c) were relevant to the context of OHS in Canada; and (d) whose effectiveness had been formally evaluated or provided evidence of potential effectiveness. Review articles were also included, as were articles about nonevaluated programs or strategies that appeared promising. Articles were excluded if they were not related to occupational disease or to primary prevention interventions or programs; involved secondary or tertiary prevention without a feedback loop to primary

TABLE 1 Search terms

Terms/keywords common to all searches		Search-specific terms
THE PROBLEM	Occupational Exposure	Noise
	Occupational Disease	Noise, Occupational
	Occupational Medicine	Sound
	Occupational Health	Acoustic
	Exposure	
	Disease	Occupational Carcinogen
		Asbestos
	occupation*	Asbestos, Occupational
	work*	Diesel*
	industr*	Diesel Exhaust
	job*	Diesel Engine Exhaust
	employ*	Silica
	worker*	Silica, Occupational
	workplace*	Shift work
	work related*	shiftwork*
		shift*
THE INTERVENTION	Primary Prevention	Noise Control
	Prevention and Control	Hearing Conservation
	Mass Screening	Hearing Loss Prevention Program Audiometry
	Preventive Health Care	Hearing Protective Devices
	Health Screening	
	Screening Test	Exposure screening
		Exposure prevention
	prevent*	
	screen*	
	detect*	
	monitor*	
	surveillance	
	surveill*	
	risk*	
THE OUTCOME	Program Development	Noise Induced Hearing Loss
	Program Evaluation	Hearing Loss
	Occupational Health Services	
	Occupational Health Nursing	Occupational Skin Diseases
	Health	Dermatitis, Contact
	Public Health	Contact and (Dermatitis or Eczema)
	Health Program	Eczema
	Health Education	Hand Eczema
	Public Health Service	
	program*	Occupational lung disease
	strateg*	
	intervention*	Asthma
	intervene*	Asthma, Occupational
	initiative*	Occupational allergy
	implement*	
	policy	
	policies	

prevention; consisted only of summaries, commentaries, reviews or conference abstracts with no documentation of impact; or, were limited to descriptions of the context or history of the occupational disease(s) of interest.

2.5 | "Charting" information from the studies

Once the research assistants had retrieved all articles, they worked with their supervisor to triage the articles before abstracting

TABLE 2 Databases searched

Peer-reviewed literature		Gray literature
MedLine (via PubMed)	Scopus	Google Scholar
Embase	Health Policy Reference Centre	Canadian Agency for Drugs & Technologies in Health (CADTH) Grey Matters
Web of Science	Cochrane Library	Canadian Centre for Occupational Health & Safety (CCOHS)[a]
Cumulative Index of Nursing & Allied Health Literature (CINAHL)	French National Research and Safety Institute for the Prevention of Occupational Accidents and Diseases (INRS)	
Public Affairs Information Service (PAIS) International		

[a]Includes: OSHLINE, NIOSHTIC, NIOSHTIC-2, HSELINE, CISILO, Canadiana, PubMed Subset.

information into a Microsoft Excel spreadsheet (Microsoft). For each article, the following data were recorded: general citation information; description and type of intervention(s); the research question or purpose of the study/review; the study design/methods; method of evaluation; descriptive statistics (eg, subjects/population studied, sample size, data sources); and key findings. In keeping with scoping review methodology, we did not evaluate the risk of bias for individual studies nor did we undertake a systematic weighing of the quality of the evidence. Rather, we flagged "promising" strategies based on whether they appeared to have a "demonstrated capacity" to prevent the occupational diseases of interest were identified. We considered a strategy to have "demonstrated capacity" if it was reported in the literature as having decreased either the level of exposure or the incidence/prevalence of the health outcome and/or having resulted in a change in behavior relevant to preventing the occupational disease or the exposure studied.

2.6 | Consulting with key informants

To supplement what we learned from the literature review, we consulted subject-matter experts via semi-structured telephone interviews. To draw up a list of potential key informants, the project coordinator canvassed the entire research team for experts' names and contact information (including both English- and French-speaking) on each of the four occupational diseases and on occupational disease prevention more generally. Thirty-seven unique experts were identified (on average, 5-9 experts per topic area). Time constraints precluded interviewing the full list. Twenty-one experts, covering all focus areas, were given priority and were contacted by email to ascertain their availability and interest in participating. Of those contacted, 14 participated in the interviews. At the outset of the phone interview, key informants were given some context on the project's objectives and the findings of the literature review. During each 30- to 60-minute conversation, the experts were prompted with a series of questions designed to elicit information on whether: (a) there were primary prevention initiatives in their jurisdiction or area of expertise that they considered to be particularly effective; (b) there were primary prevention initiatives or strategies they considered to be effective that might not have been captured in the scoping review; (c) there were campaigns targeting vulnerable workers in their jurisdiction and, if so, their perspectives on the key elements of a successful strategy to protect vulnerably employed workers; and (d) whether they had been involved in implementing any primary prevention programs and if so, any lessons they may have learned from having been involved in the implementation of these initiatives.

2.7 | Summarizing and reporting the findings

To synthesize the findings into a coherent narrative, we first created a descriptive analysis of the types of articles retrieved and then organized the findings into five clusters, each defined by their approach to primary prevention (legislation and regulations, surveillance, exposure control measures, education and training, and multifaceted approaches that combined multiple methods). For the descriptive analysis, we produced brief summaries and a series of tables that mapped the distribution of studies by type of intervention (eg, primary prevention vs combined primary/secondary prevention), study design (eg, cross-sectional vs controlled trial vs case studies/series vs narrative reviews vs systematic reviews, etc.), and the level at which the intervention was undertaken (ie, national vs regional vs organizational). This helped shed light on the kinds of primary prevention research that is predominantly being carried out and illustrated where the significant research gaps were. We then produced high-level tables that grouped the findings by primary prevention cluster and by reported outcome (ie, exposure reduction, disease incidence or prevalence, behavior change).

3 | RESULTS

3.1 | Outcome of the searches and initial screening of the literature

The searches of the peer-reviewed and gray literature databases generated over 42 000 "hits" (Table 3). The majority of the hits were

TABLE 3 Results of the literature searches and number of articles retrieved, by disease and search language

NIHL	Contact dermatitis	Occupational cancer (carcinogens)				Asthma	Total
		Asbestos	Diesel exhaust	Silica	Shiftwork		
Number of hits in the peer-reviewed literature							
5773	822	1752	1544	1786	1197	3287	16 161
Number of hits in the gray literature							
762	198	15 751	4251	3220	1523	36	25 741
Total number of hits							
6535	1020	17 503	5795	5006	2720	3556[a]	42 135
Total number of references retrieved							
384[b]	53	59	19	27	22	104	404
Number of English-language references retrieved							
113	38	31	16	23	21	90	332
Number of French-language references retrieved							
7	15	28	3	4	1	14	72
Number of studies retrieved that had an evaluation component							
69	43	20	10	19	6	55	222

[a]An additional 233 articles on occupational asthma were identified via snowballing techniques.
[b]Due to time constraints, only 120 of the 384 NIHL articles retrieved were reviewed. All 384 articles were coded by type of intervention (eg, hearing conservation, engineering noise control, etc.) and a convenience sampling strategy was applied to ensure representation of references from the various databases searched, representation of topics from each coding group, and representation of populations of interest (eg, vulnerable workers).

captured in the English-language searches; however, the French-language searches captured several additional prevention strategies. Approximately 38% (n = 16 161) of the "hits" came from the peer-reviewed literature. Articles about noise-induced hearing loss (NIHL) accounted for approximately 36% of the hits identified in the peer-reviewed literature, while articles about asbestos accounted for just over 60% of the hits identified in the gray literature. PubMed (Medline) and Embase accounted for approximately two-thirds of the articles identified in the peer-reviewed literature. Google search engines accounted for over 90% of the articles identified in the gray literature.

After the selection criteria were applied, a total of 404 articles across the occupational diseases of interest were retrieved for review (Table 3). Of these, 54 included articles reported on a secondary prevention initiative with a feedback loop that informed primary prevention or on a combined primary/secondary prevention initiative. Just over half of the articles retained for review (n = 222, or 55%) described interventions that measured the impact of the intervention on reducing exposure or disease. As noted above, one of the project's original objectives was to identify effective primary prevention strategies for the precariously employed workforce. However, we found a dearth of studies specifically designed to evaluate the impact of interventions on these workers.

3.2 | Results of the literature review

The findings of reviewed studies have been grouped into five primary prevention clusters: legislation and regulations, surveillance, exposure control measures, education and training, and multifaceted approaches that combined multiple methods. Tables 4 through 7 provide high-level summaries of selected key findings. See Tables S1 through S7 in the supplemental material for more details.

3.2.1 | Legislation and regulations

Noise-induced hearing loss

All but one of the studies identified in this cluster focussed on exposure outcomes (ie, noise levels). Findings were mixed and appeared to be dependent on context. For example, studies in multiple industries (including manufacturing) found that regulations were ineffective because of over-reliance on hearing protective devices (HPDs) vs engineered noise control[52-54]; and studies in foundries and mines found that measured noise levels routinely exceeded permissible levels, sometimes despite the presence of engineering controls.[55-57] In contrast, another study (examined in a systematic review) found that stricter regulations showed a favorable effect on measured noise levels.[25] A comparison of noise legislation in 22 countries in the Americas, published in 2014, found notable differences between jurisdictions in the permissible exposure limit and the noise exchange rates.[52] The authors noted that although most countries have adopted "mandatory" noise legislation, there was limited information available about the degree to which the noise standards and regulations are actually enforced. They conclude that millions of workers across the Americas are potentially at risk of losing their hearing because (a) regulations do not exist; (b) the

TABLE 4 Noise-induced hearing loss: selected findings by primary prevention approach

Primary prevention approach	Principal findings	Sector (Jurisdiction)	Source(s)
Legislation and regulation	Regulations ineffective because of over-reliance on hearing protective devices vs engineered noise control	Systematic review	52
		Multiple industries, incl. manufacturing (United States)	53, 54
	Measured noise levels routinely exceeded permissible levels, sometimes despite the presence of engineering controls	Foundries (United States)	55
		Mines	56
		Metal fabrication (United States)	57
	Stricter regulations showed a favorable effect on measured noise levels	Systematic review	25
	Notable interjurisdictional differences in "mandatory" permissible exposure limit and noise exchange rates. Millions of workers across the Americas are potentially risk losing their hearing because (a) regulations do not exist; (b) regulations that do exist are not protective enough; (c) enforcement of regulations is insufficient; and/or (d) a lack of information or will, or combination of the two, on part of employers, workers and governmental agencies	Systematic review	52
Exposure control	Engineering controls reduced noise levels	Steel industry (Iran)	58
	Engineering controls coupled with monthly inspections led to a reduction in noise power level	Tire manufacturing (United States)	59
	Use of a single form of hearing protection resulted in significantly more audiometric abnormalities than the combined use of earplugs and earmuffs	Construction (Spain)	60
	Women who perceived their workplace to be safe were more likely to use hearing protective devices	Multiple industries and occupations (Brazil)	61
Surveillance	Reductions in noise levels and NIHL observed with daily or continuous monitoring of exposure	Manufacturing	62
		Aluminum smelting (United States)	63
	Noise audits and reports increased awareness and noise management in farmers	Agriculture (Australia)	64
	Use of hearing protective devices increased after NIHL was detected through audiometric screening	Musicians (Poland)	65
	Audiometric testing identified increased prevalence of NIHL in farmers through audiometric testing	Agriculture (United States)	66
Education and training	The intention to wear hearing protective devices (HPD) doubled and the percentage of time that workers wore HPD nearly doubled	Agriculture (United States)	67
		Construction (United States)	68–70
	No effect on intent to wear HPD in the future	Construction workers, pipefitters (United States)	71
	Generic programs do not work	Construction, apprentice carpenters (United States)	72, 73
	Tailored, multimedia, computer-based programs more effective than basic programs. Computer-based training was no more effective than video training. Tailored interventions increase the use of HPD in the short term, but there is no difference in use after 1 year	Systematic review	74
		Multiple industries and occupations, incl. military, firefighters, operating engineers, factory workers (United States)	75–77
Multifaceted approaches that integrate multiple primary prevention activities			
Hearing loss prevention programs (HLPPs)	No impact of HLPPs on NIHL (3 studies). Risk of NIHL decreased with better use of hearing protective devices (4 studies). Workers in the program had 0.5 dB greater hearing loss at 4 kHz than nonexposed workers (4 studies). Substantial risk of NIHL despite HLPP (2 studies)	Systematic review	25

TABLE 4 (Continued)

Primary prevention approach	Principal findings	Sector (Jurisdiction)	Source(s)
Hearing conservation programs	Decreased the risk of NIHL	Musicians (Australia)	78
	No evidence of a reduction in NIHL	Agriculture (United States)	79
	Increased the use of hearing protection	Agriculture (United States)	67
		Construction (United States)	68, 69, 80
	No effect on intent to use hearing protection in the future	Construction workers, pipefitters (United States)	71
Training + audiometry + survey	Improved attitudes, beliefs, and behavior regarding the use of hearing protection	Apprentice carpenters (United States)	72, 73
Training + real-time information about measured noise levels + reminders to wear hearing protection	Increased use of hearing protective devices	Construction workers (United States)	70

regulations that do exist are not protective enough; (c) enforcement of the regulations is insufficient; and/or (d) a lack of information or will, or a combination of the two, on the part of employers, workers, and governmental agencies. See Tables 4 and S1 for more information.

Contact dermatitis

Studies examining the impact of legislation and regulation on health outcomes found, for the most part, that these interventions had a positive impact. For example, studies in the United Kingdom demonstrated that after the implementation of regulations restricting exposure, cases of latex-related urticaria and dermatitis among healthcare workers decreased[81] and the incidence of dermatitis attributed to chromate exposure among chromate workers declined.[82] Another study documented that France's 2005 ban on the use of cement with chromium VI was effective at reducing the incidence of occupational dermatitis and the number of workdays lost due to this disorder in the construction industry.[83] Data generated by a contact allergy surveillance system in the EU indicate a decrease in chromium allergy prevalence among the building trades, suggesting that the chromate regulation has been successful.[84] Conclusions regarding the effectiveness of the EU Nickel Directive are mixed: the contact allergy surveillance system identified heterogeneous trends in nickel allergy among the building trades (suggesting a partial failure of the nickel regulation),[85] while another study concluded that the regulation is starting to change the epidemiology of nickel allergy in the EU.[86] See Tables 5 and S2 for more information.

Occupational cancer

Review articles found that legislation (ie, bans) and regulations (ie, lower occupational exposure limits combined with increased enforcement of compliance) reduced asbestos-related diseases[112] and decreased the risk of cancer from exposure to diesel exhaust.[113] One primary research study found a reduction in mesothelioma risk in Swedish workers who started working after Sweden implemented a ban on exposure to asbestos in the mid 1970's.[114] A Finnish study found that levels of respirable silica decreased after a new occupational exposure limit came into effect and after the signing of an international agreement/social contract creating the European Network on Silica (NEPSI).[115] No studies examining the impact of legislative or regulatory interventions were found for shiftwork. See Tables 6 and S3 to S6 for more information.

Occupational asthma

Positive outcomes have been reported following the introduction of legislation or regulations to prevent exposure to allergens and asthmagens. Examples include: a decrease in the number of OA cases after the introduction of the *Control of Substances Hazardous to Health (COSHH)* regulations in the United Kingdom; a reduction in exposure levels, accompanied by reduced symptoms and the number of cases, following the introduction of regulations to control latex exposure in Germany, the EU, the United Kingdom, and the United States. In the latter case, these interventions also resulted in glove manufacturing improvements (ie, they were a driver of product innovation). See Tables 7 and S7 for more information.

3.2.2 | Exposure control measures

Noise-induced hearing loss

Most of the studies identified focussed on examining the impact of engineering controls on noise levels at the workplace. Studies in hospitals and the steel industry found that engineering controls reduced noise levels,[58] while a study in the tire manufacturing industry found that engineering controls coupled with monthly inspections led to a reduction in noise power level.[59] One study in the construction industry found that the use of a single form of hearing protection (ie, earplugs or earmuffs) resulted in significantly more audiometric abnormalities than the combined use of earplugs and earmuffs.[60] See Tables 4 and S1 for more information.

TABLE 5 Contact dermatitis: Selected findings, by primary prevention approach

Primary prevention approach	Principal findings	Sector (Jurisdiction)	Source(s)
Legislation and regulation	Decrease in cases of latex-related urticaria and dermatitis	Health care (United Kingdom)	81
	Incidence of dermatitis attributed to chromate exposure declined	Chromate workers (United Kingdom)	82
	Ban on the use of cement with chromium VI was effective at reducing the incidence of occupational dermatitis and the number of workdays lost due to this disorder in the construction industry	Construction (France)	83
	Decrease in chromium allergy prevalence suggests that the chromate regulation has been successful. Heterogeneous trends in nickel allergy suggest a partial failure of the nickel regulation	Building trades (European Union)	84
	The regulation is starting to change the epidemiology of nickel allergy in the European Union	Literature review (European Union)	86
Exposure control	The number of suspected skin and respiratory diseases decreased after exposure to latex was eliminated	Healthcare workers (Germany)	87
	Skin status improved with skin care and skin protection	Metal workers (Germany)	88
	Improved glove use reduced exposure to paratoluenediamine	Hairdressers (Belgium)	89
	Some positive effects of barrier creams, moisturizers, after work creams, and complex educational interventions in the primary prevention of contact dermatitis (despite a lack of statistical significance in the studies published). Lack of evidence to support or refute the use of protective gloves to prevent contact dermatitis	Systematic review	37
Surveillance	No direct evidence (a) that health surveillance is effective in the early detection of occupational contact dermatitis or occupational contact urticaria or (b) of the comparative effectiveness of different screening methods	Systematic review	90
	A tool to screen for work-related eczema increased awareness and the use of protective measures	Metal workers (Germany)	91
Education and training	Increased knowledge about skin hazards and improved work habits (eg, increased use of protective measures, decreased use of hand disinfectants, decreased use of latex gloves)	Healthcare (hospital cleaners, kitchen workers, nurses), wet workers and hairdressers (Denmark); hospital workers (United States); healthcare (geriatric nurses), bakeries, high school students (Germany); food handlers (Australia)	92 93 94 95 96 97 98 99 100 101
	Improvements in multiple skin condition measurements	Manufacturing (United States)	102
	Reduced skin disease frequency or symptoms. Decreased incidence of new cases of occupational dermatoses	Healthcare (nurse trainees), hairdressing (Germany); hairdressing, wet workers, swine slaughterhouse workers (Denmark); chemical workers (United Kingdom)	103 104 105 95 96
	Evidence that employee education and training programs help to reduce the incidence of occupational contact dermatitis and that educational interventions induce important behavioral changes in latex glove use	Systematic review: Healthcare	38

TABLE 5 (Continued)

Primary prevention approach	Principal findings	Sector (Jurisdiction)	Source(s)
Multiple combined approaches	Decreased prevalence of dermatitis with training and UVB hardening	Food processing (Germany)	98
	Reduced symptoms and severity with screening and training	Print working (United Kingdom)	107
	Decreased symptoms with a top down (ie, a skin risks occupational health and safety management system) and bottom up (ie, local project group) approach combined with gloves and an educational campaign	Dairy, swine slaughterhouses (Denmark)	108 109
	Improved awareness, knowledge, work habits and symptom self-reports with a combination of education, participatory working groups and role model training	Healthcare—hospital workers (the Netherlands)	110 111

Contact dermatitis

Three exposure control studies and one systematic review were identified. Of the exposure control studies, one examined the impact of exposure elimination on health outcomes, one assessed the impact of personal protective equipment on health outcomes, and the other examined the relationship between improved glove use and exposure outcomes. These studies respectively found: a decrease in the number of suspected skin and respiratory diseases in German healthcare workers after exposure to latex was eliminated[87]; improvements in the skin status of German metal workers with skin care and skin protection[88]; and reduced exposure to paratoluenediamine with improved glove use in Belgium.[89] The systematic review, which examined the evidence for the use of personal protective equipment and personal hygiene measures, found that there were some positive effects of barrier creams, moisturizers, after work creams, and complex educational interventions in the primary prevention of contact dermatitis (despite a lack of statistical significance in the studies published) and that there was a lack of evidence to support or refute the use of protective gloves to prevent contact dermatitis.[37] See Tables 5 and S2 for more information.

Occupational cancer

No studies were identified in the asbestos literature that specifically examined the impact of the hierarchy of controls on disease, exposure or behavioral outcomes. All of the exposure control studies identified in the diesel exhaust literature focussed on evaluating the impact of engineering controls, like local exhaust ventilation, on levels of exposure. The majority of these studies were conducted in underground mines. Findings included: engineering controls (eg, local exhaust ventilation) or controls at the source (eg, engines fitted with particulate filters) decreased emissions and were effective at reducing exposure to sulfur dioxide, hydrogen sulfide and dusts[121-123]; engineering controls combined with preventive maintenance and regular emission testing decreased exposure levels[124]; and diesel exhaust emissions decreased with the use of modern engines,[125] low emission engines,[126] or retrofitted engines.[127]

Exposure control studies identified in the silica literature examined the impact of elimination/substitution, engineering controls, and/or personal protective equipment. None of the studies retrieved evaluated the use of administrative controls. The one study examining a silica substitute (ie, a non-silica abrasive) found that it contained low levels of crystalline silica and as a consequence, its use could unexpectedly contribute to airborne silica levels.[131] The use of engineering controls, either individually or in combination, was found to positively impact the levels of silica exposure in firing ranges,[132] foundries,[133] and a range of activities in the construction industry (eg, brick cutting, masonry cutting, mortar removal, concrete cutting, and grinding).[134-137,139,140,141,177] Examples of engineering controls that were found to be effective at reducing silica exposure included: water controls (eg, misting, wet suppression), vacuum cleaners, and local exhaust ventilation (LEV) in combination with other controls (eg, a jig). Two studies in the construction industry reported that, although LEV reduces personal exposure levels, it provides incomplete dust control.[142,143] In a study of Swedish foundry workers, actual measured levels of silica exposure exceeded the occupational exposure limit, suggesting that the potential for over-exposure exists despite the use of PPE, such as respirators.[144]

The majority of the exposure control articles in the shiftwork literature focussed on the impact of administrative controls on either exposure outcomes or short-term health outcomes. One study examining the impact of an engineering control on nurses working night shifts found that controlled light exposure resulted in decreases in subjective distress associated with night shift work.[146] Other studies found that administrative controls had positive impacts on exposure and health outcomes. In the former, rotating shift schedules and increasing the number of teams reduced the number of shifts outside day work (ie, reduced the exposure), but it produced more irregular schedules[147]; in the latter, flexible working arrangements and three types of organizational interventions (ie, switching from slow to fast rotation, changing from backward to forward rotation, and self-scheduling of shifts) improved health outcomes.[148,149] See Tables 6 and S3 to S6 for more information.

TABLE 6 Occupational cancer: Selected findings, by primary prevention approach

Primary prevention approach	Principal findings	Sector (Jurisdiction)	Source(s)
(a): Asbestos			
Legislation and regulation	Legislation (ie, bans) reduced asbestos-related diseases	Systematic review	112
	Reduced mesothelioma risk for workers who started working after a 1970s ban on exposure to asbestos	Asbestos-exposed workers (Sweden)	114
Surveillance	A mesothelioma registry was useful for identifying cases and informing prevention efforts through the development of exposure histories	Patient registry (Italy)	116
	"Empathy in Advocacy" public awareness campaign based on an individual's personal cancer experience. By integrating it with a comprehensive strategy to mobilize research/policy/knowledge into action and a collaborative process of stakeholder engagement, the issue was kept in the public domain. Strategy was effective at influencing policy makers to adopt legislation creating an asbestos exposure registry in Saskatchewan	Building registry (Saskatchewan, Canada)	117
Education and training	"Asbestos Safety Awareness" training increased awareness among managers about legal obligations towards workers potentially exposed to asbestos	Building managers (Ireland)	118
	Increased levels of awareness, as well as trust and readiness to adopt a ventilation tool	Construction (the Netherlands)	119
Multiple combined approaches	Government ban + elimination of asbestos + exposure control decreased lung cancer and mesothelioma incidence	Systematic review	112
	FIOH Asbestos Program reduced exposure but impact on disease incidence was not yet measurable. Program (a cooperative effort) incorporates regulation, enforcement of asbestos abatement companies, a ban on the import of asbestos, and health monitoring	Multiple interventions (Finland)	120
(b): Diesel exhaust			
Legislation and regulation	Lower occupational exposure limits + increased enforcement of compliance decreased risk of cancer	Literature review	113
Exposure control	Engineering controls (eg, local exhaust ventilation) or controls at the source (eg, engines fitted with particulate filters) decreased emissions and were effective at reducing exposure to sulfur dioxide, hydrogen sulfide and dusts	Mining (Iran, Australia, United States)	121 122 123
	Engineering controls + preventive maintenance + regular emission testing decreased exposure levels	Mining (Australia)	124
	Modern engines, low emission engines or retrofitted engines decrease emissions	Vehicle emissions (United States, Mexico)	125 126 127
Surveillance	Diesel Emission Evaluation Program (DEEP) effectively controlled diesel exhaust exposure by emissions testing and engine maintenance testing every 28 d	Underground mines (United States)	128
Multiple combined approaches	Reductions in exposure to diesel exhaust were observed for programs combining (a) inspections + preventative maintenance, (b) scrappage + implementation of early emissions standards	Vehicle inspections (United States)	129 130
	Risk of cancer decreased with the combination of regulatory change + exposure control + training	Literature review	113
(c): Silica			
Legislation and regulation	Respirable silica levels decreased after new occupational exposure limit came into effect and an international agreement/social contract creating the European Network on Silica (NEPSI) was signed	Silica-exposed workers (Finland)	115

TABLE 6 (Continued)

Primary prevention approach	Principal findings	Sector (Jurisdiction)	Source(s)
Exposure control	Use of a non-silica abrasive found to contain low levels of crystalline silica could unexpectedly contribute to airborne silica levels	Various work sites (Canada)	131
	Engineering controls, either individually or in combination, reduced levels of silica exposure. Examples of effective controls included: water controls (eg, misting, wet suppression), vacuum cleaners, and local exhaust ventilation (LEV) in combination with other controls (eg, a jig)	Firing ranges, military training units (United States); foundries (Iran); construction, incl. brick cutting, masonry cutting, mortar removal, concrete cutting and grinding (United States, the Netherlands)	132 133 134 135 136 137 138 139 140 141
	LEV reduces personal exposure levels but provides incomplete dust control	Construction (United States)	142 143
	Actual measured levels of silica exposure exceeded the occupational exposure limit, suggesting that the potential for over-exposure exists despite the use of personal protective equipment (such as respirators)	Iron foundries (Sweden)	144
Education and training	Increased levels of awareness, as well as trust and readiness to adopt a ventilation tool	Construction (the Netherlands)	119
Multiple combined approaches	Reductions in miners' exposure and behavior observed with approaches combining risk communication + video assessment + dust abatement technology	Mining (United States)	145
(d): Shiftwork			
Exposure control	Controlled light exposure resulted in decreases in subjective distress associated with night shift work	Healthcare: nurses (Finland)	146
	Rotating shift schedules + increasing the number of teams reduced number of shifts outside day work (ie, reduced the exposure), but produced more irregular schedules	Shiftworkers at Norwegian multinational (European Union)	147
	Flexible working arrangements and three types of organizational interventions (ie, switching from slow to fast rotation, changing from backward to forward rotation, and self-scheduling of shifts) improved health outcomes	Systematic review	148 149
Education and training	Improved short-term health outcomes	Mining (United States) Literature review	150 151
Multiple combined approaches	Improved health outcomes were observed with interventions combining (a) napping, nutrition, and flexible shifts; (b) training and self-scheduled shifts; (c) fewer consecutive night shifts, bright light during night shifts, sleeping in a dark room, use of melatonin, and on-duty naps	Literature reviews of various industries and occupations Healthcare: nurses (United States)	152 153 154 149 150 151 155 156
	Negative outcomes (poorer mental health, work-related performance, and safety outcomes) reported in police officers with use of sleep and wake-promoting drugs	Police officers (North America)	157
	Combination of interventions (such as changes to shift scheduling, controlled light exposure, healthy diet and physical activity, and sleep aids like melatonin) had positive effects on chronic disease outcomes	Literature review	158

Occupational asthma

In three studies, engineering controls were found to reduce levels of exposure to flour dust in South African bakeries,[161] as well as symptoms of bakers' asthma in the United Kingdom[162] and South Africa.[163] In the former, the greatest reduction in exposures was observed when five control measures (mixer lid, divider oils, gentle bag handling, low-level bag handling and rubbing of surfaces) were implemented together.[161] Other articles reported that changes to ventilation, equipment, and work practices were effective in reducing exposure to glutaraldehyde in disinfecting[178]; and that asthma symptoms were reduced by the use of PPE on farms in the United States and Finland.[164] See Tables 7 and S7 for more information.

3.2.3 | Surveillance of hazards and/or diseases

Noise-induced hearing loss

In studies conducted across a range of industries, monitoring of noise levels was reported to positively affect exposure, health, and behavioral outcomes. For example, reductions in noise levels and noise-induced hearing loss were observed in a variety of industries, including manufacturing[67] and aluminum smelting,[63] with daily or continuous monitoring of exposure. Another study found that noise audits and reports were effective at changing behavior (eg, increased awareness and noise management) in farmers in Australia.[179] Screening for noise-induced hearing loss (through audiometric testing) was found to have a positive impact on behavioral outcomes in musicians.[65] Specifically, their use of hearing protective devices increased after NIHL was detected. Another study detected an increased prevalence of NIHL in farmers through audiometric testing.[66] Three studies identified exposure surveillance strategies for identifying ototoxic exposures at work that contribute to NIHL.[180-182] See Tables 4 and S1 for more information.

Contact dermatitis

No studies were identified that examined the effectiveness of hazard surveillance and/or exposure monitoring in preventing contact dermatitis. Two articles were identified that examined the effectiveness of disease surveillance systems and symptoms screening tools. Their findings/conclusions were mixed. A review article developing evidence-based guidelines for the prevention, identification, and management of OCD and urticaria concluded that there was no direct evidence (a) that health surveillance is effective in the early detection of OCD or occupational contact urticaria or (b) of the comparative effectiveness of different screening methods.[29] In contrast, a study of German metal workers found that a tool to screen for work-related eczema was effective, increasing awareness and the use of protective measures.[91] See Tables 5 and S2 for more information.

Occupational cancer

No articles were identified in the silica or shiftwork literature on whether hazard or disease surveillance systems were effective at preventing cancer outcomes. One article was found in the diesel exhaust literature that discussed a hazard surveillance system and one article was found in the asbestos literature about a mesothelioma registry in Italy. The diesel exhaust article highlighted an organizational-level example of a Montana mine that effectively controlled diesel exhaust exposure by emissions testing and engine maintenance testing every 28 days.[128] The Italian study described the creation of a mesothelioma registry, documenting its usefulness for identifying cases and informing prevention efforts through the development of exposure histories.[116]

The only other article addressing the topic of surveillance was found in the asbestos literature. Although not an evaluative study, it was included because it provided information on a strategy that was shown to be effective at influencing policy makers to adopt legislation creating an asbestos exposure registry in Saskatchewan, Canada. The "Empathy in Advocacy" campaign created a public awareness campaign based on an individual's personal cancer experience.[117] By integrating it with a comprehensive strategy to mobilize research/policy/knowledge into action and a collaborative process of stakeholder engagement, the issue was kept in the public domain. See Tables 6 and S3 to S6 for more information.

Occupational asthma

One article described a wide range of active asthma health surveillance programs in England, France, Italy, Finland, Germany, and the United States, based on specialist physician reporting (eg, measuring incidence; medical follow-up of identified cases; linking case identification with follow-up preventive interventions in the workplace).[183] We also identified several articles that examined asthma surveillance systems in the context of more comprehensive prevention programs; they are described in the section on "multifaceted approaches." The few articles we identified examining the efficacy of periodic health surveillance for OA reported the following: pre-placement examinations should be used to establish a baseline for periodic health surveillance rather than to detect and exclude susceptible individuals from high-risk workplaces[90]; routine health surveillance (vs a standard cross-sectional survey) can underestimate the frequency of OA[184]; there are shorter mean delays between onset of symptoms and a confirmed diagnosis in those whose symptoms were detected by health surveillance (ie, 9 months vs 4 years).[185,186] In a Canadian study where regular health surveillance of isocyanate-exposed workers was linked to a mandatory workplace exposure control program, cases of isocyanate-induced asthma were diagnosed sooner after the onset of symptoms, had better lung function and a better outcome than asthma attributed to other workplace agents not subject to the control program.[166] It is difficult to dissociate the effects of health surveillance from the effects of other risk management procedures and the authors acknowledged that the improved outcomes in the isocyanate workers might, at least in part, be attributable to the concomitant reduction in exposure. See Tables 7 and S7 for more information.

TABLE 7 Occupational asthma: selected findings, by primary prevention approach

Primary prevention approach	Principal findings	Sector (Jurisdiction)	Source(s)
Legislation and regulation	Number of occupational asthma cases decreased after the introduction of the *Control of Substances Hazardous to Health (COSHH)* regulations in the United Kingdom	Healthcare (United Kingdom)	159
	Reductions in exposure levels, symptoms and number of cases, following the introduction of regulations to control latex exposure.	Germany, European Union, United Kingdom, United States	159 87 160
Exposure control	Engineering controls reduce levels of exposure to flour dust and symptoms of bakers' asthma. Greatest reduction in exposures observed when 5 control measures (mixer lid, divider oils, gentle bag handling, low-level bag handling, rubbing of surfaces) were implemented together	Bakeries (South Africa, United Kingdom)	161 162 163
	Use of personal protective equipment reduced asthma symptoms	Agriculture (United States, Finland)	164
	Substitution of powdered latex gloves greatly reduces occupational asthma	Systematic review	165
Surveillance	Pre-placement examinations should be used to establish baseline for periodic health surveillance instead of to detect and exclude susceptible individuals from high-risk workplaces	Literature review	90
	Regular health surveillance + mandatory workplace exposure control program resulted in isocyanate-induced asthma cases being diagnosed sooner after the onset of symptoms, better lung function and better outcomes than asthma attributed to other workplace agents not subject to the control program	Isocyanate-exposed workers (Canada)	166
	Health surveillance can allow early case identification and remediation of the causative exposure	Multiple industries and occupations (United Kingdom)	167
Education and training	Educational interventions related to OHS knowledge and practices to prevent exposure on farms are feasible	Agriculture (Canada)	168
	A web-based tool designed to educate adult asthma patients about the possible work-relatedness of their disease had a positive impact on knowledge about work-related asthma and on the apparent long-term retention of that knowledge	Patients recruited from tertiary care clinic (Canada)	169 170
Multiple combined approaches	A prevention program that combined information for employers and workers with exposure standards and systematic monitoring of workers resulted in a reduction in accepted OA compensation claims due to isocyanate exposure from 1990 onwards	Multiple industries and occupations (Canada)	171
	Multifaceted interventions (that combined education, engineering controls and medical surveillance) reduced disease burden and reported total benefits of €44 659 352	Bakeries (the Netherlands)	172
	Positive outcomes with the use of a combination of pre- and post-safety health and awareness days, questionnaires, biological monitoring. Success of program attributed to the use of a staged approach, supported by research phase + targeted support for behavioral change	Motor vehicle repair (United Kingdom)	173
	Implementation of comprehensive laboratory animal allergy (LAA) prevention program (education + engineering controls + administrative controls + PPE + and medical surveillance) reduced the prevalence of LAA from 12% to 22% to 0 during last 2 y of observations	Laboratories (United States)	174
	Incidence of LAA can be reduced by effective, integrated health risk management, with the conscientious use of engineering + procedural + personal control measures	Literature review	175
	Regular, special preventive medical check-ups for employees exposed to experimental animal dust must be part of a comprehensive prevention strategy involving education, engineering controls, administrative controls, PPE and vocational integration	Laboratories (Germany)	176

3.2.4 | Education and training

Noise-induced hearing loss

Studies were identified that reported education and training interventions were effective at increasing awareness about NIHL as well as the use of (or the intent to use) hearing protective devices (HPD). For example, studies in agriculture and construction indicated that, following education and training, the intention to wear HPD doubled and the percentage of time that workers wore HPD nearly doubled,[67-70] although in one study of construction workers, the intervention had no effect on intent to wear in the future.[71] The findings of some of the studies we reviewed suggest that the effectiveness of educational interventions appears to depend on the context in which it is delivered. For example, studies evaluating uptake in construction or among carpenters found that generic programs do not work.[72,73] Tailored, multimedia, computer-based programs were found to be more effective than basic programs at changing behavior in a variety of industries and occupations, including the military, firefighters, and factory workers.[74-77] These studies found that (a) computer-based training was no more effective than video training and (b) while tailored interventions increase the use of HPD in the short term, there is no difference (between intervention group and controls) in use after 1 year. See Tables 4 and S1 for more information.

Contact dermatitis

Educational interventions delivered to workers in a variety of workplaces in the United States and the EU were reported to be effective at improving measures of skin condition, reducing the frequency or incidence of skin diseases, and in changing behavior (ie, increasing knowledge and the use of personal protective equipment, decreasing the use of hand disinfectants). The majority of these interventions (7 of 11) were based on the Danish "Skin Protection Programme." Studies in Denmark (hospital cleaners,[92,93] wet workers,[94] hairdressers[95,96]), in the United States (hospital workers[97]), and in Germany (high school students[187]) found that educational interventions increased knowledge about skin hazards and improved work habits. Examples of improved work habits identified in the literature include: increased use of protective measures among German nurses and baker apprentices[98,188]; decreased use of hand disinfectants by nurses in Germany[99] and Denmark[94]; and decreased use of latex gloves by Australian food handlers.[101] Studies also demonstrated that educational interventions resulted in improved health outcomes. Examples include: improvements in multiple skin condition measurements in U.S. manufacturing workers[102]; reduced skin disease frequency or symptoms in Germany (nurse trainees,[103] hairdressers[104]) and in Denmark (wet workers, swine slaughterhouse workers,[105] and hairdressers[95,96]); and decreased incidence of new cases of occupational dermatoses in U.K. chemical workers.[106] A systematic review concluded that there is evidence that employee education and training programs help to reduce the incidence of OCD and that educational interventions induce important behavioral changes in latex glove use among healthcare workers.[38] See Tables 5 and S2 for more information.

Occupational cancer

The literature on whether educational interventions are effective at preventing cancers associated with the four carcinogens of interest is sparse. This is not surprising given the long latency between exposure and outcome. No articles were identified in the diesel exhaust literature. The few studies identified in the asbestos and silica literature focussed on evaluating knowledge uptake, while those identified in the shiftwork literature measured the impact of the interventions on self-reported short-term health outcomes (like sleep disturbances).[150,151,189] A study of building managers in Ireland found increased levels of awareness among "Asbestos Safety Awareness" trained managers about their legal obligations towards workers potentially exposed to asbestos.[118] Similarly, educational interventions in construction in the Netherlands and elsewhere were found to increase levels of awareness about silica, as well as trust and readiness to adopt a ventilation tool.[119] See Tables 6 and S3 to S6 for more information.

Occupational asthma

No articles were identified that specifically evaluated the effectiveness of educational campaigns aimed at preventing OA. However, several were identified that examined education in the context of more comprehensive prevention programs. They are described below in the section on multifaceted approaches to primary prevention. We identified three educational interventions that had been undertaken in Canada. The first concluded that educational interventions related to OHS knowledge and practices to prevent exposure on farms are feasible.[168] The second, published in 2013, described the development of a web-based tool designed to educate adult asthma patients about the possible work-relatedness of their disease[169]; the third, published in 2016, evaluated that tool and concluded that the educational tool's effect was positive (on knowledge about work-related asthma and on the apparent long-term retention of that knowledge).[170] See Tables 7 and S7 for more information.

3.2.5 | Multifaceted approaches

Noise-induced hearing loss

Most of the NIHL studies we retrieved were focussed on hearing conservation and/or hearing loss prevention programs. The findings of these studies were mixed on how effective these prevention programs are. This is illustrated by the results of a systematic review examining the effectiveness of hearing loss prevention programs (HLPPs).[25] Of the 19 studies examined in the systematic review, three reported no impact of HLPPs on NIHL, four reported that the risk of NIHL decreased with better use of hearing protective devices, four reported that workers in the program had 0.5 dB greater hearing loss at 4 kHz than nonexposed workers, and two concluded that a substantial risk of NIHL exists despite HLPP.[25] We also identified one study that showed HCPs decreased the risk of NIHL in musicians[78] and another that reported no evidence of a reduction in agriculture.[79]

We identified several studies reporting that multifaceted programs have a positive impact on the use of hearing protection. HCPs were shown to increase the use of hearing protection in agriculture[67,68,80] and construction[69] but had no effect on the intention of construction workers to use hearing protection in the future.[71] Similarly, multimedia interventions have led to increased use of hearing protection in manufacturing.[77] We also identified two promising interventions that were undertaken with apprentice carpenters and with construction workers. In the former, apprentice carpenters showed improved attitudes, beliefs, and behavior regarding the use of hearing protection following an intervention that combined training and audiometry with a survey.[72,73] Similarly, the use of hearing protective devices increased among construction workers following an intervention that combined training and real-time information about measured noise levels with reminders to wear hearing protection.[70] See Tables 4 and S1 for more information.

Contact dermatitis

Studies evaluating multifaceted approaches to preventing contact dermatitis consistently found that multiple combined interventions had a positive impact on health outcomes (ie, decreased symptoms and/or prevalence of disease) and behavioral change. Generally, these multifaceted interventions combined education and training with another prevention activity. Examples include: a decreased prevalence of dermatitis in German food processing trades apprentices with training and UVB hardening[98]; a reduction in symptoms and severity in U.K. print workers with screening and training[107]; a decrease in symptoms in Danish dairies with a top down (ie, the implementation of a skin risks OHS management system) and bottom up (ie, local project group) approach combined with gloves and an educational campaign[108]; and improved awareness, knowledge, work habits and symptom self-reports in Dutch hospital workers with a program that combined education, participatory working groups, and role model training.[110,111] See Tables 5 and S2 for more information.

Occupational cancer

Examples of promising multifaceted primary prevention activities were identified in the literature on all four carcinogens of interest. Of the two references identified in the asbestos literature, one was a systematic review, which concluded that the combination of a government ban, the elimination of asbestos, and the control of exposure resulted in a decreased incidence of lung cancer and mesothelioma.[112] The other article concluded that the Finnish Institute of Occupational Health's (FIOH) Asbestos Program* had reduced exposure but that its impact on disease incidence was not yet measurable.[120]

Reductions in exposure to diesel exhaust were observed for programs combining (a) inspections and preventative maintenance[129] and (b) scrappage and implemented early emissions standards.[130]

A review article concluded that the risk of cancer decreased with the combination of regulatory change, exposure control, and training. Two studies in the silica literature, both in the mining industry, examined the impact of multifaceted approaches on exposure outcomes.[142,145] Reductions in miners' exposure were observed with approaches combining risk communication and video assessment or dust assessment technology. The latter study also found that the combined intervention led to behavior change.

Most of the interventions identified in the shiftwork literature were multifaceted and focussed on assessing the impact of the interventions on short-term health outcomes. Improved health outcomes were observed in various occupations/industries with interventions combining (a) napping, nutrition, and flexible shifts[152-154]; (b) training and self-scheduled shifts[149-151]; (c) fewer consecutive night shifts, bright light during night shifts, sleeping in a dark room, use of melatonin, and on-duty naps.[154-156] One study reported negative outcomes (eg, poorer mental health, work-related performance and safety outcomes) in police officers with the use of sleep and wake-promoting drugs.[157] A review article concluded that approaches using a combination of interventions (such as changes to shift scheduling, controlled light exposure, healthy diet and physical activity, and sleep aids like melatonin) had positive effects on chronic disease outcomes.[158] See Tables 6 and S3 to S6 for more information.

Occupational asthma

Several examples of promising multifaceted approaches to preventing OA were identified. A prevention program in Ontario that combined information for employers and workers with exposure standards and systematic monitoring of workers resulted in a reduction in accepted OA compensation claims due to isocyanate exposure from 1990 onwards.[171] The authors concluded that primary prevention alone aimed at reducing exposure to sensitizing agents might not be entirely effective, noting that there is also a need for education and medical surveillance of exposed workers. Multifaceted interventions in bakeries in the Netherlands (that combined education, engineering controls, and medical surveillance) reported total benefits resulting from a reduced disease burden valued at 44 659 352€.[172] A U.K. study in the motor vehicle repair industry reported positive outcomes with the use of a combination of pre- and post-safety health and awareness days, questionnaires and biological monitoring.[173] The success of the program was attributed to the use of a staged approach, supported by a research phase as well as targeted support for behavioral change. A study in Switzerland reported that reductions in isocyanate exposure levels, along with the use of respiratory prevention equipment and health surveillance over a 5-year period, resulted in only 4 individuals out of 5000 being diagnosed with OA in a large company.[190] Another study reported that the implementation of a comprehensive prevention program (that combined education, engineering controls, administrative controls, use of PPE, and medical surveillance) reduced the prevalence of laboratory animal allergy (LAA) from 12% to 22% to 0 during the last 2 years of observations.[174] A 2003 review article concluded that the incidence of LAA can be reduced by effective, integrated health risk management, with the conscientious use of engineering, procedural and personal control measures.[191]

The French-language searches identified two publications describing a multifaceted approach developed for the Québec Public Health Network in Occupational Health. The Québec approach includes identification of workplaces with sensitizers and irritants that can cause OA or rhinitis, education of workplace actors, case finding of symptomatic cases by questionnaire, a referral and evaluation process for symptomatic workers, support with compensation cases if needed, and elimination and control of exposures that can cause OA through preventive measures in the workplace.[192] See Tables 4 and S7 for more information.

3.3 | What we heard from the key informants

Our interviews with the key informants generally affirmed what we had learned from the reviews of the literature. Across all the interviews, several common themes emerged:

1. OHS outcomes are influenced by a constellation of factors that include, but are not limited to, regulatory frameworks, organizational and management structures, organizational and workplace safety culture, worker engagement, and empowered health and safety committees.
2. The dearth of well-designed evaluative studies of preventive interventions is not surprising, given the general challenges of conducting longitudinal research in the workplace and the particular challenges of studying the precariously employed workforce. Controlled trials of prevention interventions are very rarely done and for many prevention interventions, little or no attempt is made to measure effectiveness. Without baseline assessments, it is impossible to attribute with certainty any improvements in outcomes to a specific intervention.
3. The impact of regulatory interventions depends on the overall context in which they are implemented (ie, political, social, legal, and economic), the presence or absence of a strong enforcement regime, and mechanisms for keeping them up to date with current scientific knowledge.
4. Across industries and occupations, control technology is not being used to maximal benefit to reduce exposure at the source. For many hazards, employers (particularly those in small- and medium-sized enterprises where some exposures occur at the highest levels) tend to rely on PPE, which shifts the onus of protection onto the worker. Affordability is likely the main reason for this.
5. Rather than focusing on controlling exposures, the more strategic primary prevention approach would be to move upstream and focus on eliminating the hazard at its source, thereby reducing the burden on small employers and workers for prevention. Adopting or legislating such a "prevention by design" approach could create opportunities for occupational health to become an economic engine that drives innovation and technology.
6. Effective prevention requires the breaking down of silos (ie, those that separate occupational health from public health more broadly as well as those that compartmentalize the practice of occupational health). It is important to consider who has the potential to make an intervention succeed and to involve them from the outset.

A number of our key informants highlighted examples of primary prevention that they considered worthy of further exploration. These included: the Toxics Use Reduction Institute (TURI) in Massachusetts; the *Registration, Evaluation, Authorisation and Restriction of Chemicals* (REACH) regulation in the European Union; NIOSH's Prevention through Design (PtD), the *Toxics Reduction Act* in Ontario, Canada; the SOBANE approach in Belgium; programs in Scandinavia and Québec that integrate occupational health into public health; the NIOSH Total Worker Health program in the United States; and NEPSI, the European Network on Silica.

4 | DISCUSSION

4.1 | Research gaps

One of the scoping review's inclusion criteria was that studies should incorporate some measure of effectiveness, although articles about nonevaluated programs or strategies were included if they appeared promising. The relative lack of methodologically high-quality studies evaluating the effectiveness of primary prevention strategies, particularly among vulnerably situated workers, was one of the gaps in the research literature identified by the scoping review. Key informants confirmed this gap, noting that studies of randomized controlled trials of prevention interventions are very rarely done and that, for many prevention interventions, little or no attempt is made to measure effectiveness. Without baseline assessments, it is impossible to attribute any improvements in outcomes to a specific intervention. Better evaluative studies of prevention interventions, particularly in the vulnerable workforce, are required. Two recent publications discuss the practical and methodological challenges of designing these kinds of studies and offer recommendations on alternate study designs that may be appropriate for assessing occupational health evaluations.[193,194]

4.2 | Policy-relevant findings

The findings of our scoping review suggest that each approach to primary prevention (ie, legislation and regulation, exposure control, hazard/disease surveillance, education, and training) plays an important role in preventing the four occupational diseases of interest. However, each has its limitations and each is insufficient on its own. Although our project did not incorporate a systematic weighing of the evidence, our review appears to suggest that multifaceted interventions are often more effective than ones consisting of a single activity.

4.2.1 | Legislation and regulations

We identified a range of studies illustrating that legislation and regulations are an effective tool for the primary prevention of contact dermatitis,[81-83,85,86] OA,[87,159,160,195] and occupational cancers due to exposure to asbestos,[112,114] silica,[115] and diesel exhaust.[113] However, the findings from the NIHL review suggest that their impact appears to be context-dependent and related to both the nature of the regulations and the degree of enforcement.[25,52-57] A recent evaluation of the practical implementation of the EU's Occupational Safety and Health (OSH) Directives in member states[196] and a recent systematic review on the effectiveness of OHS regulatory enforcement[197] support these findings.

Other studies that examined the effectiveness of inspections and enforcement on compliance have drawn similar conclusions. Examples include: a U.K. study demonstrating that the introduction of workplace exposure limits (WELs) coincided with a significant reduction in the incidence of work-related short-latency respiratory diseases associated with agents having a WEL vs those that did not[198]; a U.K. study which found that some targeted interventions undertaken by the regulatory agency were more effective than others at reducing short-latency respiratory diseases reported to the Health and Occupation Reporting network[199]; a Cochrane review that concluded inspections as an enforcement tool have inconsistent effects on decreasing injuries in the short term, but appear to decrease injury rates in the long term (ie, after more than 3 years of follow-up)[200]; and a systematic review that found strong evidence that actual citations and penalties reduce injuries.[201]

4.2.2 | Exposure control

In theory, the hierarchy of controls is an effective primary prevention framework and our review identified studies, across a range of industries, which found that specific elements of the hierarchy are effective at preventing NIHL,[58-61] contact dermatitis,[37,87-89] and some forms of OA[161-165]; as well as reducing exposure to known carcinogens like diesel exhaust,[121-127] silica,[131-144] and shiftwork.[146-149] In practice, however, there tends to be a focus on PPE rather than on higher elements in the hierarchy. This is problematic, as it shifts the burden of protection to the worker, who may end up being over-exposed because they are not appropriately trained in the use of the equipment or may feel constrained in their ability to access and use the equipment. One example of control technology not being used to maximal benefit to reduce exposure at the source that was identified in both the literature review and in the key informant interviews is the enforcement of the OSHA Noise Standard.[52-54] Affordability is likely the main reason that many employers (particularly those in small- and medium-sized enterprises where some exposures occur at the highest levels) rely on PPE. A possible solution is "prevention by design," whereby the focus is on upstream elimination of the hazard at its source, rather than on downstream control of exposure. A suggestion made by one of our key informants was the introduction of a legal requirement that noise reduction be factored into building design standards (eg, for all new workplaces and when companies implement new production, manufacturing, or packaging lines). This would not only protect workers from noise exposure, but also minimize the need for employers to undertake costly retrofits to buildings or production lines to meet noise regulations.

4.2.3 | Hazard and disease surveillance

In the studies we reviewed, hazard and disease surveillance systems were associated with the prevention of the four diseases of interest, as well as occupational disease more generally. Exposure monitoring, medical monitoring and health screening (ie, audiometric programs) were found to be effective strategies for preventing NIHL.[62-66] Exposure monitoring and surveillance were effective at controlling exposure to diesel exhaust.[128] Medical surveillance and health screening were also identified as effective strategies for preventing OCD[29,91,107] and some forms of OA.[90,166,167] As illustrated in the contact dermatitis literature, an effective disease-reporting scheme, such as THOR (EPIDERM), is useful for evaluating the health impact of changes in OHS legislation and policy.[85,86]

In two studies evaluating national-level surveillance systems (the Canadian National Dose Registry and the Finnish ASA Register), the authors pointed to declining trends in disease over the time period for which data have been collected, concluding that the registries had contributed to protecting workers from exposure.[202,203] Similarly, a review article examining the impact of the Finnish Information System on Occupational Exposure (FINJEM) concluded that the registry was useful for monitoring trends in exposure over time and for predicting potential exposures in the future; for generating national-level estimates of exposure (eg, prevalence of exposure and over-exposure, as well as average levels) that can be used to compare with existing exposure limits, and to inform prevention policy and practice at the jurisdictional level; for assessing occupational exposure for epidemiological studies; and for assessing health risks and the burden of disease.[204]

A recent survey identified 33 occupational disease surveillance systems in 20 countries across the EU.[205] Some are compensation-based (eg, the Belgium Compensation Fund for Occupational Diseases [FBZ], the German Statutory Accident Insurance [DGUV]), while others are based on physician reports or household surveys (eg, the Health and Occupation Research [THOR] Network in the United Kingdom and the Republic of Ireland); the MALPROF† system in Italy, various disease-specific registries (eg, the French National Program for Mesothelioma Surveillance) and a network of registries (le Réseau National de Vigilance et de Prévention des Pathologies Professionnelles [RNV3P]) in France). Many of these systems are also members of MODERNET (Monitoring trends in Occupational Diseases and tracing new and Emerging Risks in a NETwork), a collaboration founded in 2008 between academic centers investigating

occupational disease and work-related ill-health incidence in the United Kingdom, Netherlands, France, Italy, Finland, and the Czech Republic. Several of the systems, including MODERNET, have been evaluated.[205-212] The findings of a study examining trends in the EU between 2000 and 2012 included: an overall decline in the incidence of shorter latency diseases (eg, contact dermatitis, OA) across the EU; and interjurisdictional variability in the incidence of noise-induced hearing loss (eg, the incidence was increasing in Belgium, Spain, Switzerland, and the Netherlands and decreasing elsewhere).[210] A study assessing the prevalence of uncompensated work-related diseases in France observed differences over time by gender, age and disease[211]; while another examining the MALPROF system in Italy determined that over the period 1999 to 2012, noise-induced hearing loss was the most frequently reported disease (n =4378, accounting for 32% of the reported diseases).[206] All of these studies concluded that the surveillance systems had been useful at identifying the incidence of known occupational diseases (and, in some cases, at illuminating emergent diseases),[212] at stimulating occupational health research, and at informing the development of preventive measures (including the setting of priorities and targets). Surveillance data were also used in another study to illustrate the positive impact of legislation on chromate allergy in the United Kingdom.[82]

The studies we identified illustrate that surveillance has multiple roles across the prevention spectrum (eg, monitoring trends in exposure to known hazards, monitoring their health impact, serving as a beacon or an early warning of new hazards, tracking progress towards prevention goals [at either the societal or the workplace level], generating an understanding of the extent and dimensions of a problem, informing the development of effective public health policy, and evaluating what works and what does not).[210,213] Accurate, trustworthy, and comparable data are critical to the success of an effective surveillance system,[213] both within and across jurisdictions. This latter point is particularly relevant to federated countries, like Canada, where no national standards exist for the collection and sharing of occupational health data.

4.2.4 | Education and training

We identified studies, across the occupational diseases of interest, that found education and training was an effective vehicle for changing behavior.[38,67-71,92,93,95-101,103,104-106,118,119,150,151,168,169,170,187,188,189,214] However, as suggested by the NIHL scoping review, the effectiveness of many educational interventions appears to be context-dependent and influenced by the manner of delivery.[72-77] Factors that were identified as critical to the success of primary prevention programs and educational campaigns included: worker engagement and involvement; having a solid understanding of the needs of the audience as well as of the potential barriers to uptake; and, particularly for smaller firms, using trusted sources (like suppliers, peers, and trade associations) to communicate messages. One example shared with us by a key informant was the development of a successful glove intervention for hairdressers in the United Kingdom. The U.K. Health and Safety Executive, in partnership with local authorities and hairdressing industry bodies, worked to raise awareness and promote good hand care, including the use of the correct type of gloves.

A recent systematic review assessed whether behavioral interventions had an impact on workers' observed or self-reported use of respiratory protective equipment (RPE).[215] Based on a review of 14 studies meeting their inclusion criteria, the authors concluded: "there is very low quality evidence that behavioral interventions, namely education and training, do not have a considerable effect on the frequency or correctness of RPE use in workers." Acknowledging that the included studies had methodological limitations and that there were no studies on incentives or organizational-level interventions, the authors identify a need for further research (specifically, large randomized controlled trials with clearer methodology) and note that further studies should "consider some of the barriers to the successful use of RPE, such as experience of health risk, types of RPE and the employer's attitude to RPE use."

In another systematic review, 16 researchers examined the findings of 20 unique randomized controlled trial studies to determine whether OHS training has a beneficial effect on workers and firms and whether higher (vs lower) engagement has a greater beneficial effect on workers and firms.[216,217] The reviewers considered the methodological quality of the available research literature and drew the following conclusions: there is strong evidence supporting the effectiveness of OHS training on targeted OHS behaviors of workers, but insufficient evidence on the effectiveness of OHS training on: (a) knowledge and attitudes and beliefs (because there are too few studies of sufficient quality), and (b) injuries or symptoms (because the effects are inconsistent and small). There is also insufficient evidence that high (vs medium/low) engagement training is more effective on targeted behaviors (either because there are too few studies of sufficient quality or because the observed effects are very small). The reviewers concluded that there is a lack of high-quality randomized trial research examining the question of OHS training effectiveness. This lack of useable evidence impeded their ability to draw conclusions in some areas.

4.2.5 | Multifaceted approaches

We heard from our key informants that OHS outcomes are influenced by a constellation of factors, including (but not limited to) regulatory frameworks, organizational and management structures, organizational and workplace safety culture, worker engagement, and empowered health and safety committees. This observation was borne out by the findings of many of the studies we identified.[25,67-73,78,79,80,98,107-113,120,129,130,145,149-157,171,172-176] Both the scoping review and key informants identified the European Network on Silica[‡] (NEPSI) as an example of a multi-level, sector-specific initiative that is likely to have a better chance of success than other more traditional prevention initiatives. Other models that offer promise include participatory risk management strategies (like the SOBANE approach in Belgium), and programs that

integrate occupational health into public health and treat work as a social determinant of overall health (eg, models in Scandinavia and Québec, the NIOSH Total Worker Health program in the United States). Breaking down silos that separate occupational health from public health more broadly as well as those that compartmentalize the practice of occupational health may be the way forward.

4.3 | Strengths and limitations

This project utilized scoping review methods[45-48] to identify, abstract, and synthesize the evidence on what is known about the effectiveness of primary prevention strategies for three occupational diseases (noise-induced hearing loss, OCD and OA) and four work exposures that significantly contribute to the burden of occupational cancer (asbestos, diesel exhaust, silica, and shiftwork). While this approach offered the advantage of allowing a broad range of questions to be considered within the project's time and budgetary constraints, scoping review methodology does have one key limitation—namely, that it typically does not incorporate a critical appraisal of individual studies or an assessment of the risk of bias.[45-47,218] This can impact on the generalizability of a scoping review's findings.[46]

The literature on scoping reviews notes that they generally have two different purposes: (a) literature, conceptual, or policy mapping exercises that examine the range and nature of a particular research area, with the goal of guiding future studies; or (2) examinations of the literature to summarize and synthesize the findings from different types of studies, to disseminate research findings or identify gaps in the literature.[45,219] The latter category tends to be more systematic, following procedures and steps similar to those that would be taken in a systematic review.[219] Our scoping review falls into the latter category.

Recent articles have suggested that scoping review methodology can be improved by engaging a large, multidisciplinary team comprised of researchers and key stakeholders; clearly articulating the research question to clarify the focus, to establish the search strategy and to guide the scope of the study; selecting studies for inclusion through an iterative, not a linear, process and having selected studies reviewed by more than one team member; collective input from the research team on how data will be extracted and charted (preferably via an iterative process of extracting data, refining and updating the form); a step-wise approach to analysis, generation of a report that links the findings back to the overall purpose of the review, and consideration of the implications for research, practice and policy; and, making consultation an integral, rather than optional, part of the review.[47,218-221]

Our scoping review was strengthened by the inclusion of many of these methodological features, specifically: the use of a published framework; inclusion of stakeholders throughout the research process, as well as consultation with subject-matter experts on the findings; a systematic and replicable search strategy (which included searches of 12 electronic databases, combined with manual and snowball searches); a systematic, transparent and replicable strategy for study selection (which included predefined and iteratively refined inclusion/exclusion criteria, and screening of titles, abstracts and full-text articles by two or more reviewers); a standardized method of charting the data (ie, use of a standardized form, which was collectively and iteratively developed by the research team; data extraction by research assistants, with subsequent verification by investigator with subject-matter expertise); and reporting of the results in three distinct steps (ie, a descriptive summary, with statistics about the numbers and types of studies retrieved (overall and by disease) and summary tables of findings; a thematic analysis by primary prevention cluster; and a consideration of the scoping review's findings within the broader context, including their implications for research, policy, and practice).

It is possible that some relevant papers were missed in the search strategy and some may have been missed in the inclusion/exclusion criteria review. We attempted to mitigate this possibility by having all the evidence examined by at least two members of the study team (ie, the investigator and the research assistant responsible for each disease area) and by engaging our key informants in a dialogue about primary prevention in their jurisdiction or area of expertise and about initiatives or strategies they considered to be particularly good that may not have been captured in the scoping review.

5 | CONCLUSIONS

There is a large body of literature focused on identifying, quantifying, and reducing the risk of occupational diseases. Despite being largely preventable, many of these diseases continue to be highly prevalent and their costs (economic, societal, and human) staggering. For these reasons, effective primary prevention strategies are essential. One of the major contributions of this project (beyond the identification of promising primary prevention strategies and significant gaps in our knowledge of efficacy) is that it develops an overview of the literature on what works in the primary prevention of occupational disease and lays the groundwork for future systematic reviews in this area. Our finding that implementation of multifaceted approaches appear to have the greatest and longest-lasting impact will be of interest to decision makers and stakeholders and is worthy of future evaluation by researchers.

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CONFLICTS OF INTEREST

The authors declare that there are no conflicts of interest.

DISCLOSURE BY AJIM EDITOR OF RECORD

John D. Meyer declares that he has no conflict of interest in the review and publication decision regarding this article.

AUTHOR CONTRIBUTIONS

A.R.K., Project Coordinator: participated in the design of the study, provided day to day oversight of the project, performed scoping review of "occupational diseases," interviewed key informants, synthesized results of all scoping reviews into final report, and was the lead author of the manuscript. P.A.D., Coinvestigator and Occupational Cancer Team Lead: participated in the design of the study and all phases of the occupational cancer scoping review process, and reviewed drafts of the manuscript. B.N., Coprincipal Investigator and Occupational Asthma Team Lead: participated in the design of the study and all phases of both the overall scoping review process and the occupational asthma scoping review, and reviewed drafts of the manuscript. V.H.A., Coinvestigator and Occupational Cancer Team Lead: participated in the design of the study and all phases of the occupational cancer scoping review process, and reviewed drafts of the manuscript. H.W.D., Coinvestigator and Noise-induced Hearing Loss Team Lead: participated in the design of the study and all phases of the NIHL scoping review process, and reviewed drafts of the manuscript. Z.G., Coinvestigator: participated in the design of the study and the occupational asthma scoping review process. K.H., Occupational Asthma Research Assistant: participated in the design of the study and performed the occupational asthma scoping review. D.L.H., Coinvestigator and Occupational Contact Dermatitis Team Lead: participated in the design of the study and all phases of the occupational contact dermatitis scoping review process, and reviewed drafts of the manuscript. M.K., Coinvestigator: participated in the design of the study and reviewed drafts of the manuscript. S.R.S., Coinvestigator and French Language Team Lead: participated in the design of the study and all phases of the French language scoping review process, and reviewed drafts of the manuscript. S.B., Coprincipal Investigator: participated in the design of the study and all phases of the overall scoping review process and reviewed drafts of the manuscript.

ETHICS APPROVAL AND INFORMED CONSENT

This study was deemed exempt from formal ethics review at each of the authors' Research Ethics Boards as no personal health information was collected or analyzed and interviews were only conducted with "authorized personnel to release information or data in the ordinary course of their employment about organizations, policies, procedures, professional practices or statistical reports" (TCPS2, 2014).

ENDNOTES

* This program is a cooperative effort that began in the late 1980s and incorporates regulation and enforcement of asbestos abatement companies, a ban on the import of asbestos and health monitoring.

† "MALattie PROFessionali" (or, "occupational diseases" in English).

‡ NEPSI is a social contract between employers, government, trade unions, and trade associations focused on preventing exposure to crystalline silica through multiple levels of intervention (monitoring, training, surveillance, etc.).

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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