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**A systematic review of OHS interventions with
economic evaluations**

VOLUME 1

sharing **best evidence**

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Foreword

In recent years, the Institute for Work & Health has been actively engaged in building relationships with Prevention System agencies and organizations in Ontario.

In these encounters, we often hear that potential research users want more evidence about the effectiveness of interventions aimed at protecting workers' health. We are also told that even when research evidence exists, it is often hard to access, difficult to understand and is not always presented in language and formats suitable to non-scientific audiences.

In response to these needs, the Institute for Work & Health has established a dedicated group to conduct systematic reviews of relevant research studies in the area of workplace injury and illness prevention.

- Our systematic review team monitors developments in the international research literature on workplace health protection and selects timely, relevant topics for evidence review.
- Our scientists then synthesize both established and emerging evidence on each topic through the application of rigorous methods.
- We then present summaries of the research evidence and recommendations following from this evidence in formats which are accessible to non-scientific audiences.

The Institute consults regularly with workplace parties to identify areas of workplace health protection that might lend themselves to a systematic review of the evidence.

We appreciate the support of the Ontario Workplace Safety & Insurance Board (WSIB) in funding this four-year Prevention Systematic Reviews initiative. As the major funder, the WSIB demonstrates its own commitment to protecting workers' health by supporting consensus-based policy development which incorporates the best available research evidence.

Many members of the Institute's staff participated in conducting this Systematic Review. A number of external reviewers in academic and workplace leadership positions provided valuable comments on earlier versions of the report. On behalf of the Institute, I would like to express gratitude for these contributions.

Dr. Cameron Mustard
President, Institute for Work & Health
July, 2007

1.0 Introduction

Does investing in occupational health and safety (OHS) pay? Many believe that it does. Yet if that is the case, why hasn't there been a greater uptake of the measures available that would improve both health and safety? The proposed review does not seek to answer this question directly, but rather a prior, fundamental question – what is the credible evidence that incremental investment in health and safety is worth undertaking?

To address this question, we proposed to undertake a systematic review of workplace-based OHS interventions with economic evaluations. We included intervention studies directed at both primary and secondary prevention. We use the term “primary prevention” to refer to workplace interventions focused on reducing and preventing work-related injuries and illness. We use the term “secondary prevention” to refer to interventions focused on preventing and reducing disability in those with work-related illness or injury.

In spring 2005 we undertook a feasibility study. The purpose of this first phase was to assess whether there were enough published studies of workplace-based interventions with economic evaluations to warrant a systematic review. We also wanted to devise a suitable search strategy and assess the scope of the literature to propose ways of categorizing studies. The details of Phase 1 are reported elsewhere (1). After completing this phase, we recommended undertaking a systematic review of OHS intervention studies with economic evaluations in two subsequent phases.

Phase 2, which was also undertaken in 2005, was an environmental scan on a narrower topic. It focused on assessing the quality of studies as a prelude to developing a quality assessment tool. The results of this phase produced a Working Paper that was presented at two conferences (2; 3) and was subsequently published in a peer-reviewed journal (4). This work was also the basis for three chapters of a forthcoming methods text entitled, *Developing Good Practice in the Economic Evaluation of Workplace Interventions for Health and Safety*. The Institute for Work & Health is preparing this text for publication (5; 6; 7).

Phase 3, which began in 2006, was a full-fledged systematic review of OHS intervention studies with economic evaluations. An interim report on this phase was prepared in 2006 and submitted to Ontario's Workplace Safety and Insurance Board (1). This final report describes the findings and evidence synthesis from the completed systematic review.

As noted in the previous report (1) and further elaborated in our publication (3), we found that the quality of application of economic evaluation methodologies was rather weak. We identified a number of methodological

shortcomings in many studies. However, several studies were exemplary in their efforts to confront the challenges of undertaking a quality economic evaluation (8; 9; 10; 11).

In general, economic evaluation is an under-developed component within the OHS literature. In fact, most intervention studies do not undertake one. This may be due to limited expertise in economic evaluation methodologies by OHS researchers, or to the low priority given to economic analysis by evaluators. It is also likely related to practical limitations of the workplace context.

Formulaic methods books, often designed for use in clinical settings, are difficult to adapt to workplace contexts. Undertaking economic evaluations in the workplace can be difficult for a number of other reasons:

- the policy arena of OHS and labour legislation is complex, with multiple stakeholders and sometimes conflicting incentives and priorities
- there are substantial differences in the perceptions of health risks associated with work experiences amongst workplace parties and policy-makers
- the burden of costs and consequences may be borne by different stakeholders in the system
- there are multiple providers of indemnity and medical care coverage so that no one measure accurately captures the full cost of work-related injury and illness
- industry-specific human resources practices (e.g. hiring temporary workers, using self-employed contracts, outsourcing non-core activities) can make it difficult to identify all work-related injuries and illnesses
- in general the dearth of data available from organizations on costs and consequences can make it challenging and expensive to obtain good measures.

This is the motivation behind the Institute's decision to develop a text on methods in economic evaluation design expressly for application in OHS settings. As noted, three chapters of this text have drawn directly from work undertaken in this systematic review.

2.0 Methods

2.1 Stakeholder workshops

At three points during the process of this systematic review, we consulted with stakeholders to get their feedback on the subject matter, scope of the review and findings. The first stakeholder workshop was held in March 2006, after completing an environmental scan. The purpose was to get feedback on the merits of continuing the systematic review on a larger scale, given the quality issues we had identified. Stakeholder views were also sought on matters such as the breadth of literature and subject matter to cover, the principles by which to organize the subject matter, and suggestions on how to address issues of quality. The participants included representatives from Ontario's Workplace Safety & Insurance Board of Ontario (WSIB), the Occupational Health and Safety Branch of the Ontario Ministry of Labour, and some of the health and safety associations in Ontario (see Appendix A).

A second stakeholder workshop was held in December 2006. The purpose of this workshop was to get feedback on the developments, decisions and findings to date. At this stage we had identified the articles that would be included in the systematic review, and we were more knowledgeable about the breadth and nature of the literature. In light of this, we were particularly interested in suggestions from stakeholders on how best to synthesize and report on the information provided by the studies to make it more useful to them. In the first workshop, stakeholders had stated that they were keenly interested in receiving any information about the financial merits of interventions – whether from a peer-reviewed source or not –since this information was not readily available to them. Given the breadth of the non-peer reviewed literature, this was not possible.

A third stakeholder workshop was held in March 2007. The focus of this workshop was to present a synthesis of findings and outline the methodological issues. In particular, we were interested in getting feedback from stakeholders on how best to cluster the broad range of studies identified, and how to meaningfully report on findings within clusters.

2.2 Literature searches

We identified relevant studies through four sources: 1) structured searches in journal databases; 2) other systematic reviews being undertaken at the Institute for Work & Health; 3) a summary table of studies on office ergonomics (9); and 4) a request for studies identified by content experts (see Appendix B for a list of experts contacted).

The following journal databases were searched for relevant articles: MEDLINE, EMBASE, BIOSIS, Ergonomic Abstracts and Business Source Premier. We developed a keyword search for use with MEDLINE based on

four criteria: 1) the type of study (e.g. intervention); 2) the setting (e.g. workplace); 3) the outcome measure (e.g. work injury), and 4) the type of economic analysis or outcome measure (e.g. cost-benefit analysis). At least one keyword from each of the four categories needed to be included in the title, abstract or classification terminology of a citation (see Appendix C for details of terms used for MEDLINE and Appendix D for title and abstract guidelines). This framework was subsequently customized for each of the other databases.

Several additional inclusion/exclusion criteria were part of the study selection process. First, studies had to be published from 1990 onward. We chose this date because we had identified few workplace studies with economic evaluations published prior to 1990 in our environmental scan. In addition, the few relevant studies from this time period would likely have used methods of lower quality, since the use of economic evaluation methods was less advanced prior to the 1990s.

Second, studies had to be published in a peer-reviewed journal. We found many non-peer-reviewed publications that had stylized case studies, with little to no information on the context of the intervention, minimal information on methods and analyses, and selective reporting of consequences. We felt that these stylized examples would be of limited value since the robustness of reported consequences would be difficult if not impossible to evaluate.

Third, we excluded studies based on several criteria concerning context and subject matter: 1) if the intervention was undertaken in a developing country (based on the notion that issues relevant to developing countries are very different than in developed countries); 2) if the intervention was associated with illegal activities (e.g. drug use or prostitution); 3) if the industry/context was army-related or on a military base; 4) if the intervention was focused exclusively on non-health consequences such as cost reduction and/or productivity/quality improvement (these were included only if there was a primary or secondary prevention outcome); and 5) if the intervention was a health promotion initiative focused on general health rather than work-related health exposures (the literature on health promotion interventions is large, and these interventions are distinct from OHS interventions; they generally focus on modifying individual health behaviours related to exercise, smoking and nutritional habits).

2.3 Quality assessment

All studies that met the subject matter and other inclusion criteria described above were kept for evidence synthesis. This decision was based on feedback received at the first two stakeholder workshops. Stakeholders felt very strongly about including all studies, since there was so little information available to them on the financial merits of workplace

interventions. They felt it was premature to eliminate studies based on quality. Hence, we developed a quality assessment tool to rate the quality of included studies, but no studies were excluded due to their quality rating.

The quality assessment tool was based on work undertaken in Phase 2 of this study. It also drew from other quality assessment tools from other IWH systematic reviews. In Phase 2 of this research project, 10 quality issues were identified as follows (4):

Study design and related issues

- 1) *Study design*: Studies were predominantly before-after studies with no concurrent controls, randomization or adjustment for confounders.
- 2) *Study perspective*: In most cases the perspective was not expressly stated, though the firm's perspective is implied. Few studies considered a societal perspective or multiple perspectives.
- 3) *Measurement time frame and sustainability*: In many cases the measurement time frame was not sufficiently long, and generally there was no assessment of the sustainability of the intervention.

Measurement and analytic issues

- 4) *Consideration of all important costs and consequences*: The few studies that undertook a full economic evaluation generally considered only a subset of costs and consequences.
- 5) *Valuation of costs and consequences*: In valuing costs and consequences, studies generally took measures at face value, without questioning whether their “sticker price” reflected their true value.
- 6) *Analytical time frame and future costs and consequences*: Future costs and consequences were rarely considered even though most interventions were ongoing.
- 7) *Adjustment for inflation and time preference*: In most cases there was no clear indication that monies from different years were adjusted for inflation using the consumer price index or discounted for time preference before they were aggregated.
- 8) *Use of assumptions and treatment of uncertainty*: Assumptions were often made with little justification or sensitivity analysis, particularly with regard to the effectiveness of the intervention and its implied savings.

Computational and reporting issues

- 9) *Choice of summary measure*: Most studies undertaking a full evaluation employed cost-benefit analyses, though it was not clear what, if any, measures were used to value health (e.g. many studies focused on changes in workers' compensation expenses, which do not necessarily reflect changes in health). Few studies considered cost-effectiveness analysis and only one study was identified that undertook cost-utility analysis.
- 10) *Reporting issues*: In many cases a clear reporting of context, measures, and computations was seriously lacking, making it difficult to evaluate the quality of the analysis and generalizability of the findings.

The questions developed for the quality assessment tool were divided into four sections: 1) overarching issues that frame the purpose of the study and the nature of the intervention; 2) study design and issues related to evaluating the intervention's effectiveness; 3) measurement and analytic issues related to the economic analysis; and 4) issues related to the discussion and interpretation of results. Though some of the questions in the tool focused on the assessment of effectiveness, and others on the cost-effectiveness, the tool was not designed to separately rank the quality of the epidemiologic analysis and of the economic analysis. The primary focus of the tool was to assess the quality of evidence related to the economic analysis.

The quality assessment tool consisted of 14 questions, and an additional question on the reviewer's overall ranking of the study quality. The last item was added to assess the robustness of the 14 items by comparing their average score to the overall assessment of the reviewer. Each item was ranked on a five-point Likert scale with 1 as the lowest score and 5 the highest. In some cases a question was not applicable to a particular study. In such cases the question was labelled 'NA' and was not included in the quality assessment for that study.

Two reviewers tested the tool on a sample of five studies. The reviewers met several times to discuss how well the tool captured all the relevant aspects of the study and a number of modifications were made. The final version of the quality assessment tool can be found in Appendix E.

The average score across the 14 items constituted the final score for a study. A study with an average score between 1 to 2.4 was considered to provide low quality evidence related to economic analysis. A score between 2.5 and 3.4 was medium quality, and a score between 3.5 and 5 was high quality.

2.4 Data extraction

A data extraction tool was developed with sections similar to the quality assessment tool. Specifically, it focused on four areas of the study: 1) contextual factors such as jurisdiction, industry and occupational group targeted; 2) details about the intervention; 3) characteristics of the epidemiologic design and related statistical analyses; and 4) characteristics of the economic evaluation. As with the quality assessment tool, the data extraction tool was tested with a sample of five studies by two reviewers. Through several meetings, the tool was reviewed and refined to better capture the studies' key aspects that were critical for evaluation and synthesis.

The most challenging aspect of developing and refining the data extraction form was determining how much epidemiological information to extract. The key concern was that the focus of this review is on economic analysis

rather than the effectiveness/epidemiologic analysis. Yet many studies had detailed and lengthy effectiveness analyses that did not directly feed into the economic analyses. In fact, in many cases, the economic component was a very minor part of the study. The final version of the data extraction tool can be found in Appendix F.

2.5 Evidence synthesis

As noted, the intervention studies included in this systematic review covered a broad range of interventions in a number of industries. Some focused on primary prevention, others on secondary prevention and some looked at both. Some undertook full economic evaluations (considering both costs and consequences, and in some cases, only costs with the assumption that consequences were similar), though many undertook only partial evaluations (considering only the consequences in monetary terms and not the costs).

Given the diverse range of studies, we stratified them by two key characteristics, namely industry and type of intervention. Within each stratum we considered type of economic analysis (full or partial evaluation) and study quality.

The evidence was synthesized using Slavin's (1986, 1995) best evidence synthesis. This is a qualitative approach that bases the strength of a relationship on the quality, quantity and consistency of evidence available to support a relationship between variables. We ranked the evidence supporting the hypothesized relationship on a five-level scale consisting of strong evidence, moderate evidence, limited evidence, mixed evidence or insufficient evidence (see Figure 1). Evidence was tested against the criteria for the highest level, and if it was not met, the criteria for the next highest level were considered. The process continued cascading down the three levels of strong, moderate and limited evidence until a set of criteria was met. If the evidence met none of the criteria, it defaulted to one of the two categories, mixed evidence or insufficient/no evidence. The full evidence ranking algorithm can be found in Appendix G.

Figure 1: Best evidence synthesis

Level of evidence	Minimum quality	Minimum quantity	Consistency
Strong	High	Three	Three high quality studies agree. If more than three studies, $\frac{3}{4}$ of the medium and high quality studies agree.
Moderate	Medium	Two high quality OR Two medium quality and one high quality	Two high quality studies agree. OR Two medium quality studies and one high quality study agree. If more than three studies, more than $\frac{2}{3}$ of the medium and high quality studies agree.
Limited	Medium	One high quality OR Two medium quality OR One medium quality and one high quality	If two studies (medium and/or high quality), the studies agree. If more than two studies, more than $\frac{1}{2}$ of the medium and high quality studies agree.
Mixed	Medium and high	Two	Findings from medium and high quality studies are contradictory.
Insufficient	No high quality studies, only one medium quality study, and/or any number of low quality studies.		

Since the overall quality of economic analyses in this literature was a concern, and the analyses were mostly positive (i.e. the interventions resulted in lower injury rates and savings), we were reticent to make a strong statement about the level of evidence unless there were high and/or medium quality studies on a topic. Hence, if there were only low quality studies, we decided that would constitute insufficient evidence. When the quality of a study is low, there is little confidence that the results are accurate. However, due to stakeholder interest, we did retain low quality studies in our presentation of the results of the literature searches, data extraction summary tables and narrative profiles, for information purposes only.

3.0 Results

3.1 Stakeholder workshops

First stakeholder workshop

At the first stakeholder meeting in March 2006, we presented the thesis question of the systematic review, the results from our pilot, and our study search plan (i.e. the databases to be searched and the keyword strategy). The following key points emerged from the meeting:

1) Overarching question: One participant felt that we should consider rewording the overarching question, by emphasizing that we planned to synthesize evidence on whether *incremental/additional* investments in health and safety were worth undertaking.

Response: The overarching question was modified accordingly, and now reads, “What is the credible evidence that incremental investments in health and safety are worth undertaking?”

2) Databases: Several participants felt that we should consider the grey literature (non-peer-reviewed literature), and one person emphasized an interest in knowing about developments in the field regardless of whether the findings were published. One participant suggested considering the PsycINFO database as well as business databases.

Response: We considered including the grey literature, but found that the published literature was itself quite vast. In MEDLINE alone we had 6,381 title and abstract citations, and in EMBASE there were 6,696. PsycINFO was evaluated as a source database, but was ultimately not included because it did not cover the literature we were seeking to retrieve.

3) Keyword strategy: Several participants suggested ways to broaden the keyword search to be more inclusive of relevant topics. One concern was that “health and safety” may fall under performance management, healthy workplace or risk management.

Response: The keyword strategy was reviewed. Several modifications were made and tested to assess their impact on the number of hits.

4) Quality of studies: In response to the observation that most studies presented positive findings, one participant suggested clustering and synthesizing studies by quality and the extent of rigour in the economic evaluation (e.g. a more rigorous study would consider indirect costs). In general, it was felt that more information would be better than less, since it would be highly valuable to know what was happening in the field.

Response: We followed through with the strong preference of including all studies regardless of quality. We decided to use the quality assessment of studies as one of the stratification criteria when synthesizing the evidence.

5) Synthesis criteria: We proposed stratifying studies by industry and type of prevention (i.e. primary versus secondary). Within each stratum we would consider type of economic evaluation (i.e. full or partial), type of intervention (e.g. disability management, participatory ergonomics) and study quality. One person suggested that we also consider firm size and firm sophistication.

Response: We considered stratifying by firm size, but found that many studies did not report firm size. We found that “firm sophistication” was difficult to define as a construct, and therefore were unable to extract data on this construct.

Second stakeholder workshop

At the second stakeholder workshop participants heard about the progress we had made with the systematic review. They were particularly interested in the methods article and chapters that were spin-off products of the review.

Participants agreed that excluding the grey literature would be acceptable, given the number of peer-reviewed studies, and the low quality of economic analyses in both the peer-reviewed and non-peer-reviewed literature. However, the group felt that low quality peer-reviewed studies should be included in the analysis. To address the issue of quality, the suggestion of stratifying by quality was reiterated. Other stratification criteria proposed were industrial sector, type of intervention, rationale for the intervention, firm size category and geographic/ jurisdictional location. One participant was particularly interested in interventions focused on training and education, which was one of the categories in “type of intervention.”

Response: The rationale for the intervention was added as a category to the data extraction. Specifically, we added three items: 1) motivation for the intervention (text was to be taken directly from the study), 2) motivation category (e.g. legislative requirement, high injury rates, high costs of injuries and illnesses), and 3) the research question/objective of the study. The other categories suggested for consideration in the stratification were items already included in the quality assessment and data extraction forms, with the exception of firm size.

Third stakeholder workshop

A third stakeholder workshop was held in March 2007. This workshop focused on the data extracted from the studies. We presented and focused on the data extraction tables from manufacturing and warehousing, and health-care, as these two industries had the most studies. We sought feedback from stakeholders on the evidence identified and how best to present it in a useful

manner. In particular, we were concerned about the broad range of interventions, settings and methods found in the literature. Even with stratification of the evidence by industry, type of prevention, and type of economic evaluation, the nature of studies within each stratum was quite different. In particular, the economic analysis varied from study to study, making it difficult to synthesize findings across studies within a stratum. Predominantly positive findings continued to be an issue (i.e. there is a concern that studies may have a bias towards showing positive results, or that publications may have a bias toward publishing positive studies), We also noted there was a heavy reliance on workers' compensation data with the result that most studies focused on insurance savings rather than on health. The issue of quality related not only to the economic analyses within studies, but also the effectiveness analyses. Specifically, many studies had a simple before-after study design with no control group, and no randomization or control for contextual factors.

Stakeholders once again emphasized the importance of retaining the low quality studies. Despite the low quality of some studies, they felt it was worthwhile to see these studies to learn about the literature. One stakeholder stated that this alone was better evidence than most workplaces have on which to base their decisions.

Stakeholders provided several suggestions about the presentation of the findings. It was suggested that we cluster the studies in tables by industry and type of intervention. Stakeholders noted patterns in types of interventions in different industries and thought that clustering around these two dimensions (i.e. industry and type of intervention) would be most useful. The group agreed that further sub-categories would not be helpful due to the limited number of studies in each cluster. It was also suggested that we report the costs and consequences of the economic evaluation separately, in addition to reporting on the overall findings. Essentially, a structured presentation of results would be preferred that included a report on the magnitude of effects.

In terms of the synthesis of evidence, stakeholders felt that it was important to make a definitive statement about the "credible" evidence. This does not require making a strong statement about the evidence towards investing in OHS interventions. However, stakeholders considered it important that we provide descriptions of the various layers of evidence identified.

Stakeholders suggested we report on overriding issues across studies. For example, if we found that studies tended to report the costs as being too high or low, it would be helpful to report on this. We should also describe the gaps in the literature. It would also be helpful to provide advice for future evaluations, for example, by providing a model with different approaches to conducting economic evaluations and describing the strength and weaknesses of each approach. (N.B. A methods text is in the works, and it

draws substantially on the findings from this systematic review (4). A methods piece has also been published from the pilot of this study (5).)

3.2 Literature searches

In the first two phases of this systematic review, a number of studies had already been identified for inclusion. These came primarily from a MEDLINE search, supplemented with studies from other systematic reviews undertaken at the Institute, bibliographic searches, and a table of studies prepared by Goggins (12). These sources produced 27 studies, which were summarized in an earlier report and publication (1; 4).

A broader MEDLINE search resulted in 6,381 citations; EMBASE in 6,696 citations; BIOSIS in 2,568 citations; Business Source Premier in 687 citations; Ergonomic Abstracts in 25 citations; and other sources in 199 citations. Once these citations were merged and duplicates were removed, the total number of citations was 12,903. After title/abstract and article inclusion review, 180 articles were retained. In some cases, more than one article had been published on the same intervention. After clustering these articles and eliminating non-peer-reviewed studies, this left a total of 72 studies with economic analyses (see Appendix G). For a complete list of included studies see References.

Five of the 72 studies did not evaluate interventions that had actually taken place, but rather evaluated interventions that were being considered. We chose to exclude these studies in the synthesis, since they were quite different from the remaining studies. Rather, we report on them separately in the Discussion section of this report. Three of these studies were in agriculture and two were in health care.

Sixty-seven studies remained. Within these 67 studies, a total of 72 interventions were evaluated, as some studies had more than one intervention evaluation.

3.3 Descriptive Statistics

The interventions were undertaken in a number of industries. In total, we listed studies under 12 industry sectors. In a few cases we assigned an intervention to an industry cluster based on the occupation rather than industry. For example, a study by Rempel (2006) was undertaken in the health-care sector, but the occupational group was customer services workers at a call centre who worked at computer terminals. We included this study in the administrative and support sector because other studies in this group also focused on workers at computer terminals. A study by Landstad (2002) in the health-care sector focused on cleaning personnel. We placed this study in the accommodation and food services sector, since occupations in that sector were similar.

Frequency of industry representation across the 72 intervention evaluations remaining in the review was as follows (see Appendix I for descriptive statistics on the studies):

- health care and social services - 25
- manufacturing and warehousing - 16
- administrative support services 8
- multiple sector interventions - 7
- transportation - 3
- public administration - 4
- mining and oil/gas extraction - 3
- accommodation and food -2
- retail trade; education; information and culture; utilities - 1 each.

Some studies focused on primary prevention, others on secondary prevention, and yet others on both. We noted that certain types of interventions were more common in certain sectors. For example, ergonomics interventions were the predominant type of intervention in manufacturing and warehousing. In health care, both occupational disease prevention interventions and ergonomic interventions were common. The specific nature of interventions ranged in scale and intensity. They covered a wide range of features, some of which were labour-intensive (e.g. participatory ergonomics teams, exercise programs) while others were capital intensive (e.g. ceiling lifts in hospitals).

Some undertook a full evaluation (considering both costs and consequences), though many undertook only a partial evaluation (considering only the consequences in monetary terms). The predominant outcome of focus in the economic analyses component of studies was workers' compensation expenses, including both the wage replacement and health-care component of these expenses.

Given the diverse range of studies, we stratified the syntheses by two characteristics, industry and type of intervention. As per the feedback from the stakeholder meetings, these characteristics were deemed most relevant to an understanding of the financial merits of workplace interventions. Within each stratum we focused on study quality and on the type of economic analysis (full or partial evaluation).

The intervention evaluations reported on a range of intervention types. We clustered interventions into a total of six types, which we labelled as follows:

- ergonomic and other musculoskeletal (MSK) injury prevention interventions
- occupational disease prevention interventions

- disability management interventions
- multi-faceted interventions, which included two or more types of interventions.
- health promotion interventions
- interventions to reduce violence in the workplace

The most common type of intervention was *ergonomic and other MSK injury prevention interventions*, followed by *disability management interventions*.

Many intervention evaluations had only partial economic evaluations (i.e. only costing of outcomes in monetary terms) although we did find a fair number of full evaluations. The number of partial and full evaluations in each industry was as follows:

- health care and social services (10 and 15)
- manufacturing and warehousing (7 and 9)
- administrative and support services (1 and 7)
- multiple sector interventions (1 and 6)
- public administration (4 and 0)
- transportation (1 and 2)
- mining and oil/gas extraction (1 and 2)
- remaining industries (2 and 4 in total).

In terms of perspective, the vast majority of studies took the firm perspective.

3.3 Quality assessment and data extraction tools

We found the quality assessment tool to work quite well. Of the five studies tested by two reviewers, the average score given across the 14 items for each study was within 0.5 of a point of the overall study score given by a reviewer.

The data extraction tool underwent several iterations to ensure that it captured all the relevant aspects of the context, the nature of the intervention, the effectiveness evaluation and the economic evaluation. Overall, there were approximately 40 categories of information extracted.

Though there were several exemplary economic analyses of interventions that received a high quality score (e.g. Arnetz 2003; Daltroy 1997; Derango 2003; Jensen 2005; Karjalainen 2003; Lahiri 2005; Lanoi 1996; Loisel 2002), the majority of interventions had low quality economic analyses. This is understandable, since the economic analysis component in many of the studies was not the primary focus. Essentially, many studies were primarily

focused on the effectiveness evaluation, with only a secondary or minor focus on the economic analysis.

Summary tables of the data extracted from each intervention evaluation can be found in Appendix K. This appendix has 12 sets of tables, one for each industry sector. Within each industry sector there are four tables that contain core information on each evaluation retained in the systematic review. The four tables are as follows:

Table 1: <Industry> Description of Intervention

Table 2: <Industry> Effectiveness Analysis

Table 3: <Industry> Economic Analysis Details

Table 4: <Industry> Economic Analysis Results

Within each table, studies are clustered by type of intervention and ranked from highest to lowest quality.

3.4 Evidence synthesis

With 12 industry sectors and six intervention types, in many cases there were not enough studies of high and/or medium quality in a particular stratum to identify support for the financial merits of an intervention. Hence many strata were found to have insufficient evidence. In total we identified seven industry-intervention type strata in which there was evidence in support of the intervention, and 17 industry-intervention type strata with insufficient evidence. See Appendix J for details. We follow with a summary of the seven strata. They have a sufficient number, quality and consistency of intervention evaluations so that the level of evidence from evaluations within each stratum supports, to some degree, undertaking the intervention on the basis of its financial merits.

Full results for each sector appear in tables in Appendices K to V. These tables include quality scores, descriptions of the interventions, effectiveness of outcomes, and costs and consequences of the interventions for each study.

In the administrative and support services sector, a cluster of eight intervention evaluations were identified within the category of ergonomics and other MSK injury prevention interventions. Two intervention evaluations were of high quality (Amick 2003 & DeRango 2003; Lahiri 2005), one was of medium quality (Rempel, 2006), and five were of low quality. This translates into **moderate evidence** that such interventions in the administrative and support services sector are worth undertaking on the basis of their financial merits. They may be meritorious/beneficial due to a reduced frequency or severity of injuries, which ultimately results in savings, and/or productivity improvements that result in savings.

In the health-care sector, five occupational disease prevention interventions were identified. Three were of medium quality (Laufer 1994; Yassi 1995;

Orenstein 1995) and two were of low quality. The two types of interventions in this group consisted of needlestick injury prevention programs, and the conversion from powdered latex gloves to powder-free gloves. This stratum provided **moderate to limited evidence** that such interventions are worth undertaking for their financial merits. The reason for the evidence straddling two levels is that the Yassi (1995) study finds losses or savings due to the intervention depending on the assumptions made. If we focus on the positive findings of this study, then there is a sufficient number and quality of interventions in the cluster to conclude moderate evidence. If we focus on the negative findings, the two other medium quality studies have positive findings, and hence the cluster ultimately provides limited evidence.

Also in the health-care sector, the ergonomic and other MSK injury prevention interventions stratum provided **moderate evidence** that such interventions are worth undertaking for economic reasons. There were 11 studies in total in this stratum. Four were of medium quality (Collins 2004; Chhokar 2005; Gundewall 1993; Evanoff 1999), and the remainder were of low quality. Most of the studies in this group evaluated the introduction of mechanical ceiling lifts for moving and transferring patients. Some investigated other approaches to reducing back injuries, such as the introduction of a lifting team, ergonomic training on manual handling techniques for moving and transferring patients, or exercise programs to increase back strength.

In the manufacturing and warehousing sector, the stratum consisting of ergonomic and other MSK injury prevention interventions provided **strong evidence** that these interventions are worth undertaking for their financial merits. There were nine interventions in this cluster in total. Three were of high quality (two in Lahiri 2005; Lanoie 1996), two were of medium quality (Abrahamsson 2000; Halpern 1997), and the remainder were of low quality.

Also in the manufacturing and warehousing sector, the multi-faceted intervention stratum provided **limited to mixed evidence** of negative findings. There was a total of four interventions, with two of medium quality (Kjellen 1997; Lemstra 2003), and two of low quality. Kjellen (1997) reported negative findings from an intervention in which an occupational health and safety management system was introduced. Lemstra (2003) reported negative findings from an early intervention program, and positive findings from an occupational management protocol for primary and secondary prevention. The negative findings were consistent with Kjellen (1997), whereas the positive findings were in contrast with that study. Hence, we conclude there is limited evidence of negative findings or mixed evidence.

Disability management interventions across multiple sectors was the stratum that provided **strong evidence** that such interventions are worth undertaking based on economic analyses. There were five interventions in total, with

four of high quality (Loisel 2002; Jensen 2005, 2001; Arnetz 2003; Karjalainen 2003), and one of low quality. All the high quality studies took a systems or societal perspective rather than focusing on the employer perspective.

The last stratum with substantive evidence was ergonomic and other MSK injury prevention interventions in the transportation sector. This stratum provided **moderate evidence** that such interventions result in economic returns. In this group there were three interventions. One was of high quality (Daltroy 1997), and two were of medium quality (Versloot 1992; Tuchin 1998). Interestingly, each was undertaken in a different country, namely the United States, the Netherlands and Australia.

4.0 Conclusions

Our main goal with this systematic review was to obtain a better understanding of the evidence on the costs and consequences associated with workplace interventions for health and safety. The research question we posed was, “What is the credible evidence that incremental investment in health and safety is worth undertaking?” We have been able to directly respond to this question in seven industry-intervention type clusters. In the remaining 17, there was insufficient evidence due the small number of studies, and/or their low quality.

To summarize, the substantive findings of our review are as follows. (For a description of the evidence criteria, see Figure 1 in section 2.5.) There is:

- (1) strong evidence supporting disability management interventions in multiple sectors
- (2) strong evidence supporting ergonomic and other MSK injury prevention interventions in the manufacturing and warehousing sector
- (3) moderate evidence supporting ergonomic and other MSK injury prevention interventions in the administrative and support sector
- (4) moderate evidence supporting ergonomic and other MSK injury prevention interventions in the health-care sector
- (5) moderate evidence supporting ergonomic and other MSK injury prevention interventions in the transportation sector.
- (6) moderate to limited evidence supporting occupational disease prevention interventions in the health-care sector
- (7) limited to mixed evidence of negative findings for multi-faceted interventions in the manufacturing and warehousing sector

This systematic review is unique in that no other reviews have examined this topic in a systematic and comprehensive fashion. Due to the dearth of evidence on the financial merits of workplace interventions for health and safety, this systematic review begins to fill an important gap in the literature. It also provides insight into what sectors and what types of interventions need to include economic evaluations in future studies. We would recommend that all researchers who are thinking of undertaking an evaluation of a workplace intervention should consider including an economic evaluation. Our findings are of value to workplace parties, OHS practitioners, and policy-makers who are interested in knowing not only what interventions are effective, but also if they are worth undertaking. The

findings are also of value to OHS researchers, who might seek to fill some of the gaps in the literature and strive to improve the quality of future economic evaluations.

4.1 Discussion of quality issues

Although our focus was on the economic analysis component of workplace interventions, a necessary aspect of these studies is the evaluation of their effectiveness. Consequently, we reviewed the analyses of the effectiveness of interventions in the studies included, though to a lesser degree than our key area of interest. We found that many studies relied on study designs that assessed the effectiveness before and after the introduction of an intervention, often without a control group. Quite frequently they did not adjust for contextual factors when assessing the impact of the intervention. Such studies often attributed all the changes that occurred after the introduction of an intervention to the intervention itself, and not to other factors that could have also led to changes. A few studies used multivariate regression analyses to control for contextual factors. The dearth of randomized controlled studies in this area reflects the difficulty of undertaking randomization in workplaces. Factors such as short measurement time frames and small sample sizes are also related to the difficulty of undertaking research in the workplace.

We found that there was often a disconnect between the effectiveness and economic analysis of studies. In other words, one set of analyses fed into the former, and a separate set of analyses were undertaken for the latter. For many studies the economic analysis component was not the principal focus of the investigation. In some cases, it was a very small component of the overall analysis. This fact might begin to explain why many studies undertook only a partial analysis that considered only the consequences of the intervention in monetary terms.

There were issues with the measures of consequences used in studies. As presented in Appendices K to V, many studies relied on workers' compensation expenses as the key, and often only, measure of consequences. It was not clear whether these expenses were proxies for human capital, or simply a measure of reduced insurance expenses; it is most likely the latter. If the former, then the measure is poorly chosen, since workers' compensation wage replacement rates are less than 100 per cent of wages, and therefore underestimate the wage value of time lost due to work injury. If the latter, it would appear that the health component of the intervention is missing in the economic analysis. Furthermore, wage replacement and health-care costs incurred by the insurer are generally not an accurate measure of the incremental insurance expense of a firm, since most firms' premiums are not fully experience rated (i.e. a certain portion of expenses incurred by the insurer are pooled across firms). If a firm perspective is taken, the impact of injuries and illnesses on future firm

premiums should be considered, rather than the expenses incurred by the compensation insurer.

Less frequently considered were productivity losses associated with time off work due to disability, or productivity losses while at work due to disability (the latter is sometimes described as presenteeism). Secondary health and non-health outcomes such as first aid cases and turnover were rarely considered, though several studies mentioned intangible benefits such as improved worker morale, industrial relations climate, work organization and product quality. In general, few studies considered and measured a broad range of consequences.

Since most studies took a firm perspective, a consideration of consequences to workers and other stakeholders was rare. However, there were several studies, particularly of disability management interventions, which adopted a systems level perspective. These interventions were often initiated by a workers' compensation insurer and the programmatic features were often associated with the services provided by the insurer.

There were several common economic analysis concerns that frequently arose in the studies. A common error was the failure to adjust for inflation when there were monetary values from different time periods. This adjustment is necessary so that values are comparable. Another common error was the failure to consider the time value of money. Calculations need to be made to consider interest rates over time, so that the time value of money is accounted for when aggregating monetary values from different time periods. This is known as discounting. Discounting should also be undertaken with non-monetary measures of health if they are realized over several time periods. In some cases the calendar year of the monetary measures was not even provided or was not clear. For these reasons, it is difficult to meaningfully compare monetary measures across studies.

Many studies made strong assumptions when estimating the health and financial merits of an intervention. It is customary to undertake sensitivity analyses when assumptions are questionable, in order to assess the robustness of results to the assumption made. Yet very few studies undertook any type of sensitivity analysis.

We also noted an apparent positive publication bias. Most studies showed that the interventions under evaluation were worth undertaking in terms of their financial returns. This bias makes it difficult for consumers of this research to discern which interventions are truly worth undertaking in terms of their financial merits, and which are not. If most interventions are truly worth undertaking, why do organizations not more readily adopt such interventions?

In several of the studies we reviewed, we found the reporting of context, measures, computational formulas and assumptions were inadequate. In order to assess the transferability or generalizability of an intervention to other settings, a consumer of the research requires sufficient information to assess its applicability or generalizability. Information that assists with this process includes details about the context; the nature of the intervention; the timing, magnitude and the type of activities within the intervention; and the amount and variability of costs and consequences. At another level, clear and complete reporting facilitates a reader's ability to assess the quality of a study, or simply understand what assumptions and calculations were made to arrive at a final value. The poor reporting made it difficult for us to determine how values were derived to evaluate the quality of the analysis and to assess the generalizability of the findings. For example, an important variable for stakeholders was firm size. This information may provide an understanding of the resources needed to support an intervention, and/or the economies of scale that might be required before warranting uptake. Yet firm size was not often reported in studies. Other critical information often missing was details on number of workers involved, uptake, and the intensity of involvement in the intervention.

To address concerns about quality, 10 quality issues were identified in the feasibility stage and incorporated into the quality assessment tool. Though quality assessment is a critical component of evidence synthesis, stakeholders felt strongly that all published articles should be retained in the review, regardless of quality, because of the dearth of evidence on the financial merits of workplace interventions. The group decided to exclude the grey literature as well as published studies that were not peer-reviewed. Additionally, only studies published in 1990 or thereafter were included. This criterion was also included to control for quality, since methods, applications and the workplace context have changed substantially over the last decade and an half.

As noted in our results section, there were five economic evaluations we identified that were not kept in the final synthesis because they did not evaluate interventions that had actually taken place, but rather evaluated interventions that were being considered (13; 14; 15; 16; 17). In general, we found these types of studies were of higher quality than many in our review, so there is much to be learned from them. These studies focused exclusively on undertaking an economic evaluation, and generally employed decision tree analysis to present the possible outcomes and the probabilities associated with each of them. They drew on information from a range of published studies for data on the probabilities and magnitude of costs and consequences. The use of secondary data sources made it possible to fill in many of the information gaps that would not always be available from a single intervention. They gave clear treatment and presentation of all the core aspects of a comprehensive economic evaluation, such as adjustment for inflation, discounting and testing of the robustness of results through

sensitivity analysis of core assumptions. The main lessons learned from such studies are:

- consider all possible health outcomes, their probabilities and the expenses associated with them;
- consider filling information gaps with data from other studies;
- consider all the core aspects of a comprehensive economic evaluation and articulate these details in the write-up;
- test robustness of results through sensitivity analysis of core assumptions;
- recognize that an economic analysis should stand on its own, and may warrant a publication separate from the effectiveness analysis rather than be treated as a sidebar issue.

4.2 Concluding remarks

This is the final report related to this systematic review. Subsequent plans include completing one or more journal articles from the report. Further work will continue on products related to methods in economic evaluation of OHS interventions. Key products completed to date are two interim reports (1), a journal article based on the environmental scan (4), two conference presentations (2, 3) and three methods chapters (5; 6, 7).

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