Preventing Occupational Disease: Designing a System that Works

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1 Point Form Summary

1.1 Main research findings

- Primary prevention activities (i.e., legislation and regulation, exposure control, hazard/disease surveillance, education and training) play an important role in preventing occupational diseases.
- The success of the European Union's directive on chromium in cement (EU Directive 2003/53/EC) demonstrates that legislation, combined with an effective enforcement regime, can be effective at preventing occupational diseases.
- National or provincial surveillance systems make it possible to examine temporal changes in the incidence of occupational disease cases and to evaluate the impact of legislative or regulatory change.
- Linked population-based administrative databases are powerful tools for monitoring outcomes in vulnerable workers who may not be captured in conventional injury and disease surveillance systems.
- The effectiveness of education and training as a vehicle for changing behaviour appears to be context-dependent and influenced by the manner of delivery. Worker engagement and involvement is essential.
- Occupational health and safety outcomes are influenced by a constellation of factors and multi-faceted interventions appear to be more effective than ones with a single activity. The Québec Public Health Network in Occupational Health is an example of an effective multi-faceted program that has been implemented in Canada.

1.2 Implications for research, policy and practice

- Well-designed evaluative studies of preventive interventions are needed to inform evidence-based policy and practice decisions about which interventions are the most effective to implement nationally, provincially or at the workplace level.
- Investing in enhancements to linked population-based administrative datasets, in making the data more accessible and in developing research expertise to utilize the data would foster more policy-relevant research that would, in turn, enable better targeted prevention campaigns to be developed and implemented. This would benefit all workers and vulnerable workers, in particular.
- The impact of regulatory interventions depends on the context in which they are implemented, the presence/absence of a strong enforcement regime, and a process for keeping them up to date with current scientific knowledge.
- Adopting or legislating a "prevention by design" approach would prevent exposure from happening in the first place and would create opportunities for occupational health to become an economic engine that drives innovation and technology.
- There is an appetite in Canada for strategic action on occupational disease prevention at the provincial level, as well as for resourcing and harmonization of systems and strategies across the country. The absence of a national OHS legislative framework, combined with the inter-provincial differences in OHS across Canada, currently make it challenging to implement national level interventions.

2 Executive Summary

2.1 Introduction

Canadian stakeholders have expressed great interest in the primary prevention of occupational disease, but there is currently little systematic evidence to guide them in the search for effective approaches for Canadian contexts. The challenges of preventing occupational disease are global and are accentuated by changing industry structures and labour force demographics/dynamics, contributing to an increasing proportion of workers being precariously employed. In Canada, a political system that delegates jurisdiction for occupational health and safety to the provinces (i.e., there is no national OHS framework in Canada) exacerbates these challenges. Inter-provincial differences in industry sectors, OHS legislation and the organization of OHS services mean that strategic and programmatic requirements, approaches and resources to prevent occupational disease vary quite considerably across the country. This creates an uneven prevention landscape, presenting particular challenges for industries operating in more than one province and makes it difficult to monitor trends in occupational disease and exposure across the country as a whole, to design and implement prevention strategies and to document their effectiveness.

2.2 Purpose

The project had three primary objectives:

1. To identify strategies with a demonstrated capacity to prevent the following four occupational diseases: noise-related hearing loss, occupational cancers, occupational asthma and occupational contact dermatitis.
2. To assess whether these strategies are applicable in the Canadian context including in small and medium enterprises (SMEs) and among vulnerably situated labour forces including those that are precariously employed.
3. To involve key stakeholders in occupational disease prevention across Canada as members of the team, through key informant discussions and broader consultations.

2.3 Methods

A multidisciplinary team, with expertise in the four occupational diseases of interest, worked with a network of researchers, regulators and other prevention stakeholders to guide the project. Data were collected in three stages: 1) searches of the peer-reviewed and grey literature; 2) identification of the most promising strategies in both the English and French literature; and 3) consultation with key informants and other experts. Scoping review methods were used to identify and select the most promising primary prevention strategies identified from the English and French literature. Key informant interviews were conducted to collect feedback on the process and output, as well as to identify any gaps in the findings.

2.4 Key findings

For each of the occupational diseases, the scoping review identified a range of types of primary prevention interventions. These included: legislation and regulation, exposure control, hazard/disease surveillance, education and training, and multi-faceted prevention approaches.

Key findings from the scoping review, which were supported by discussions with our key informants include:

1. Some jurisdictions have incorporated primary and secondary occupational disease prevention into legislation. In some circumstances, legislation and regulations are effective at reducing (or eliminating) exposure, at changing behaviour and at reducing the prevalence of occupational diseases. However, regulations are insufficient on their own and their impact appears to be context-dependent and reliant on the degree of enforcement.
2. The hierarchy of controls is, in theory, an effective prevention strategy. However, there tends to be a reliance on personal protective equipment *vs*. engineering controls in practice. This is problematic for all workers (and particularly so for vulnerably situated workers) because this shifts the onus of risk awareness and protection to the worker.
3. Some hazard and disease surveillance systems were shown to be effective for helping to prevent the occupational diseases of interest, as well as for evaluating the health impact of changes in OHS legislation and policy.
4. The effectiveness of education and training as a vehicle for changing behaviour appears to be not only context-dependent but also influenced by the manner of delivery. Worker engagement and involvement is essential.
5. Occupational health and safety 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 empowerment of health and safety committees.

2.5 Conclusions

Each approach to primary prevention (i.e., legislation and regulation, exposure control, hazard/disease surveillance, education and training) plays an important role in preventing occupational diseases. However, each has their limitations (e.g., in some cases, their impact appears to be context-specific) and each is insufficient on their own. Although this project does not incorporate a systematic weighing of the evidence, the literature suggests that multi-faceted interventions are often more effective than ones with a single activity.

A more general conclusion that has implications for future research is that there are few well-designed evaluative studies for many primary prevention interventions. Interventions to reduce hazardous exposures do exist for many occupational diseases. However, for practical and methodological reasons, few of them have been evaluated for impact. The lack of high quality evaluation studies limits our ability to make causal inferences and to draw conclusions about what actually works. Thus, there is a critical need for better evaluative studies of preventive interventions so that better evidence-informed policy and practice decisions can be made about which interventions are the most effective to implement nationally, provincially or at the workplace level.

Very few of the studies identified were undertaken in Canada or were specifically designed to examine the impact of primary prevention interventions on outcomes in vulnerable workers. While some of the workplace level interventions are likely transferable to Canadian workplaces, the absence of a national OHS legislative framework combined with the inter-provincial differences in OHS across Canada make it challenging to implement any of the national level

interventions. That said, feedback from Canadian OHS policy makers and administrators indicates that there is an appetite for strategic action on occupational disease prevention at the provincial level, as well as for resourcing and harmonization of systems and strategies across the country.

2.6 Implications for future occupational health research

One of the scoping review's inclusion criteria was that studies should incorporate some measure of effectiveness, although articles about some non-evaluated programs or strategies were included if they appeared promising. In addition, the project focused on identifying programs or strategies that had actually been implemented (rather than being conducted solely for research), that are relevant to the Canadian context, and that take into account changing industry structures and labour force demographics. 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. Better evaluative studies of prevention interventions, particularly in the vulnerable workforce, are required.

2.7 Applications for policy and prevention

This project showed that the impact of regulatory interventions depends on the context in which they are implemented (i.e., outcomes differ by industry), the presence/absence of a strong enforcement regime, and a process for keeping them up to date with current scientific knowledge. This has implications for the regulation/policy development and implementation process.

Other potentially effective ways to reduce levels of exposure and prevent occupational disease include: adopting or legislating a "prevention by design" approach (i.e., shifting from the requirement to control exposures to a focus on eliminating the hazard at source) and control banding. The former prevents exposure from happening in the first place and creates opportunities for occupational health to become an economic engine, driving innovation and technology. The latter may provide an easy to understand and easy to apply approach to controlling hazards in workplaces that have limited expertise in workplace health and safety, industrial hygiene, or chemical control. It also allows for control recommendations to be made for products that do not have occupational exposure limits. However, because control banding has not been fully validated and there is no universally accepted approach to banding, more research examining the validity of control banding and its applicability to the Canadian context is recommended.

The effective protection of the vulnerable or precariously employed workforce is a broad social issue characterized by their lack of social power. Because occupational diseases, particularly among vulnerable workers, may not be captured in conventional injury and disease surveillance systems (e.g., workers' compensation databases), it is important to invest in linked population-based administrative databases. However, a major challenge is the lack of occupation or industry information in administrative records, which could start to be addressed by the inclusion of this field in electronic medical records. Linking records in these types of databases and making them accessible to occupational health researchers and public health surveillance practitioners, as well as fostering policy-relevant research partnerships and developing research expertise to utilize the data, would enable targeted prevention campaigns to be developed and implemented in this population of workers.

3 Main Report

3.1 Introduction

Occupational or work-related diseases remain largely invisible in comparison to industrial accidents, despite the enormous human, productivity and work capacity, compensation and healthcare costs associated with them. The World Health 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). Although largely preventable, occupational diseases continue to be highly prevalent and costly in Canada and elsewhere (4-10). In British Columbia, for example, more than 106,000 lost-time compensation claims for occupational disease were accepted between 1991 and 2015. Included in this total were 12,282 hearing loss claims, 1,014 occupational cancer claims, 3,816 dermatitis claims, and 1,220 occupational asthma claims. The cost per claim was reported to be: $5,300 for hearing loss, $6,000 for dermatitis, $104,900 for cedar dust asthma, $41,500 for "other" occupational asthma, $175,600 for asbestos-related cancer and $228,400 for "other" occupational cancers (11). Furthermore, compensation figures such as these substantially under-represent the real burden of occupational diseases (12-16) and are inadequate as a guide for public policy (14, 17-20). Effective prevention strategies are essential to reduce the incidence and the high economic, societal and human costs of occupational disease.

This report presents the findings of a project undertaken to identify the most promising strategies and programs to prevent four occupational diseases: noise-induced hearing loss, contact dermatitis, occupational asthma and occupational cancer associated with four specific work exposures (asbestos, silica, diesel exhaust and shiftwork). It begins by explaining why these four occupational diseases were selected and what we mean when we talk about "primary prevention". It goes on to describe the methods we used to identify promising strategies and to summarize what we learned from a scoping review of the peer-reviewed and grey literature. It concludes with a synthesis of the

findings and places them in the context of insights gleaned from discussions with stakeholders and key informants.

3.1.1 Rationale for the project

Canadian stakeholders have expressed great interest in the primary prevention of occupational diseases, but there is currently little systematic evidence to guide them in the search for effective approaches for Canadian contexts. In Canada, as elsewhere, changing industry structures and labour force demographics/dynamics further accentuate the challenges of preventing occupational disease. These changes include: the growth of small and medium enterprises (SMEs) (21), a decline in rates of unionization (22), the spread of part-time/temporary/casual (23) or precarious employment, increased subcontracting, and growing use of temporary employment agencies to provide workers for high-risk jobs (24). A further relevant change, in Canada in particular, is the shift of economic activity from manufacturing to rural and remote resource development, which often operates in transient work sites and relies on labour migrants who live, and often access health care, far from their places of employment. Prevention is particularly challenging among this growing proportion of vulnerably situated workers.

Addressing the challenge of primary prevention in Canada is further complicated because Canada is a federation of thirteen provinces and territories and because, for most workers, occupational health and safety falls under provincial, rather than federal, jurisdiction[1]. As a consequence, each province has its own occupational health and safety (OHS) legislation[2]. The downstream implications of this are twofold. First, with few exceptions, occupational disease prevention programs do not exist at the national level in Canada. Second, because of inter-provincial differences in industry structure, OHS legislation and the organization of services, strategic and

[1] In Canada, labour legislation (which includes specific pieces of legislation related to OHS) falls under the jurisdiction of the provinces. Depending on the jurisdiction, OHS requirements are set out in the *Occupational Health and Safety Act* and/or the *Workers' Compensation Act*, along with their related regulations.

[2] At the federal level, OSH legislation applies to workers in the federal government, federal corporations, and federally regulated industries (e.g., inter-provincial and international transportation, shipping, telephone and cable systems). Provincial or territorial legislation applies to most other workplaces.

programmatic approaches and opportunities to prevent occupational disease may vary quite considerably across the country. This creates an uneven prevention landscape, presents particular challenges for industries operating in more than one province and for preventing occupational disease among vulnerably situated workers, and makes it difficult to examine trends in occupational disease and exposure across the country as a whole and to document the effectiveness of prevention efforts.

3.1.2 Defining prevention

Prevention is defined as "actions aimed at eradicating, eliminating, or minimizing the impact of disease and disability, or if none of these is feasible, retarding the progress of disease and disability" (25). Three levels of prevention most commonly inform the practice of occupational health and safety: primary, secondary and tertiary (26). Primary prevention is the main focus of this report. It is the act of preventing injury or disease *before* it occurs (26-30). Primary prevention activities may be single interventions focused on a specific hazard or disease at the organizational level or they may be crosscutting and multifaceted, operating at multiple (including national) levels. Secondary prevention is the *early* identification of a health problem in order to prevent the occurrence of a debilitating injury or disease (26-30). Although secondary prevention initiatives are technically outside the scope of this report, some have been included because they can play a key role in primary prevention when the documentation of symptoms and illness is coupled with interventions to reduce exposures. Tertiary prevention includes activities aimed at reducing the impact of an injury or a disease that has *already* occurred (e.g., a vocational rehabilitation program to restore functional ability) (26-30). Tertiary prevention strategies and programs were outside the scope of this project.

3.1.3 Research Objectives

The project had three primary objectives:

1. To identify strategies with a demonstrated capacity to prevent noise-related hearing loss, occupational cancers, occupational asthma and occupational contact dermatitis.

2. To assess whether these strategies are applicable in the Canadian context (including SMEs, vulnerably situated workers, and those that are precariously employed).

3. To involve key stakeholders in OHS disease prevention across Canada as members of the team, through key informant discussions and broader consultations.

3.2 Methodology

A multidisciplinary team with expertise in the four occupational diseases of interest worked with a network of researchers, regulators and other prevention stakeholders to guide the project. The project utilized scoping review methods to identify and select the most promising strategies, but did not incorporate a systematic weighing of the evidence. This allowed for a broader range of questions to be considered with available resources than would have been possible with a systematic review methodology. Data were collected in three stages: searches of the peer-reviewed and grey literature; identification of the most promising strategies; and consultation with key informants and other experts.

3.2.1 Stage 1: Searches of the literature

Health sciences librarians assisted the team to define the search criteria, to map keywords to database-specific search terms and to develop search strategies. Searches were conducted iteratively, which allowed for search strategies to be refined based on review of the findings and for the refinement of inclusion/exclusion criteria. For details of the search strategy, along with a complete list of search terms, see Appendix A1.

Electronic databases of the peer-reviewed literature were targeted first. The findings of these searches were used to inform searches of the grey 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 peer-reviewed and grey literature databases were searched (Table 1). All searches were limited to English and French language articles, published since 1996.

Table 1: Databases Searched

Peer-reviewed literature		Grey literature
• MedLine (via PubMed) • Embase • Web of Science • Cumulative Index of Nursing & Allied Health Literature (CINAHL)	• Scopus • Public Affairs Information Service (PAIS) International • Health Policy Reference Centre • Cochrane Library • INRS	• Google Scholar • Canadian Agency for Drugs & Technologies in Health (CADTH) Grey Matters • Canadian Centre for Occupational Health & Safety (CCOHS)**

**includes 7 databases: OSHLINE, NIOSHTIC, NIOSHTIC-2, HSELINE, CISILO, Canadiana, PubMed Subset

3.2.2 Stage 2: Identification of the most promising strategies

To filter out sources outside the scope of the project, a step-wise screening approach was developed and implemented. Articles included were restricted to those focusing on occupational disease primary prevention programs or strategies implemented in Canada, the United States, Europe, Australia, or other developed countries. Of particular interest were programs or strategies that: (a) have actually been implemented, rather than being conducted solely for research; (b) take into account changing industry structures and labour force demographics; (c) are relevant to the context of OHS in Canada; and (d) incorporate some measure of effectiveness (either self-reported or objectively measured). Review articles were also included, as were articles about non-evaluated programs or strategies that appeared promising[3]. Articles about secondary prevention were included if there was evidence of a mechanism or feedback loop to inform primary prevention activities.

Articles were excluded if they were: not related to occupational disease; not related to prevention interventions or programs; not occupationally-related, involved secondary or tertiary prevention without feedback loop; or consisted of very high level summaries with no documentation of impact, conference abstracts with minimal detail and no documentation of impact, duplicate articles covering identical interventions on the same cohort, studies describing context or history of the occupational disease of interest, commentaries on review articles already captured, or duplicate copies of articles captured from another database.

[3] These latter articles were flagged in the spreadsheets as "not evaluated".

Once all articles were appropriately triaged, information from the included sources was abstracted into a Microsoft Excel™ spreadsheet and summarized descriptively. 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, whether or not it had been evaluated, method of evaluation, descriptive statistics (e.g., subjects, sample size, data sources), and key findings.

3.2.3 Stage 3: Consultation with key informants and other experts

To supplement information collected in the literature searches and the scoping review, 14 key informants and experts were consulted via telephone conversations. Key informants were first given some context on the project's objectives, along with a summary of the findings' highlights. As each 30–60 minute discussion unfolded, informants were prompted with a series of questions designed to elicit information on: (a) primary prevention initiatives in their jurisdiction or area of expertise, (b) initiatives or strategies they considered to be particularly good that may not have been captured in the scoping review, (c) their perspectives on key elements of a successful program to protect vulnerably employed workers, and (d) any lessons learned from the implementation of primary prevention initiatives. At the end of the conversation, key informants were asked whether they would be interested in reviewing and/or receiving a copy of the final report. A list of the key informants interviewed, along with a summary of the questions posed, is provided in Appendix A2.

3.3 Results

This section of the report summarizes the outcome of the literature searches and the initial screening of the literature and the findings of the scoping review. It also provides a crosscutting synthesis of the findings. The synthesis looks across the four occupational diseases to pull out common themes and discusses them in the context of what we heard from the key informants and

discussions with other experts in sessions held during two conferences[4].

3.3.1 Results of the searches and initial screening of the literature

The searches of the peer-reviewed and grey literature databases generated over 40,000 hits[5]. Approximately one-third (n=14,810) came from the peer-reviewed literature. The majority of the hits were captured in the English language searches; however, the French language searches turned up a number of additional promising strategies that might have otherwise been missed. Articles about NIHL accounted for nearly 40% of the hits identified in the peer-reviewed literature, while articles about asbestos accounted for just over 60% of the hits identified in the grey literature.

After the screening criteria were applied, 876 articles remained. Of these, 85%, or 745, were on NIHL. To manage the volume of articles on NIHL, they were coded on the basis of type of intervention (e.g., hearing conservation, engineering noise control, medical screening, etc.) and a convenience sample of articles (n=384) was examined to ensure representation of references from the various databases searched and representation of topics from each code. Because of time constraints, only 117 NIHL articles were reviewed. Across the occupational diseases of interest, a total of 404 articles were retrieved for more in-depth review (Table 2).

Table 2: Number of references retrieved, by disease category & search language

NIHL	Contact Dermatitis	Occupational Cancer (carcinogens)				Asthma	Total
		Asbestos	Diesel Exhaust	Silica	Shiftwork		
English-language references							
113	38	31	16	23	21	90	336
French-language references							
7	15	28	3	4	1	14	72
Total number of references retrieved:							
120	**53**	**59**	**19**	**27**	**22**	**104**	**404**

[4] The 9th biennial meeting of the Canadian Association for Research on Work and Health (CARWH), held in Toronto on October 16-18, 2016; and an occupational disease symposium hosted by the Occupational Health Clinics for Ontario Workers (OHCOW) on October 26, 2016.
[5] A breakdown of the hits by disease and database/search engine is provided in Appendix B2.1.

3.3.2 Descriptive results about the articles retrieved

Descriptive results about the articles retrieved for review are highlighted in Appendix B. Included in this appendix are the results of the literature searches, broken down by disease and database (Appendix B2.1), the types of articles reviewed (Appendix B2.2), and descriptive summaries of the articles retrieved, by disease (Appendix B2.3).

3.3.3 Results of the scoping reviews

Detailed results of the scoping reviews are presented in Appendix C. Findings are grouped by broad category of prevention activity or intervention: legislation and regulation (Appendix C2), control of exposures (Appendix C3), surveillance of exposures or health outcomes (Appendix C4), education and training (Appendix C5), and multifaceted approaches (Appendix C6). The appendix presents a summary of what was learned, moving from the general (i.e., strategies aimed at preventing 'occupational disease' more broadly) to the specific (i.e., promising disease-specific strategies). Appendix D provides a bibliography of the articles examined for each occupational disease. What follows here is a high-level synthesis of the information contained in Appendix C setting our findings in the context of what we heard from key informants.

3.3.3.1 Legislation and regulation

Occupational health and safety legislation and regulations[6] are a method for the primary prevention of injury and disease at the societal level. They are intended to establish a minimum level of protection either for all workers or for those in specific industries[7]. The framework typically

[6] In Canada, *Occupational Health and Safety Acts* are the governing or enabling legislation (i.e., laws or statutes). Regulations are subordinate legislation and flow from provisions in the enabling statute.

[7] In Canada, the specific industries and workers covered by the *OSH Acts* vary by jurisdiction. For example, in British Columbia, Section 108 of the *Workers' Compensation Act* states that Part 3 (Occupational Health and Safety) and its regulations do not apply to mines covered under the *Mines Act*; Section 1 of Alberta's *Occupational Health and Safety Act* does not include persons engaged in farming or ranching operations in its definition of workers covered under the *Act*; Section 3 of Ontario's *Occupational Health and Safety Act* states that the *Act* does not apply to private residences, farming operations, or persons employed as teachers under the *Education Act*; and in New Brunswick, Section 3(2) of the *Occupational Health and Safety Act* states that the *Act* does not apply to any place of employment exempted by regulation. New Brunswick's *Underground Mine Regulation* exempts certain categories of mines from the *OHS Act* by stating that where there is a discrepancy between the *Act* and the *Regulation*, the provisions of the latter prevail. Workplaces under

incorporates general duty clauses, as well as hazard- or disease-specific requirements, and employs either a performance-based ("goal-oriented") or a prescriptive approach to determining compliance[8]. A jurisdiction's governing health and safety legislative framework will set out the parameters for enforcement and compliance (which may be mandatory or voluntary).

Regulatory approaches to preventing occupational disease include: an outright government ban on the manufacture and/or use of a hazardous substance, limits on levels of exposure, and/or recommended guidelines on the safe use of a substance (31). The most commonly used approach involves adoption and enforcement of regulated exposure limits. In some jurisdictions, supplementary strategies (e.g., symptom or disease surveillance) may also be required where a substance is deemed to be particularly hazardous.

Detailed findings from the scoping review on the effectiveness of legislation and regulations are presented in Appendix C2. The scoping review revealed how some jurisdictions have incorporated primary and secondary occupational disease prevention into legislation (e.g., the Health and Safety Executive (HSE) in the United Kingdom). It also showed that, in some circumstances, legislation and regulations are effective at reducing (or eliminating) levels of exposure, at changing behaviour and at reducing the prevalence of occupational diseases. This was particularly evident in the literature on contact dermatitis, asbestos, silica and some forms of occupational asthma. However, as the findings from the NIHL review suggest, their impact appears to be context-dependent and reliant on the degree of enforcement.

federal jurisdiction are regulated by the *Canada Labour Code*. Examples include: aviation, some grain elevators, banks, interprovincial trucking, shipping, railway and bus companies.

[8] A performance-based regulation establishes the endpoint and allows the employer to identify the most suitable means of achieving it. A prescriptive regulation specifies the endpoint and the means by which it is to be achieved.

This finding is supported by a recent evaluation of the practical implementation of the European Union's (EU) Occupational Safety and Health (OSH) Directives in member states (32), as well as by feedback from some of the key informants, who noted that the success of regulatory interventions at preventing occupational disease is influenced by the overall context (i.e., political, social, legal, and economic) in which they are adopted and implemented. As an illustration, key informants highlighted examples of how inter-jurisdictional differences in legislation lead to different "evidence-" or "health-based" exposure limits being adopted for the same substance. Another crucial consideration is whether the legislation and regulations exempt hazardous agents, industries or occupations from coverage. Key informants also noted that to be truly effective, regulations require not only a strong enforcement regime, but they also need to be kept up to date. The ten years it took to modernize the European Union Occupational Safety and Health Directives was one example given of how long it can take to update regulatory frameworks.

Example of an effective regulatory intervention

Objective: eliminate exposure to hexavalent chromate in cement and reduce the risk of allergic contact dermatitis (ACD)

The intervention: a prohibition on the use or supply of cement containing >2 ppm of hexavalent chromate in the UK, following the European Union's adoption of EU Directive 2003/53/EC.

Outcomes:

- A significant decline in the incidence of ACD was observed in the period after the legislation was implemented (2005–2009), compared to the period before (2002–2004).
- A significantly greater decline was observed in ACD attributed to chromate *vs*. ACD not attributed to chromate.
- An even greater decline was observed in workers potentially exposed to cement.
- The majority of the decline in incidence occurred during 2005 immediately after the legislation was implemented.

Key Take-Away Messages:

- Legislation, combined with an effective enforcement regime, was effective at preventing occupational contact dermatitis.
- A national occupational disease reporting scheme made it possible to examine whether there were changes in the incidence of work-related ACD cases over time and to evaluate the health impact of changes in the legislation.

Source: Stocks SJ et al (2012)

3.3.3.2 Exposure control measures

The hierarchy of controls (HOC) is a primary prevention tool designed to select appropriate methods to protect workers from exposure. In decreasing order of effectiveness, the hierarchy consists of: elimination, substitution, engineering controls (e.g., ventilation), administrative controls (e.g., changes in work practice), and personal protective equipment (e.g., respirators, gloves,

earplugs) (33). Depending on the jurisdiction, the HOC may be embedded in the regulatory framework, either as a prescriptive requirement (in which case, compliance is mandatory) or as recommended practice (in which case, compliance is generally voluntary).

Detailed findings from the scoping review on the effectiveness of exposure control measures can be found in Appendix C3. The scoping review identified studies showing that measures across the hierarchy of controls (i.e., elimination/substitution, engineering controls, administrative controls, and personal protective equipment) have been effective at preventing certain occupational diseases (e.g., NIHL, contact dermatitis, and some forms of occupational asthma) and at reducing the levels of exposure to known carcinogens like diesel exhaust, silica, and shiftwork. Key informants acknowledged that, in theory, the hierarchy of controls is an effective strategy but noted that, in practice, there tends to be a reliance on personal protective equipment rather than engineering controls. Because this shifts the onus of protection to the worker, key informants flagged this as problematic, especially for precariously employed workers. The enforcement of the OSHA Noise Standard was highlighted as an example of where control technology is not pushed so long as employers give their workers hearing protection. This observation is borne out by several of the interventions examined in the review of the NIHL literature.

Noting that some of the highest exposures are now found in small and medium enterprises, key informants identified affordability as one of the key reasons that many of these employers rely on personal protective equipment. Small enterprises often can't afford to implement the control measures that actually work. One key informant suggested that "prevention by design" is a possible solution to this problem. That is, rather than focussing on controlling exposures, the better primary prevention strategy is to move upstream and focus on eliminating the hazard at its source. Another key informant echoed this perspective using noise as an example and suggested that there is a need for legislation that requires noise reduction to be taken into account in building standards for all new workplaces and when companies consider implementing new production or packaging lines. Such a requirement

would lead to prevention being done at the source prior to exposure and employers would avoid costly retrofits to buildings or production lines in order to meet noise regulations. The key informant noted that there is currently too much reliance on PPE if noise levels exceed the exposure limits despite numerous drawbacks to the use of personal hearing protection.

Key informants highlighted the following examples of where they believed the upstream approach to prevention has been successful: the Toxics Use Reduction Institute (TURI)[9] in Massachusetts, the *Registration, Evaluation, Authorisation and Restriction of Chemicals* (REACH) regulation in the European Union[10], NIOSH's Prevention by Design[11]. A Canadian example is the Ontario *Toxics Reduction Act*[12]. The objective of the *Act,* which was adopted in 2009, is to protect public health and the environment by reducing the use and emission of toxic substances. Its impact has yet to be evaluated. The Massachusetts' Toxic Use Reduction program has been evaluated and large reductions in the use and release of carcinogens have been documented(34). One key informant observed that by thinking about prevention in the context of "sustainable production", it might be possible to reframe the conversation so that occupational and environmental health is seen as an economic engine and a driver of innovation.

The scoping review identified control banding as one possible solution to address the challenges faced by small employers and the large proportion of hazards for which there are no occupational exposure limits. Control banding is a qualitative assessment and performance-based exposure control technique developed by the pharmaceutical industry that is often used to determine control measures when occupational exposure limits are not known (35, 36). A number of control banding systems exist in the EU and elsewhere (37-39). The most widely known are the UK's COSHH

[9] Information on TURI can be found at: http://www.turi.org/.
[10]Information on the REACH regulation can be found at: https://echa.europa.eu/regulations/reach.
[11]NIOSH is leading a "Prevention Through Design" initiative, which encompasses all of the efforts to anticipate and design out hazards to workers in facilities, work methods and operations, processes, equipment, tools, products, new technologies, and the organization of work. Information is available at: https://www.cdc.gov/niosh/topics/ptd/.
[12]Information on Ontario's *Toxics Reduction Act* can be found at: https://www.ontario.ca/laws/statute/09t19

Essentials[13] (40) and the ILO's International Chemical Control Toolkit[14] (41). The scoping review identified several studies that had been undertaken to determine the level of agreement between measured concentrations of hazardous substances and the exposure ranges predicted by the COSHH Essentials model (42-46). These studies concluded that control banding is a reasonable approach and recommended further investigation.

The principal advantages of control banding are that it provides an easy to understand and easy to apply approach to controlling hazards in small- and medium-sized workplaces that have limited expertise in workplace health and safety, industrial hygiene, or chemical control (47, 48); and that it allows for control recommendations to be made for products that do not have occupational exposure limits (36). However, it is important to note that the method has not been fully validated and that there is not yet a universally adopted approach (i.e., hazard bands can vary by jurisdiction (49) and

A Canadian example of a promising risk assessment tool for construction companies

Background: BC researchers, in collaboration with an industry safety association and the local regulator, have developed a web-based risk assessment tool.

Purpose of the tool: to help OHS personnel quantitatively assess risk for exposure to respirable crystalline silica (RCS) on construction worksites.

What it does: The tool generates a formal "exposure control plan" and provides information on administrative controls that should be followed to minimize exposure to RCS.

How it works: A task-based model (constructed from 4,550 silica exposure measurements) estimates uncontrolled exposure for 47 silica-generating tasks and the exposure levels anticipated following standard control interventions. To create the exposure control plan, the model factors in: work environment (indoor vs. outdoor), sampling duration, activity sector (e.g. residential, commercial), project type (e.g. new construction, renovation), use of engineering controls, and region.

If controlled exposures are above the exposure limit, the tool provides advice on respirator selection. Uncertainty is quantified and communicated using a 'green, yellow, red' coding system. This simplified approach allows the tool to inform non-expert users when the level of uncertainty is unacceptable. Where insufficient data are available, users are advised to collect exposure and are encouraged to share data to allow the model to be continually updated.

Potential benefits:

- Using the tool can provide many of the advantages of quantitative exposure-based risk assessment (including benchmarking, surveillance, and comparative analysis).
- It can be used to educate construction employers and employees about RCS, the relative hazard posed by different work activities, and control effectiveness.
- There is potential for continual improvement in risk reduction as new data become available and new controls are assessed and added to the database.

Source: Gorman Ng M and Davies HW (2016)

[13]The Health and Safety Executive (HSE) developed COSHH Essentials following the implementation of the *Control of Substances Hazardous to Health (COSHH)* legislation. Information is available online at: http://www.hse.gov.uk/coshh/essentials/.

[14]The International Chemical Control Toolkit was designed to assist small and medium sized enterprises in developing countries prevent exposure to hazardous chemicals in the workplace. Information is available online at: http://www.ilo.org/legacy/english/protection/safework/ctrl_banding/toolkit/icct/.

each jurisdiction's method has its own limitations (36)). The lack of a standardized method is particularly relevant to the Canadian context because, as noted in Section 2.1.1, the OHS landscape varies across the country.

3.3.3.3 Surveillance of hazards and/or diseases

Defined as the assessment of "trends in exposure to toxic chemical agents ... and to other hazards responsible for disease and injury", hazard surveillance is a means of identifying the work processes or workers associated with high levels of exposure to specific agents in particular industries and job categories (50). One of the principal benefits offered by a hazard surveillance system is that it allows for the early identification of at-risk jobs or workers and the implementation of interventions that will prevent occupational injury and illness from occurring. Exposure registries, which collect information on an ongoing basis about populations exposed to one or more specific risk factors and monitor trends in exposure, are one method of hazard surveillance. A recent review of Canadian hazard and disease registries concluded that a well-constructed exposure registry can be a valuable tool for the surveillance, epidemiology and, ultimately, prevention of occupational disease (51).

Disease surveillance (also known as health screening/tracking or medical monitoring) is defined by the World Health Organization as “the continuous, systematic collection, analysis and interpretation of health-related data needed for the planning, implementation, and evaluation of public health practice” (52). Health surveillance systems may be designed to watch out for single events (“sentinel events”) that signal a breakdown in prevention or they may be based on the review of aggregate data to monitor and discern trends in the occurrence of illnesses, injuries, or deaths at the population level (26). A population-based injury/disease registry (e.g., a provincial cancer registry or a workers' compensation claims dataset) is a method of health surveillance.

The data generated by an injury/disease registry can be used for: triggering the screening for early signs of occupational illness or disease in groups with high levels of exposure; informing the

development of primary prevention activities to reduce or eliminate exposure (i.e., by identifying situations where control measures are inadequate); and identifying new relationships between levels of exposure and disease outcomes (when linked with an effective hazard surveillance system) (26). Because the data collected create opportunities to intervene early in the exposure-disease pathway if the system is linked to an effective intervention program, a disease registry facilitates both primary and secondary prevention.

Detailed findings from the scoping review on the effectiveness of hazard and disease surveillance can be found in Appendix C4. The scoping review identified examples of hazard and disease surveillance systems that played a role in preventing the diseases of interest, as well as occupational disease more generally.

A Canadian example:
Occupational Disease Surveillance System

Background: The Occupational Disease Surveillance System (ODSS) is a new initiative being spearheaded by the Occupational Cancer Research Centre at Cancer Care Ontario (in partnership with research collaborators in British Columbia, Nova Scotia and elsewhere). Although the project is currently focused on Ontario workers, it provides a model that could be adapted for other jurisdictions in Canada.

Purpose of the system: to provide timely information about existing and emerging work-related health risks through the linkage of existing health data sources.

How it works: The system links WSIB claims data to Ontario Cancer Registry records, as well as hospital, ambulatory care and medical billing records to identify work-related risks for 28 cancers and 14 other health outcomes.

Preliminary analyses identified an increased risk of mesothelioma (a cancer of the pleural lining that is caused by exposure to asbestos) in educational services that would not have been caught in other systems. These findings led to the Ontario Ministry of Labour doing a health and safety blitz in schools.

Potential benefits:
- It creates opportunities for researchers to identify previously unknown work-related risks.
- It will enable rapid assessment of existing and emerging risks associated with various jobs in Ontario, and will highlight at-risk groups that should be targeted with risk-reduction strategies.

Ultimate goal: to translate ODSS-generated information into evidence-based prevention strategies to reduce workplace hazards through project engagement with occupational health and safety partners (e.g., health and safety associations, occupational physicians).

Source: McLeod J et al. (2016)

The national level surveillance systems identified demonstrate that surveillance has multiple roles across the prevention spectrum (e.g., monitoring trends in exposure to and the health impact of known hazards, serving as a beacon or an early warning of new hazards, tracking progress towards prevention goals (either at a societal or at the workplace level), allowing for an understanding of the extent and dimensions of a problem, informing the development of effective public health policy, and evaluating what works and what doesn't) (53, 54). Good data (i.e., accurate, trustworthy, comparable)

are critical to the success of an effective surveillance system (53), both within and across jurisdictions. This latter point is particularly relevant to the Canadian context as no national standards currently exist on the collection and sharing of occupational health data.

At the disease level, exposure monitoring (with appropriate feedback mechanisms) was found to be effective for NIHL, as was a system of medical monitoring and health screening (i.e., audiometric programs). Exposure monitoring and surveillance was effective at controlling exposure to asbestos and diesel exhaust. Medical surveillance and health screening were also identified as effective strategies for preventing occupational contact dermatitis and some forms of occupational asthma. 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.

Because vulnerable workers may not be captured in more conventional injury and disease surveillance systems (e.g., workers' compensation databases), linked population-based administrative databases were identified as powerful tools for monitoring outcomes in this population. Key informants reinforced the importance of effective reporting systems for tracking prevalence of exposure and disease, particularly among vulnerably employed workers

3.3.3.4 Education and training

Numerous articles have been published examining the factors influencing the effectiveness of worker health and safety training. It is outside the scope of this project to review and summarize this literature in detail. Detailed findings from the scoping review on the effectiveness of education and training, including brief summaries of two recent systematic reviews, can be found in Appendix C5. The scoping review identified more examples of education and training or awareness campaigns in the literature about NIHL, contact dermatitis, and occupational cancer (in particular, asbestos, silica, and shiftwork) than in the literature about diesel exhaust and occupational asthma. Of the examples identified, more than half of them were in the occupational dermatitis literature.

The findings of the scoping review suggest that the effectiveness of education and training as a vehicle for changing behaviour appears to be not only context-dependent but also influenced by the manner of delivery. Key informants echoed this finding, noting that worker engagement and involvement is critical to the success of primary prevention and offering examples from their own experience to support their position. Examples included: the development of a glove intervention in hairdressers in the United Kingdom[15] and hazard mapping exercises undertaken by the Occupational Health Clinics for Ontario Workers (OHCOW) (55). In this latter example, workers were engaged to identify the problems, brainstorm solutions and assign responsibility for accomplishing the tasks identified. Workers created a database to track progress and within 2 years, 95% of the items they identified were accomplished[16].

Regardless of the approach taken to educate and train workers, key informants

An example of a sustained national project to control isocyanate exposure in motor vehicle repair (MVR)

Objectives: improve the control of isocyanate exposure in 20% of UK MVR premises and reduce the risk of occupational asthma

The intervention: 3-interlinked elements

1. Safety and Health Awareness Days (SHADs): short presentations, video clips, schematics and working scale models (of a spray booth and a spray room) to show how exposure occurred, could be controlled and simple ways of checking that controls were working and being used appropriately (e.g., biological monitoring, smoke tests).
2. Workplace visits by HSE inspectors
3. Engagement with, and influencing through, third-party stakeholders: key trade associations (e.g., British Coatings Federation) and individuals, automotive paint suppliers, and most UK suppliers of spray booths

Outcomes:

- 32 SHADS held across the UK: approximately 18% of UK body shops attended. Those who attended the SHADs were generally able to recall key messages at least 1 year later.
- Over 90% of attendees expressed an “intention to act” to improve exposure control measures. At least 50% of body shops improved exposure control measures.
- Of 109 inspections, enforcement action was taken at 40 per cent of visits.
- Third-party engagement produced a joint HSE-industry designed poster, new guidance on spray booths and dissemination of SHAD material.
- Improved knowledge of booth clearance time: 85% of booths now have pressure gauges.
- Biological evidence of lower exposures post-SHAD: over 8000 samples analyzed; 80% showed no detectable levels; only 7% exceeded current UK Guidance Value.

Key Take-Away Messages:

- Finding the appropriate communication strategy to suit the target population is an essential prerequisite for behaviour change.
- To engage, and gain the attention, interest and trust of small and medium enterprises, key messages need to be tested, expressed simply and illustrated effectively so that businesses are motivated to undertake effective control actions.

Source: Piney M et al (2015)

[15]The Health and Safety Executive, in partnership with Local Authorities and hairdressing industry bodies have worked together to raise awareness and promote good hand care, including the use of the correct type of gloves. Information on the Bad Hand Campaign is available online at: http://www.hse.gov.uk/hairdressing/bad-hand.htm.
[16]Personal communication with John Oudyk of OHCOW.

emphasized the importance of understanding the needs of one's audience and identifying potential barriers to uptake ahead of time. Some emphasized the importance of using trusted sources (like suppliers, peers and trade associations) to convey messages to small- and medium-sized enterprises, while others flagged the importance of understanding the cultural contexts that influence both workers and workplaces. The former is key to the success of engaging small workplaces in primary prevention and the latter is key to the success of engaging the workforce (particularly vulnerable workers) and having them act on what they have learned. Several key informants noted that effective protection of the precariously employed workforce is a broader social issue characterized by a lack of power. Training and education of such workers can be meaningless if they are unable to act on what they have learned.

Key informants also offered some suggestions for improving uptake and producing behaviour change at the individual level. One suggestion was that, for occupations where apprenticeships are required, experiential education and training should be embedded in the program. Examples of creative and innovative ways to get the message across included having students wear gloves that make their hands feel like they have dermatitis or wear respirators that increase their breathing load so that they experience what it is like to have asthma.

3.3.3.5 Multi-faceted approaches

Multi-faceted approaches to prevention are more comprehensive in design and incorporate multiple types of interventions. Hearing conservation programs (HCPs) are a good example of a multi-faceted approach. Although they are often mandated by regulation, they incorporate a variety of activities (such as exposure monitoring, disease screening, training and program evaluation) aimed at reducing noise exposure and noise-induced hearing loss[17].

[17]For example, in British Columbia, Section 7.5 of the *Occupational Health and Safety Regulation* stipulates that if noise levels exceed allowable levels, an effective noise control and hearing conservation program must be implemented and that it must incorporate the following elements: noise measurement; education and training; engineered noise control; hearing protection; posting of noise hazard areas; hearing tests; and, annual program review.

Detailed findings from the scoping review on the effectiveness of multi-faceted approaches can be found in Appendix C6. The scoping review found that multi-faceted interventions were effective at preventing all of the occupational diseases. This finding was supported by the key informants who noted that there is a constellation of factors that influence occupational health and safety outcomes, including (but not limited to) regulatory frameworks, organizational and management structures, organizational and workplace safety culture, worker engagement and empowered health and safety committees.

Some key informants pointed to the SOBANE approach in Belgium[18], while others drew our attention to approaches in Scandinavia and Québec, as well as the NIOSH Total Worker Health program in the USA, that build on traditional approaches to occupational health through the recognition that work is a social determinant of overall health. Several

A Canadian example of multi-faceted primary prevention: the delivery of occupational health services in Québec

Background: Québec integrates occupational health services into the broader public health framework through three key pieces of legislation.

Legislative framework:
1. The *Public Health Act*
2. The *Health Services and Social Services Act*
3. The *Occupational Health and Safety Act*

What makes it unique in Canada: The *OHS Act* mandates doctors in the public health system to carry out occupational disease prevention.

How it works:
- Responsibility for implementing occupational disease prevention services is delegated to the Québec Public Health Network in Occupational Health (RSPSAT). Although each member organization has its own legislated mandate, they share the common goal of reducing risks and preventing occupational disorders among workers across a range of industry sectors in Québec.
- In each region of the province, local teams of occupational health professionals (includes physicians, nurses and hygienists or hygiene technicians and sometimes ergonomists) visit workplaces in high priority sectors to identify risks to health and negotiate prevention strategies with the employer and/or occupational health and safety committee.
- The local teams carry out risk identification and assessment, provide information and training sessions, perform occupational disease screening activities and worker health surveillance as well as first aid and emergency response support activities.
- The teams are supported by regional occupational health professionals, a provincial OHS coordinating committee, provincial discipline-specific coordinating committees and the Occupational Health Unit of the Québec Institute of Public Health (INSPQ) who provide back-up expertise, develop prevention protocols, analyze and disseminate surveillance information and/or provide training to the RSPSAT professionals.

Source: Fontaine G et al. (2013)

[18]SOBANE is a participatory risk management strategy, which incorporates four levels of intervention: screening, observation, analysis and expertise. Its aim is to make risk prevention faster, more cost effective, and more effective in coordinating the contributions of the workers themselves, their management, the internal and external OH practitioners and the experts. Information is available online at: http://www.deparisnet.be/sobane/SOBANEeng.htm.

observed that effective prevention requires the breaking down of silos (i.e., 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 all stakeholders (e.g., regulators, workers, employers, and NGO's) from the outset. One example that was identified in the scoping review and drawn to our attention by key informants was the European Network on Silica (NEPSI)[19]. NEPSI is a social contract between employers, government, trade unions, and trade associations focussed on preventing exposure to crystalline silica through multiple levels of intervention (monitoring, training, surveillance, etc.). It was flagged as an example of a multilevel, sector-specific initiative that is likely to have a better chance of success than other more traditional prevention initiatives.

4 Conclusions

4.1 General conclusions

Each approach to primary prevention (i.e., legislation and regulation, exposure control, hazard/disease surveillance, education and training) plays an important role in preventing occupational diseases. However, each has their limitations (e.g., in some cases, their impact appears to be context-specific) and each is insufficient on their own. Although this project does not incorporate a systematic weighing of the evidence, the literature suggests that multi-faceted interventions are often more effective than ones with a single type of activity. This supports the position put forward by a number of the key informants that occupational health and safety 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 empowerment of health and safety committees.

[19]Information on NEPSI can be found at: http://www.nepsi.eu/.

A more general conclusion that has implications for future research is that there are few well-designed evaluative studies for many primary prevention interventions. As the literature points out (56-58) and as the findings of this project illustrate, interventions to reduce hazardous exposures do exist for many occupational diseases. However, for practical and methodological reasons, few of them have been evaluated for impact (56-58). The lack of high quality evaluation studies limits our ability to make causal inferences and to draw conclusions about what actually works. There is a critical need for better evaluative studies of preventive interventions so that evidence-informed policy and practice decisions can be made about which interventions are the most effective to implement nationally, provincially or at the workplace level.

Very few of the studies identified were undertaken in Canada or were specifically designed to examine the impact of primary prevention interventions on outcomes in vulnerable workers. While some of the workplace level interventions are likely transferable to Canadian workplaces, the absence of a national OHS legislative framework combined with the inter-provincial differences in OHS across Canada make it challenging to implement any of the national level interventions. That said, feedback from Canadian OHS policy makers and administrators indicates that there is an appetite for strategic action on occupational disease prevention at the provincial level, as well as for harmonization of systems and strategies across the country. For example, Alberta held a symposium in January 2017 for provincial stakeholders to explore how administrative data could be better used in the prevention of occupational diseases; Manitoba is in the early stages of planning an occupational disease strategy; and Ontario has convened a working group to develop an Occupational Disease Action Plan.

4.2 Implications for future occupational health research

One of the major contributions of this project (beyond the identification of promising primary prevention strategies) is that it develops an overview of existing evidence on what works in the primary prevention of occupational disease and lays the groundwork for a future systematic review in this area.

Time and financial constraints prevented the research team from undertaking a comprehensive systematic review. While the scoping review methodology allowed for a broader range of questions to be considered than would be possible with a systematic review, it did not incorporate a systematic weighing of the evidence. A more comprehensive review and systematic evaluation of the evidence would allow for better comparison of the impact of interventions and thus enhance the knowledge base.

One of the scoping review's inclusion criteria was that studies should incorporate some measure of effectiveness, although articles about non-evaluated programs or strategies were included if they appeared promising. In addition, the project focused on identifying programs or strategies that had actually been implemented (rather than being conducted solely for research), that are relevant to the Canadian context, and that take into account changing industry structures and labour force demographics. 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 randomized controlled trial studies 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. Regarding the dearth of studies evaluating impact in vulnerable workers, one key informant commented that it is hard to do good research on the precarious workforce. Noting that the best way to assess the effectiveness of an intervention is over a 10-year period, the key informant observed that because the nature of this group's employment tends to be sporadic, researchers have had to rely on cross-sectional versus longitudinal studies when studying this population. This affects the quality of the research and limits the applicability of the findings. 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 evaluating occupational health evaluations (56, 58).

4.3 Applications for policy and prevention

This project showed that while regulatory interventions can be effective at reducing (or eliminating) exposure, changing behaviour and reducing the prevalence of occupational diseases, their impact depends on the context in which they are implemented (i.e., outcomes differ by industry), the presence/absence of a strong enforcement regime, and a process for keeping them up to date with current scientific knowledge. This has implications for the regulation/policy development and implementation process.

In many industries, control measures (e.g., the hierarchy of controls, exposure control banding) are an effective strategy to reduce levels of exposure and prevent occupational disease. However, because engineering control technology can be very expensive, many small employers tend to rely on personal protective equipment to prevent exposure. 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 potential solution is to adopt or legislate a "prevention by design" approach (i.e., shift from the requirement to control exposures to a focus on eliminating the hazard at source). This prevents exposure from happening in the first place and creates opportunities for occupational health to become an economic engine, driving innovation and technology.

Control banding is another solution that may help SMEs because it (a) provides an easy to understand and easy to apply approach to controlling hazards in workplaces that have limited expertise in workplace health and safety, industrial hygiene, or chemical control; and (b) it allows for control recommendations to be made for products that do not have occupational exposure limits. Although it is in widespread use in the European Union and its utility has been assessed in other

contexts including the US and Québec, it has not been fully validated and there is no universally accepted approach to banding. More research examining the validity of control banding and its applicability to the Canadian context is recommended.

The findings of this project suggest that the effectiveness of education and training appears to be not only context-dependent, but also influenced by the manner of delivery. The following factors were identified as critical to the success of primary prevention programs and educational campaigns: 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.

Because vulnerable workers may not be captured in conventional injury and disease surveillance systems (e.g., workers' compensation databases), population-based, linked administrative databases that include health services utilization data (such as Population Data BC) can potentially be powerful tools for monitoring health outcomes in this population. However, a major challenge is the lack of occupation or industry information in administrative records, which could start to be addressed by the inclusion of this field in electronic medical records. Investing in the development and enhancement of these types of linked databases and making them accessible to occupational health researchers and public health surveillance practitioners (as well as fostering policy-relevant research partnerships and developing research expertise to utilize the data) would enable targeted prevention campaigns to be developed and implemented.

It is extremely important to recognize that effective protection of the vulnerable or precariously employed workforce is a broad social issue characterized by their lack of social power. For precariously employed workers who are immigrant workers or international migrants, it is necessary not only to target them directly but also to understand the cultural contexts that influences both workers and workplaces. Educational and training materials must be culturally sensitive, in a variety of

languages that the workforce understands, and at a reading level they can comprehend. Pictograms are an effective communication tool and web-based strategies might be a good way to reach this population. Another potentially effective way of reaching vulnerable workers is by educating their healthcare providers and giving them materials written in a variety of languages.

5 Knowledge translation and exchange

A key objective of this project was to involve stakeholders in OHS disease prevention across Canada as members of the team, through key informant discussions and through broader consultations. This approach fosters stakeholder engagement and builds capacity to facilitate the uptake and application of the research findings. The project team included four stakeholders: Colin Murray of WorkSafeBC, Alec Farquhar of the Office of the Worker Advisor and Bill Hynd and Mary Shortall of the NL Federation of Labour. Their participation helped to ensure that the project was designed to fill a knowledge gap that is strongly felt by the stakeholders rather than emerging from the research agendas of the academic members of the team.

The project team hosted a special session at the 9th biennial meeting of the Canadian Association for Research on Work and Health (CARWH), held in Toronto on October 16-18, 2016. This session was an additional opportunity for the team to seek input from the symposium participants on the preliminary findings from the literature reviews. In addition, the preliminary findings were presented at an occupational disease symposium hosted by the Occupational Health Clinics for Ontario Workers (OHCOW) on October 26, 2016.

Going forward, SafetyNet will mobilize the findings of this project via a series of webinars, conference presentations and a related journal manuscript. These webinars will introduce the general findings and incorporate presentations from some of lead people who are associated with some of the prevention strategies identified in the scoping review.

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