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Report on process and implementation of participatory ergonomic interventions: A systematic review

VOLUME 1

sharing best evidence

About this report:

Authors: Dwayne Van Eerd[1,2], Donald Cole[1,2], Emma Irvin[1], Quenby Mahood[1], Kiera Keown[1], Nancy Theberge[3], Judy Village[4], Marie St. Vincent[5], Kim Cullen[1], Heather Widdrington[1]

Affiliations:

[1]Institute for Work & Health, Toronto, ON Canada
[2]Department of Public Health Sciences, University of Toronto, Toronto, ON Canada
[3]Department of Kinesiology, University of Waterloo, Waterloo, ON Canada
[4]School of Environmental Health, University of British Columbia, Vancouver, BC Canada
[5]Institut de recherche Robert-Sauvé en santé et en sécurité du travail, Montréal, QC Canada

If you have questions about this or any other of our reports, please contact us at:

Institute for Work & Health
481 University Avenue, Suite 800
Toronto, Ontario, M5G 2E9

Email: info@iwh.on.ca
Or you can visit our website at www.iwh.on.ca

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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. In instances where there are too few studies to conduct a full Systematic Review, we may provide our audiences with a narrative review.

- 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 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
January, 2008

1.0 Introduction

Participatory ergonomic (PE) interventions or programs are considered useful to reduce work-related musculoskeletal disorders (MSDs) in workplaces (1; 2). Wilson defined PE as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals" (3). Kuorinka defined PE as "practical ergonomics with participation of the necessary actors in problem-solving" (4).

A characteristic feature of most PE interventions is the formation of some type of "team" or committee, typically made up of employees or their representatives, managers, ergonomists, health and safety personnel, and possibly research experts. Once formed, teams usually receive training from an expert, most often an ergonomist, to become familiar with ergonomic principles (5). Once this foundation is in place, the group uses its newly developed knowledge to make improvements in the workplace (6; 7; 8).

Because team members work together to improve workplace conditions through participation, communication and group problem-solving in PE interventions, they can have a positive impact on workers' health (8; 9; 10; 11; 12; 13; 14). Ideally, the PE approach encourages workers to be involved in controlling their own work activities, which consequently decreases work organization or psychosocial risk factors for MSDs (3; 15; 16).

1.1 Previous reviews of participatory ergonomics

Important narrative reviews have reflected on the implementation and evaluation of PE interventions (8; 17; 18; 19; 20). Hignett's narrative review provided an excellent summary of the strengths of PE with examples from a range of industries, including health-care, military, manufacturing, production and processing, services, construction and transportation (20). The prerequisites and benefits of implementing successful PE programs have also been described (3; 9).

In a previous IWH systematic review, we examined the evidence for PE interventions in improving health outcomes (21; 22). Using a "best evidence" synthesis approach, we identified 12 studies that were rated as medium or higher quality. These studies provided partial to moderate evidence that PE interventions could have a positive impact on musculoskeletal symptoms, on reducing injuries and workers' compensation claims, and on lost days from work or sickness absence. The magnitude of the effect requires more precise characterization in future research.

Although stakeholders found the effectiveness review helpful, they requested further information on how best to implement PE interventions. By their very nature of being "participatory," PE interventions are

heterogeneous. While they often share common elements, interventions can address different risk factors and propose different changes to address these risk factors. An evaluation of the process of PE implementation is important to understand how changes can be brought about despite such diversity. There is both qualitative and quantitative literature on PE processes examining the implementation of PE interventions (23; 24).

Although "ideal" processes are outlined in a number of articles and reports, (24; 25) and narrative reviews have synthesized the elements of process (17), to our knowledge there has not been a systematic review of the literature on implementation aspects of PE interventions. Stakeholders expressed interest in a literature summary describing the processes, facilitators and barriers to implementing a PE intervention.

This systematic review differs in several respects from previous reviews in our prevention review series. First, it examines the process and implementation of PE interventions and does not evaluate evidence of effectiveness. As a result, in order to answer the review question, we required specific content or information describing the process of PE interventions in the documents we reviewed. We also had to adapt the quality requirements and moved away from an evidence synthesis approach. Second, we did not restrict our search or relevance criteria to research articles or studies; instead, we included documents that described practice and interventions even if they did not describe a scientific evaluation. Finally, we decided to include the "grey literature" (conference proceedings, books and book chapters, technical documents and reports not published in peer-reviewed journals) in order to see what effect it would have on answering the question. Despite these methodological adaptations, the review included a comprehensive search of the literature and was systematic and transparent in how documents were obtained and reviewed.

1.2 Review question

This review of the literature set out to answer the question, "What is the evidence regarding context, barriers and facilitators to the implementation of participatory ergonomic interventions in workplaces that have the intent of improving worker health by attempting to make changes in: i) work processes, ii) work tools & equipment, and/or iii) work & workplace organization?"

2.0 Stakeholder Engagement

Since the goal of this review was to examine the literature on the process and implementation of participatory ergonomics, we felt that the input of practitioners involved in the design, implementation and evaluation of these types of interventions was particularly important. To this end we asked Judy Village, a practicing ergonomist, to be a member of our review team. In addition we sought and were successful in receiving external funding from WorkSafeBC and the Workers Compensation Board (WCB) of Manitoba to expand our stakeholder groups to include those provinces. One objective in contacting a wider group of stakeholders was to elicit more information about possible grey literature sources. The second objective was to understand how stakeholders from different geographical locations in Canada would respond to the information from this review and to ascertain suggestions about constructing, tailoring and disseminating messages from the review.

As part of the IWH Systematic Review Program we have consistently involved our stakeholders during the review process to maximize opportunities for research uptake, for utilizing research findings in decision-making, and to get feedback about review specifics. This inclusion of stakeholders can lead to an increased uptake of the project findings. Involving stakeholders in the review process has positive outcomes that include increasing the relevance of the review and building the relationship between the decision-maker and the researcher (26).

2.1 Identification of stakeholders

In Ontario, the stakeholder group consisted of 12 ergonomic and prevention representatives from a variety of prevention partners (health and safety associations, the Workplace Safety & Insurance Board (WSIB), the Ministry of Labour), the Ontario Federation of Labour and various Ontario employers. These stakeholders were invited to provide feedback on various aspects of this review. They were identified through existing networks and relationships that had been developed via the knowledge transfer and exchange department at IWH.

Stakeholders in British Columbia were identified via two B.C. contacts, Judy Village and Dan Robinson, who was a previous IWH stakeholder. They both provided names of organizations and individuals. We also approached contacts at WorkSafeBC, who suggested a senior ergonomist, who then provided a list of relevant WorkSafeBC staff and external organizations. Some of the initial invitees were then able to provide additional contacts, who were also invited. In addition to these approaches, organized labour contacts from Ontario were notified about the meetings and asked to provide the names of appropriate individuals in the Vancouver area.

To identify stakeholders in Manitoba, the research department from the Manitoba Workers Compensation Board (WCB) suggested its internal representatives and an ergonomist from the Ministry or Labour, Andrew Dolhy, as a stakeholder with a strong network of relevant contacts, who then provided a list of specific contacts from a variety of organizations.

Additional stakeholder contacts in Manitoba were determined via web searches focused on identifying equivalent stakeholders as in both Ontario and British Columbia. In total, 89 stakeholders from B.C. and Manitoba were identified and invited to these feedback sessions and 60 signed up to attend. For a full list of attendees please refer to Appendix A. The number of stakeholders participating in B.C. and Manitoba was much larger than equivalent meetings in Ontario. We invited more participants to take advantage of our limited time in those provinces and to interact with a maximum number of interested stakeholders.

2.2 Stakeholder feedback

In Ontario the same group of stakeholders was invited to three meetings of two hours each at various points in the review process. At the initial meeting the stakeholders helped to clarify the review question, provided additional search terms and suggested including specific grey literature sources. In the interim meeting, this same stakeholder group provided feedback on the data extraction and synthesis approaches developed by the review team. Stakeholders were also asked to supply additional grey literature sources and ideas for dissemination. Their feedback helped to guide the data extraction process and to provide a useful way to present the findings. They felt that the data from this review would ultimately provide them with practical findings that could be implemented in their work settings. At a final meeting the stakeholders were presented with the results of the review. They provided feedback related to the clarity of the report and the best ways to frame the messages from this review. Overall the Ontario stakeholders have been very supportive of this review and have expressed an interest in its outcome.

In both British Columbia and Manitoba, three separate stakeholder meetings lasting two hours each, were arranged during one week to accommodate the larger number of stakeholders. These meetings occurred at approximately the mid-point of the review, when peer-reviewed results and preliminary synthesis of the grey literature were available. Two meetings were organized at each province's WCB and the third meeting was arranged at a neutral external location. Administrative support from each WCB's research division provided assistance in booking internal rooms, equipment, catering and offering useful suggestions for external locations. These meetings were set up in the same fashion as stakeholder meetings held in Ontario.

The B.C. and Manitoba stakeholder meetings were by necessity more focused on specific topics, given that there was a single meeting with each stakeholder group due to the limited amount of meeting time. Topics discussed included:

- What potential grey literature sources should we examine?
- How could we best report the findings?
- Should the peer-reviewed and grey literature findings be presented together?
- Are there additional categories to capture barriers and facilitators?
- How and to whom should this information be disseminated?

Overall the British Columbia and Manitoba stakeholder meetings were successful and informative. Stakeholders were engaged and had many good questions about the systematic review process and points raised in discussion. The stakeholder input is summarized below. This feedback has had an impact on the synthesis of the findings, the writing of the report and the plans for dissemination. Based on a survey of the stakeholders, administered after these meetings, the majority found these sessions useful to very useful and 75% would attend similar sessions in the future.

The main messages from all of the stakeholder meetings can be grouped under the following headings:

- Reporting review findings
    - Use plain language and extract relevant messages for specific audiences.
    - Summarize the findings as a tool or best practice guideline.
    - Include specifics and keep industries/sectors in mind.
    - Be specific about how to implement PE interventions.
    - Report the grey literature and peer-reviewed findings together and include information regarding how these findings may differ.
    - Provide additional categories to capture barriers and facilitators.
    - Clearly report aspects of PE that are not well documented in the current literature, to enable better reporting in the future.
    - Highlight the critical components of PE process and implementation.
    - Provide descriptive detail in the final messages.

- Dissemination
    - Approach specific provincial organizations and trade publications.
    - Provide website links and CD-ROMS to specific groups.
    - Develop tool or best practice guidelines

- General comments
    - Review is very timely because of new ergonomics regulations in Manitoba.
    - The findings of this review will be relevant to non-research parties.
    - Ergonomists are not paid to set up a "good experimental design" or to write up their interventions.
    - It is difficult to implement scientific research.
    - There is a lack of publications on unsuccessful interventions in both grey and peer-reviewed literature.

Taken together, the stakeholder feedback among the three provinces was very similar. The expanded stakeholder engagement confirmed that the review findings were relevant across the country and will facilitate the dissemination of messages from this review. Overall this stakeholder engagement was very helpful for the review and helped guide our review process and reporting of the findings. The remaining sections of the report reflect our incorporation of the stakeholder feedback from all provinces.

3.0 Methods

3.1 Literature search

The literature search for this review involved several different sources including: electronic bibliographic databases, websites (both academic and specific to the review topic), conference proceedings, documents recommended by subject experts and documents from relevant reference lists. A list of appropriate search terms for each of these sources was generated from knowledge of the literature, previous searches on this topic and stakeholder suggestions. The literature search process is described in five steps.

Step 1: Search of electronic bibliographic databases

The following English language databases were searched:

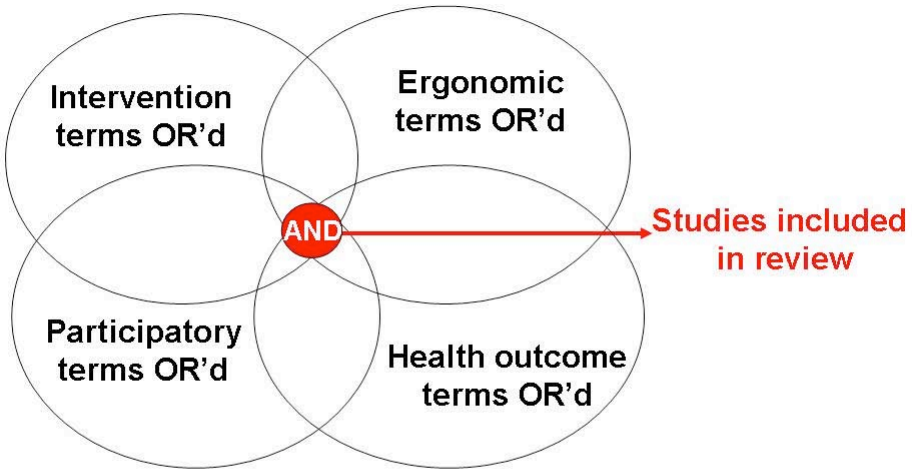
> **Peer-reviewed:** MEDLINE, EMBASE, CINAHL.
>
> **Peer-reviewed and grey literature:** Business Source Premier, Risk Abstracts, CCINFOWeb, Ergonomics Abstracts Online, Scopus (for Scopus, our focus was solely for grey lit).
>
> **Grey literature:** ProQuest Digital Dissertations, Foreign Doctoral Dissertations, Index to Theses (Great Britain and Ireland), IDEAS and the Canadian Institute for Scientific Information (CISTI) catalogue, Conference Papers Index, ISI Proceedings, PaperFirst, ProceedingsFirst.

As the controlled vocabulary used in each database differs significantly, the terms used in our search were customized for each database. The search was not limited by language. However, due to the language proficiency of review team members, only documents in the following languages were selected for review: English, French and Spanish.

The search terms covered the following broad areas: participatory terms, ergonomic terms, intervention terms and health outcome terms. An attempt was made to be as inclusive as possible in the development of the search strategy. An example of the combination of these search terms is graphically represented by the Venn diagram in Figure 1.

The search strategy combined terms among the four broad areas using the Boolean operator "AND," while the terms within each area were combined using the Boolean operator “OR.” When possible, the titles, abstracts, case registry or subject headings were searched using the predetermined set of search terms. A detailed list of the terms used may be found in Appendix B.

Figure 1: Boolean logic of the search



Additional parallel searches were conducted in some of the electronic databases using a simplified search strategy. The simpler search strategy incorporated two truncated terms: "participat*" and "ergonomic*". There were three reasons for carrying out these additional searches. First, we wanted to capture additional relevant references that might have been missed with the more complex search strategy, which required terms in all four areas. Second, we wanted to build on earlier IWH research that compared the comprehensiveness of simple and complex search strategies in the low-back pain literature. Third, we wanted to make sure we researched databases that were not able to accommodate more sophisticated search strategies.

A key part of the literature on participatory ergonomics may be considered grey literature. Grey literature has been defined as "information produced at all levels of government, academia, business and industry in electronic and print formats not controlled by commercial publishing" (27). Our stakeholders suggested that we explore the grey literature on the topic of participatory ergonomics. The review team discussed the extent to which we wanted to consider this literature and felt that we should be inclusive and systematic. Therefore our inclusion of grey literature came from sources that we could search systematically, such as databases of dissertations, databases of conference proceedings, academic websites, selected conference proceedings (where available) and institutional reports. Grey literature

originating from content experts was also documented. In addition, we asked our stakeholders from Ontario, British Columbia, and Manitoba to suggest potential grey literature sources for this review. We sought and were successful in receiving external funding from WorkSafeBC and WCB of Manitoba for this purpose.

The team considered magazine articles, trade press articles, academic theses, institutional reports, consultant reports, books or book chapters, and conference proceedings as grey literature. While some conference proceedings may be considered peer-reviewed, we as a review team decided to treat them all as grey literature to be consistent.

We had initially planned to search and review the French language literature in this review. However we, as a team, decided that this was not feasible. Two members of our review team (MS-V & DC) sought and received funding to pursue such a review in Quebec, which is underway. Therefore we did not search the French language databases listed below. Rather information about our search strategy and the list of French language databases that we had planned to search was shared with the Quebec team. Any French language documents we became aware of from our searches were also passed on to our Quebec colleagues.

> **French language databases:** FRANCIS, PASCAL, Institut national de recherche et de sécurité - INRS Bibliographie, Perspectives interdisciplinaires sur le travail et la santé (PISTES), Revue électronique <Activité>, Site de la Société d'ergonomie de langue Français (Actes des Congrès), Éditions Octares, Case Nationale d'Assurance Maladie, Agence Nationale pour l'Amélioration des Conditions de Travail (ANACT), Institut de recherche Robert-Sauvé en santé et en sécurité du travail (IRSST), Conservatoire national des Arts et Métiers (CNAM), Centre National de la Recherche Scientifique (CNRS)

Step 2: Search sensitivity check

As a preliminary check of the search's sensitivity, all review team members were asked to compile a list of references from their personal libraries that should be captured in our broad search. This list of "must-have" references was then compared to the results of the literature search to confirm the sensitivity of the search. We captured 74% of the "must-have" references in our searches. We determined that 8% of the remaining references did not contain either an "ergonomic*" or a "participat*" term and therefore would not be captured in any of our searches. In addition, 3% were not indexed in any of the databases that we searched. The review team felt that the search was suitably sensitive and proceeded with the review.

Step 3: Consultation with content experts
The review team compiled a list of content experts. These experts were contacted to suggest articles in press, articles accepted for publication and grey literature documents (e.g. technical reports, book chapters, theses or dissertations, and conference presentations).

Step 4: Reference lists
The reference lists of all relevant documents selected for review were manually searched and checked for duplicates against the list of references from our search.

Step 5: Hand-searching conference proceedings
Another source that we felt we could search systematically was conference proceedings from three well-known ergonomics societies. As we were unsure of how well indexed conference proceedings of the various ergonomics societies were in available databases, we contacted the Association of Canadian Ergonomists (ACE), the Human Factors and Ergonomics Society (HFES) and International Ergonomics Association (IEA) and requested their conference proceedings. We received 23 proceedings in total, primarily from ACE. Each proceeding was hand-searched by one of four review team members (JV, KK, DVE, QM). This meant that the table of contents, as well as titles and abstracts of each document, were screened for relevance to our review question. All documents not previously captured within our literature search were added to our review.

3.2 Document relevance
After completing the literature search, the references we found were reviewed for relevance in two stages. In the first stage, pairs of reviewers looked at titles and abstracts to determine if a participatory ergonomic (PE) intervention was described. In addition to this criterion, we also categorized the references on broad methodological type, or the approach to analysis (quantitative, qualitative or mixed-methods), literature type (grey or peer-reviewed) and document language. References that were not in English, French or Spanish were not included for further review. If it was unclear whether a PE intervention was described, the reference moved to the next stage of relevance review and the full document was obtained. In the second stage of review, full documents were assessed by pairs of reviewers to determine if a PE intervention was described, type of analysis, literature type and document language. This stage employed the same relevance criteria as the first stage and also included a search of references to identify other possible documents for review.

3.3 Content and quality appraisal

Since it would be unfair to judge non-scientific literature (or any non-research documents) using traditional methodological quality appraisal criteria, the review team was challenged to find a way to judge which documents should contribute to the evidence. After careful consideration and discussion, the review team developed a content and quality appraisal instrument for both the peer-reviewed and grey literature identified in the review. Content and quality questions were answered by two reviewers independently, who then came to consensus on each question. If the document presented enough detail on content, in the opinion of two reviewers, then it was judged on the additional seven quality criteria (see Quality criteria questions). The review team felt that this provided the correct balance between content and quality that was required to best answer our review question.

For *content* we considered whether the document contained sufficient information about the process and implementation of PE. Specifically we focused on information about context, barriers and facilitators, and whether some change was implemented through the PE process. The review team decided that a document had sufficient content when there was a description of the context ("context" includes type of business/work done, geographical location(s) of the organization(s) involved, information about the organization(s), how the intervention originated), as well as some description of the facilitators and/or barriers to the PE process. In addition the review team felt that there should be some description of the changes that were proposed or implemented as a result of the PE intervention (see questions 1and 2 of the content and quality criteria in Appendix C). We felt that these content questions would help us determine the documents that had the information required to answer our review question about PE process and implementation.

For *quality* the review team created an instrument with seven quality criteria and one additional question (see list below). We felt that these quality criteria could provide us with a consistent indication of document quality and that they could be applied to all documents we wanted to consider (i.e. not only research on effectiveness). The review team applied weights to the questions by giving each a score based on our perception of the quality criteria importance. Partial scores were possible for questions one to four worth one half of the full score noted in the list below.

Quality criteria questions (score):

1) Was the purpose of the paper clearly stated? (2)
2) Was the rationale for implementing a PE intervention described? (2)
3) Were the various steps of the intervention clearly outlined? (4)
4) Was the duration of the intervention documented? (2)

5) Was the length of follow-up greater than one month? (2)
6) Does the paper describe the impact of the PE intervention? (2)
7) Was the potential influence of any co-interventions or any other concurrent activities/trends considered? (2)
8) Do you think that this paper should proceed to DE? (no score)

Content and quality questions were answered in stages by two reviewers independently, who then came to consensus on each item. Documents with sufficient content receiving minimum quality scores of 10 (out of 16) proceeded to data extraction (DE). Some documents were considered rich in information about PE processes. These documents proceeded to DE even if they did not achieve quality scores of 10. When two reviewers agreed that there was considerable information about PE processes they allowed the document to proceed to data extraction with a score less than 10 (see Appendix C for details).

In addition to the content and quality appraisal, the review team also classified the broad methodological type or approach to analysis of the documents found in the comprehensive literature searches. We categorized the documents as quantitative research reports, qualitative research reports, or a combination of quantitative/qualitative and technical reports (non-research).

At this stage of the review we identified documents that reported on the same PE intervention at the same location. When more than one document reported on the same intervention(s), we grouped related documents together for review and assigned the earliest document as the primary document and the others as supplemental. When both peer-reviewed and grey literature documents described the same intervention we designated the peer-reviewed document as primary and the others as supplemental. In this way the content and quality appraisal and data extraction stages each took into account all documents that reported on the same PE intervention(s).

3.4 Data extraction

Data were extracted from all documents that met the minimum content and quality criteria. The data extraction (DE) instrument was developed and tested by the review team. The data extracted included: context, the organizational structure of the process, ergonomic training, the process of the PE intervention (using the PE Framework (PEF) proposed by Haines et al (14; 17) and additional questions), facilitators and barriers of the process, and the reported effectiveness of the intervention (see Appendix D for details about the PEF instrument). Data was extracted from documents by two reviewers independently, who then came to consensus on the data extracted for each item of the DE instrument (See Appendix E).

For facilitators and barriers we created an *a priori* list of categories to use in the data extraction. The categories were determined by three of the co-authors (NT, DCC, and DVE). See Table 1 for the list of facilitator and barrier categories and our working definitions of each. For the facilitator and barrier categories in Table 1, each category could be presented as a facilitator or a barrier. For example a document could suggest that there was very good communication (category #13) among ergonomic team members and workers, or they could suggest that communication was poor or lacking.

Table 1: Categories of facilitators and barriers to the PE process

Category	**Definition/examples**
1) Climate of workplace	Some indication of climate or culture affecting the PE process (e.g. emphasis on safety). Indication of cooperativeness.
2) Create a team: steering committee, workgroup or Ergonomic Change Team – with all required members	A team was described in each document. Was the team a facilitator or barrier to the process?
3) Ergonomic training/ knowledge/ abilities	Mention of training or existing knowledge/skills of ergonomics (e.g. hazard identification, solution development)
4) Organizational training/ knowledge/ abilities	Mention of training or existing knowledge/skills of an organizational nature (e.g. admin skills, bureaucratic skills, including team building skills)
5) Resource availability (time, material, personnel)	Indication of making funds, materials or personnel (time) available
6) Awareness of PE intervention among: management, supervisors and workers	Specific mention of the level of awareness about the PE intervention among different participants (individuals may be aware but not supportive of the PE intervention)
7) Support of PE intervention among: management, supervisors and workers	Specific mention of support of the PE intervention among different participants
8) Develop and follow systematic plan or approach	Some indication of the development of a plan/approach or that some specific approach or plan was followed in the course of the intervention process.
9) Production requirements	Indication that the production process had an effect on (interfered or aided) the PE process. This includes the concept of "margin of economic manoeuvrability."
10) Personnel turnover: at management, supervisor or worker level	Indication that staff turnover was a barrier or facilitator to the process at any level (management, supervisor or worker)
11) Working relations	Concept of collaboration or lack thereof (e.g. management vs. union, within team(s) or between supervisors)

12) Nature of work	Mention that the nature of work (e.g. task variability or cyclical tasks) was an issue
13) Communication	Specific mention of levels of communication as an issue (but need to be distinct from working relations and climate issues)
14) Change (resistance or ability to change among individuals workers or supervisors)	Concept of workers/supervisors/managers being resistant or unable to change according to the recommendations of the PE process
15) Champion/leadership/facilitator	Was a champion or facilitator mentioned specific to the process?
16) History of intervention attempts	Indication of previous intervention attempts either aiding or inhibiting the PE process
17) Research methodology – as facilitator or barrier to PE process	Did the research project have an effect on the process?
18) Easy changes to implement	Mention of easy changes as motivators or barriers (low hanging fruit concept)
19) Other	Anything not covered in the above categories.

3.5 Information Synthesis

Preparing the synthesis of this literature presented considerable challenges. We included a variety of types of documents in this review, including research studies with varying designs, and technical documents that described practice. This resulted in rich descriptions of PE processes, facilitators and barriers. The documents differed considerably in their purpose (description or analysis), the kind of interventions used, the industrial sectors involved, the kind of participants, the PE processes undertaken, the unit of analysis (individual, group or workplace), and the methods of data collection and analysis. This made direct comparisons between the document types difficult. However, we have described some attributes that were consistent across documents. We used these attributes to describe, compare and contrast findings.

The review team decided that it would *not* be possible to use a "best evidence" synthesis approach, where the levels of evidence are ranked on a scale from "strong evidence" through to "insufficient evidence." The evidence is usually ranked on quality, quantity and consistency. Quality refers to the methodological strength (e.g. high response rates in questionnaire-based research, or explicit and rigorous methods in qualitative research). Quantity refers to the number of documents that provided evidence of adequate strength. Consistency refers to the uniformity of results across the documents on the same health outcome.

We decided instead to synthesize the information about process and implementation of PE interventions across the documents with sufficient

content that met our minimum quality criteria. We made no further comments on quality comparisons among the documents reviewed. We focused instead on the quantity or endorsement (e.g. the number of documents that dealt with particular aspects of process) to assess the importance of the key elements of the PE process. However, we also focused on the consistency of information about rationale, context, facilitators and barriers, which is more in line with qualitative analytic approaches (28).

4.0 Results

4.1 Literature search

The findings from the various searches are presented in Table 2. The total yield, with duplicates removed, was 2,151 references. The search yields were considerably greater than that of a previous review of PE effectiveness (n= 442, with duplicates removed) (21; 22). This greater yield was primarily due to our broadening the scope of the search beyond the question of intervention effectiveness, and our more concerted effort to capture the grey literature. Of the references that were captured in our search, 61.2% were peer reviewed and 38.8% were grey literature references, before duplicates were removed.

Table 2: English-language search yields

Database or source	Lit type	Yield
MEDLINE	Peer	483
EMBASE	Peer	592
CINAHL	Peer	244
CCINFOweb	Both	237
Ergonomic Abstracts	Both	428
Business Source Premier	Both	71
Risk Abstracts	Both	59
Other sources*	Both	92
Hand searching**	Both	118
Scopus***	Grey	215
ProQuest Digital Dissertations	Grey	65
Foreign Doctoral Dissertations Search	Grey	1
Index to Theses (Great Britain and Ireland)	Grey	8
CISTI	Grey	28
ISI Proceedings	Grey	182
PapersFirst	Grey	186
ProceedingsFirst	Grey	193
IDEAS	Grey	0
Conference Papers Index	Grey	18
Total with duplicates		3,220
Duplicates		-1,069
Total		2,151

* includes review team recommendations, content experts and stakeholder suggestions

** hand searching of conference proceedings and tables of contents

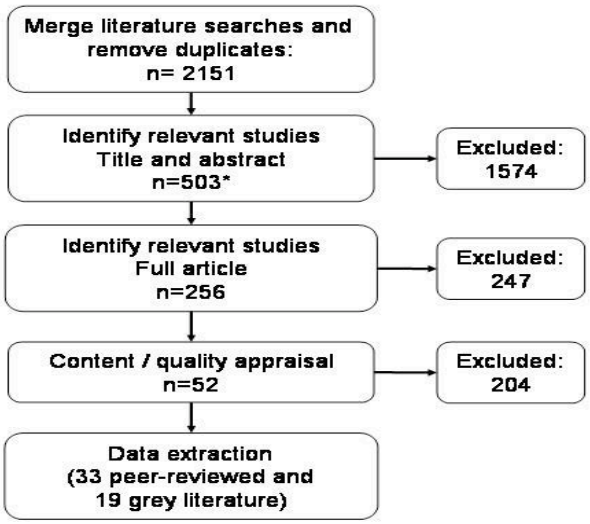
*** Scopus database does list peer-reviewed references but we only used it for grey literature in this search.

4.2 Document relevance

At the first stage, 1,574 out of 2,151 references were excluded as they were not relevant to our research question based on titles and abstracts, leaving 577 references. Among these, 74 grey literature references were not reviewed in stage two as we were unable to obtain the full document even after extensive searching of our sources. Of the 503 documents proceeding to the second stage of relevance review, 188 were peer-reviewed, 183 were grey literature and 132 were unknown, as there was not enough information in the reference alone to determine the type.

At the second stage of full document review, 247 of 503 documents were excluded because they were not relevant (see Figure 2). With the full document, we determined that there were 96 peer-reviewed and 160 grey literature documents, or 256 relevant documents. These documents were then reviewed for content and quality about process and implementation of participatory ergonomics (see Table 3). Please note that the content and quality of non-relevant documents was not assessed.

Figure 2: Flowchart of documents progressing through review steps



* 74 grey literature documents could not be obtained.

Table 3: Type of literature included for further review at each stage of the review.

Review stage	Peer-reviewed	Grey	Unsure
1. Relevance: titles and abstracts	188	257	132
2. Relevance: full documents	96	160	0
3. Content / quality	96	160	0
4. Data extraction	33	19	0

4.3 Content and quality appraisal

In total, 256 relevant peer-reviewed and grey literature documents were reviewed for redundancy (reporting on same intervention), classification as to type of document, and content and quality (see Figure 2). The content/quality appraisal step provided reviewers the best opportunity to determine whether a document was reporting on the same intervention or study as another document in the review. A total of 204 documents were excluded at this stage.

Of these, 53 (19 peer, 34 grey) were considered supplemental to other documents in the review. The larger number of grey literature documents considered supplemental was likely due to the fact that the same intervention was described in conference proceedings and then in peer-reviewed documents. However there were also cases where multiple peer-reviewed documents described the same intervention. A further 13 documents were excluded at this step because they were written in French. Our colleagues in Quebec (including members of our review team) are in the process of a review of the French language literature and will incorporate these documents in their review.

For the remaining 190 documents, the breakdown according to whether the document was a quantitative research report, qualitative research report, combination quantitative/qualitative report, or technical report (non-research) document type is presented in Table 4.

Table 4: Number of documents (n=190) by document type reviewed at content and quality step. Note this does not include the 66 supplemental and French language documents

Document type	Peer-reviewed	Grey	Total
Quantitative research	35	34	69
Qualitative research	4	6	10
Combination Quantitative/Qualitative	9	8	17
Technical report (non-research)	26	68	94

The review team classified the majority of the documents (excluding supplemental or French documents) at the content and quality appraisal stage as technical documents (n=94) and most of these were from the grey literature. Among the research reports the majority were considered quantitative research. The quantitative research documents (n=69) came equally from peer-reviewed and grey literature. A similar breakdown emerged in the small numbers of qualitative research and combination documents.

Of these 190 documents, 126 (36 peer-reviewed, 90 grey) did not meet our criteria for content as the reviewers felt that the documents did not contain enough information to contribute to answering the review question. Hence, 64 documents underwent a quality appraisal (see Table 5). An additional 12 (4 peer, 8 grey) were excluded at this stage because they did not have rich content nor meet the quality criteria (see Table 5).

Table 5: Quality scores for the 64 documents that were appraised for quality.

First author, year	Peer or grey	Q1*	Q2*	Q3*	Q4*	Q5*	Q6*	Q7*	Total	Include in DE†
Berg Rice, 2002 (24)	peer	2	2	4	2	2	2	2	16	Yes
Halpern, 1997 (7)	peer	2	2	4	2	2	2	2	16	Yes
Laitinen, 1997 (10)	peer	2	2	4	2	2	2	2	16	Yes
Moore, 1998 (29)	peer	2	2	4	2	2	2	2	16	Yes
Gjessing, 1994 (30)	grey	2	2	4	2	2	2	2	16	Yes
May, 1994 (31)	peer	2	2	4	2	2	2	2	16	Yes
Rivilis, 2006 (32)	peer	2	2	4	2	2	2	2	16	Yes
Neumann, 2000 (33)	grey	2	2	4	2	2	2	2	16	Yes
Laing, 2005 (34)	peer	2	1	4	2	2	2	2	15	Yes
Schurman, 1994 (35)	peer	2	2	4	2	1	2	2	15	Yes
Vink, 1995 (36)	peer	2	1	4	2	2	2	2	15	Yes
King, 1997 (37)	peer	2	1	4	2	2	2	2	15	Yes
Murphy, 2002 (38)	grey	2	2	4	1	2	2	2	15	Yes
Bohr 1997 (39)	peer	2	2	2	2	2	2	2	14	Yes
Rosecrance, 2000 (40)	peer	2	2	4	2	2	2	0	14	Yes
Haims 1998 (8)	peer	2	2	4	2	2	2	0	14	Yes
Mansfield, 1997 (41)	peer	2	1	4	2	1	2	2	14	Yes
Westlander, 1995 (42)	peer	2	0	4	2	2	2	2	14	Yes

First author, year	Peer or grey	Q1*	Q2*	Q3*	Q4*	Q5*	Q6*	Q7*	Total	Include in DE†
Burgess-Limerick, 2006 (43)	peer	2	2	4	2	2	0	2	14	Yes
Allard, 2000 (44)	grey	2	2	4	2	2	0	2	14	Yes
Smith, 1994 (45)	grey	2	2	2	2	2	2	2	14	Yes
van der Molen, 2005 (46)	peer	2	2	4	2	1	0	2	13	Yes
de Jong, 2002 (47)	peer	2	2	4	1	2	2	0	13	Yes
Loisel, 2001 (48)	peer	2	2	4	1	2	0	2	13	Yes
Vink, 1997 (49)	peer	2	1	4	2	2	2	0	13	Yes
Bellemere, 2006 (50)	grey	2	2	4	2	1	0	2	13	Yes
Wilson, 1995 (51)	peer	1	2	4	2	2	0	2	13	Yes
Lavoie-Trembley, 2005 (52)	peer	2	0	4	2	2	2	0	12	Yes
Hess, 2004 (53)	peer	2	2	4	2	0	2	0	12	Yes
Anema, 2003 (54)	peer	2	2	4	2	2	0	0	12	Yes
Motamedzade, 2003 (55)	peer	2	2	4	2	0	0	2	12	Yes
Steinbrecher, 1999 (56)	peer	2	2	2	0	2	2	2	12	Yes
Garmer, 1995 (57)	peer	2	2	4	2	2	0	0	12	Yes
Lifshitz, 1988 (58)	grey	2	2	2	2	2	2	0	12	Yes
St Vincent, 1997 (59)	peer	2	2	4	1	1	2	0	12	Yes
McLean, 1997 (60)	grey	2	2	4	1	1	2	0	12	Yes
de Looze, 2001 (61)	peer	2	2	4	0	1	2	0	11	Yes
Udo, 2001 (62)	peer	2	2	2	1	2	2	0	11	Yes
Kardborn, 1998 (63)	peer	2	2	4	2	1	0	0	11	Yes
Zink, 1991 (64)	grey	2	2	4	0	1	2	0	11	Yes

First author, year	Peer or grey	Q1*	Q2*	Q3*	Q4*	Q5*	Q6*	Q7*	Total	Include in DE†
Buchholz, 2001 (65)	grey	2	2	4	2	0	0	0	10	Yes
Wilson, 1995 (66)	peer	2	1	4	0	1	2	0	10	Yes
Polanyi, 2005 (67)	peer	2	2	2	0	2	0	2	10	Yes
Faville, 1995 (68)	grey	2	1	4	1	2	0	0	10	Yes
Wands, 1992 (69)	peer	1	2	2	2	0	2	0	9	No
Sakai, 1993 (70)	peer	1	2	4	1	1	0	0	9	No
Hasle, 1997 (71)	grey	1	2	2	1	1	0	2	9	Yes
Miller, 1992 (72)	grey	2	0	4	0	1	2	0	9	No
Karlsson, 1998 (73)	grey	1	1	2	1	1	2	0	8	Yes
Sundin, 2003 (74)	grey	2	1	2	0	1	2	0	8	No
Nastasia, 2006 (75)	grey	1	2	4	0	1	0	0	8	Yes
Dixon, 2005 (76)	grey	2	0	2	2	2	0	0	8	Yes
Kawakami, 2006 (77)	peer	2	2	2	0	1	0	0	7	No
Bellemare, 2000 (78)	grey	1	1	2	2	1	0	0	7	Yes
Gibbons, 2000 (79)	grey	1	1	4	0	1	0	0	7	No
Miller, 1993 (80)	grey	2	0	4	0	1	0	0	7	No
Carter, 1995 (81)	grey	2	1	4	0	0	0	0	7	No
Matarazzo, 2000 (82)	grey	2	2	2	0	1	0	0	7	Yes
Natale, 2002 (83)	grey	1	1	2	0	1	0	2	7	No
Kawakami, 1999 (84)	peer	0	1	2	0	1	2	0	6	No
McGlothlin, 1999 (85)	grey	2	1	2	0	1	0	0	6	Yes
Jegerlehner, 1995 (86)	grey	1	2	2	0	1	0	0	6	No
Kuorinka, 1997 (87)	grey	1	0	0	0	1	0	0	2	Yes

First author, year	Peer or grey	Q1*	Q2*	Q3*	Q4*	Q5*	Q6*	Q7*	Total	Include in DE†
Koda, 1995 (88)	grey	0	0	0	0	1	0	0	1	No

* Questions: Q1 Was the purpose of the paper clearly stated? Q2 Was the rationale for implementing a PE intervention described? Q3 Were the various steps of the intervention clearly outlined? Q4 Was the duration of the intervention documented? Q5 Was the length of follow-up greater than 1 month? Q6 Does the paper describe the impact of the PE intervention? Q7 Was the potential influence of any co-interventions or any other concurrent activities/trends considered? All questions were scored out of two but Q3 which was scored out of 4. See Appendix C for detailed list of quality questions and scoring algorithm; partial scores were possible.

†A quality score of 10 was usually required to proceed to DE, unless reviewers specified that the paper was rich in information despite a score lower than 10

In Table 5, total quality scores range from one to 16, with the majority falling between 10 and 16. Scores for quality questions about purpose (Q1), rationale (Q2), and intervention steps (Q3) were generally high across all documents. Quality questions about intervention duration (Q4), follow-up time for outcome (Q5), impact of intervention (Q6), and potential confounders/co-interventions (Q7) were not scored consistently high across documents.

The peer-reviewed documents tended to score higher on all quality questions than the grey literature documents (see Tables 5 and 6). This was despite the fact that we designed an instrument applicable to both research and non-research documents from peer-reviewed and grey literatures.

Table 6: Average quality scores for each quality question and the total score for documents according to literature type.

Lit type	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Total
Peer-reviewed	1.9	1.7	3.6	1.5	1.6	1.4	1.1	12.8
Grey	1.6	1.3	2.9	0.9	1.2	0.8	0.6	9.3
Overall	1.8	1.5	3.3	1.3	1.4	1.1	0.9	11.3

The review team placed a great deal of emphasis on the content of the documents at this stage of the review as well as appraising the quality of the documents reviewed. After seeing the documents during the review, the review team felt that the information available on the process and implementation of PE was more important than the overall quality score. Hence eight documents that described in detail some aspects of process and implementation of PE were included in data extraction, even though they did not meet our minimum quality score. In retrospect the quality criteria that

we developed may not have been required to answer the review question that we asked.

4.4 Data extraction

This section presents the data extracted using the overall (or total) results from both peer-reviewed and grey literature documents. Where there are differences between the peer-reviewed and grey literature, we highlight them. The results and synthesis are based on 52 documents (33 peer-reviewed and 19 grey literature) that met our content and quality criteria.

Context

Context includes geographical location(s) of the organization(s) involved, type of business/work done, information about the organization(s), and how the intervention originated. The documents reviewed here report on PE interventions from many different countries and industries/sectors (see Table 7). The majority of the documents report on PE interventions in North America followed by the Netherlands and Sweden. Australia, Iran, Japan and other European countries are all represented in the literature reviewed. The majority of the interventions took place in the manufacturing sector but many other sectors were represented as well.

Table 7: Percentage of documents by jurisdiction and sector according to literature type.

Context item	Peer-reviewed (%) n=33	Grey (%) n=19	Overall (%) n=52
Juris-dictions	Canada (18.2)	Canada (42.1)	Canada (26.9)
	USA (33.3)	USA (31.6)	USA (32.7)
	Netherlands (18.2)		Netherlands (11.5)
	Sweden (9.1)	Sweden (5.3)	Sweden (7.7)
	UK (6.1)		UK (6.1)
	Australia (3.0)	Australia (5.3)	Australia (3.8)
	Finland (3.0)		Finland (1.9)
	Iran (3.0)		Iran (1.9)
	Japan (3.0)		Japan (1.9)
		Denmark (5.3)	Denmark (1.9)
		Germany (5.3)	Germany (1.9)
		Italy (5.3)	Italy (1.9)
Sector*	manufacturing (51.5)	manufacturing (73.7)	manufacturing (59.6)
	health care (12.1)	health care (5.3)	health care (9.6)
	public admin (12.1)	public admin (5.3)	public admin (9.6)
	construction (15.2)		construction (9.6)
	information and cultural (9.1)	information and cultural (5.3)	information and cultural (7.7)

	accommodation and food (3.0)	accommodation and food (10.5)	accommodation and food (5.8)
	other services (9.1)		other services (5.8)
	mining oil and gas (3.0)	mining oil and gas (5.3)	mining oil and gas (3.8)
	finance and insurance (0)	finance and insurance (5.3)	finance and insurance (1.9)
	wholesale trade (3.0)		wholesale trade (1.9)
	agriculture (3.0)		agriculture (1.9)
	waste management (3.0)		waste management (1.9)

*Note that some documents report on PE interventions in more than one workplace/sector.

Data were extracted from the documents about additional contextual information. The data extraction question about context was open-ended and the information we gathered was quite diverse, as may be expected given the variety of jurisdictions and sectors represented. The descriptions of context covered both broad issues and specific details of a particular workplace. The list below presents all context factors extracted:

- Jurisdiction (country-specific initiatives, legislation, compensation systems)
- Workplace with multiple sites
- Large workforce
- Downsizing/outsourcing
- Restructuring/mergers
- Worker turnover
- Production increase/demands
- Line changes
- New building design
- Workplace culture/management style
- Type of work available
- Competitive industry
- Unionization

The authors of the documents included these details about context suggesting that they felt they were important to consider. Such information was often separate from (or in addition to) the origin or rationale for implementing a PE intervention.

Origin and rationale for PE interventions

The review team extracted information about the reasons given for implementing a PE intervention. We categorized the origins of the PE

interventions into four categories (Table 8). The majority of the documents (48%) cited reducing injury rates, sickness absence or the associated costs as the primary reasons for the PE intervention. The other main reason was to reduce musculoskeletal risk factors (MSDs), which was cited in 25% of the documents. Production issues and research were each noted in 10% of the documents. Eight per cent did not report an origin/ rationale for implementing the interventions. There were no differences between the peer-reviewed and grey literature in distribution across these categories.

Table 8: Percentage of documents reporting the origin/rationale for implementing a PE intervention by literature type.

Origin category*	**Peer-reviewed (n=33)**	**Grey (n=19)**	**Total (n = 52)**
Injury rates/ Absenteeism – includes issues of compensation costs and RTW	48.5%	47.4%	48.1%
MSD risk factors – identify and decrease risks	24.2%	26.3%	25.0%
Production issues	9.1%	10.5%	9.6%
Research – about PE	9.1%	10.5%	9.6%
Not reported	9.1%	5.3%	7.7%

* One document simply indicated that management was interested in PE. It is not included in the categories in this table.

Organizational structure

Various aspects of the organizational structure of the PE process were examined. The teams described in the documents included steering committees, change teams, or department/work group teams. Most documents contained enough information about the team for us to categorize its nature with only a few details lacking. As Table 9 shows, there was very often more than one type of team reported. In some cases all three types of teams were described in a single PE intervention.

Specific to the teams, data was extracted about whether a "champion" or facilitator was described. This person may have been part of the teams or may have initiated the team formation. Unfortunately this was not well reported in the documents reviewed. It was often difficult to determine when a champion/facilitator was (or was not) present, which resulted in many unclear/not reported responses (see Table 9).

Table 9: Percentage of documents for each organizational structure of PE teams by literature type.

	Peer-reviewed (n=33)	Grey (n=19)	Total (n = 52)
Team structure:*			
Steering committee	42.4%	57.9%	46.2%
Change team (across dept)	45.5%	31.6%	40.4%
Dept or work group	51.5%	52.6%	53.8%
Unknown	9.1%	15.8%	11.5%
Champion described:			
Yes	24.2%	21.1%	23.1%
No	18.2%	0%	11.5%
Unclear/not reported	57.6%	78.9%	65.4%
Cooperation reported:			
Yes	27.3%	10.5%	21.2%
No (lack of cooperation)	12.1%	0%	7.7%
Mixed	18.2%	0%	11.5%
Not reported	42.4%	89.5%	59.6%
Worker involvement:*			
Describing nature of work	57.6%	42.1%	51.9%
Risk analysis	72.7%	63.2%	69.2%
Solution development	90.9%	78.9%	86.5%
Solution implementation	81.8%	47.4%	69.2%
Not involved	3.0%	0%	1.9%
Unclear	9.1%	21.1%	13.5%
Issues of time to attend meetings reported*	27.3%	21.1%	25.0%

* Columns and rows not expected to add up to 100%

Indicators of trust or cooperation among the team members were not well reported in the reviewed documents, with only 21% of documents reporting on this.

The definition of PE emphasized the need for workers to be involved in the process. Therefore we specifically sought to determine how they were involved in the process of the PE intervention. Table 9 shows that the workers were often described as part of risk analysis, solution development and solution implementation and many were also involved in describing the nature of work. Consistent with the relevance criteria, there were few documents that indicated that workers were not involved in these specific activities. There were, however, some documents (14%) where it could not be ascertained how the worker was involved.

The review team examined the issue of time to attend meetings but it was not generally reported. We also sought information about the frequency and

length of team meetings. Neither was well reported. In total, 44% of peer-reviewed documents and 26% of grey literature documents did not give an indication of how often the teams met. Among those that did, the frequency of meetings ranged from a single meeting to up to four times a week (for a six-month period). In all, 75% of peer-reviewed documents and 79% of grey literature documents did not give details on the length of team meetings. Among those that did, the length of team meetings ranged from 30 minutes to two full days.

Ergonomic training

Ergonomic training was described in 73% of the documents reviewed (78.8% of peer-reviewed and 63.2% of grey literature documents).

The length of the training sessions was not described with consistent levels of detail across documents. When some details about the length of training sessions were provided, it was often not enough for others to be able to reproduce the training procedure in another setting. The time devoted to training ranged from two hours to 100 hours across the documents.

The nature of the training also varied greatly, though many described general ergonomic training (see list below). The nature of ergonomic training is set out in the following list:

- General ergonomic training: mechanisms of injury, risk factors, identification of hazards (including training on tools used), strategies for reducing hazards
- Basic ergonomic principles
- Awareness training – spreading the word…
- Problem solving
- Team work
- Specific training on tools e.g. Rapid Upper Limb Assessment (RULA) etc
- Specific training on solutions e.g. Workstation adjustments

Another important aspect of the ergonomic training in the PE interventions was who provided and received the training. Over one-third of the documents did not report who provided the training. Among those that did, an ergonomist was most often indicated (see Table 10). In many cases, however, the researcher or ergonomic team or some other person was described as providing the training.

Table 10: Percentage of documents reporting details of ergonomic training by literature type

	Peer-reviewed (n=26)*	Grey (n=12)*	Total (n=38)*
Who provided training:			
Ergonomist	34.6%	50.0%	39.5%
Researcher or team	26.9%	33.3%	28.9%
Other	26.9%	33.3%	29.0%
Not reported	46.2%	8.3%	34.2%
Who received training:			
Workers	76.9%	58.3%	52.6%
Supervisors	34.6%	33.3%	23.7%
Management (senior)	11.5%	0%	7.9%
Team (ECT)	57.7%	58.3%	39.5%
Other	26.9%	25.0%	18.4%
Unclear	26.9%	0%	18.4%

* only those that reported training counted here

Most often it was the workers who received the ergonomic training, followed by the ergonomic team. About one-quarter of the documents indicated that supervisors received training as well. A small percentage of the documents (8%) indicated that senior management received training.

Details about PE process and implementation

An established instrument was used to evaluate process and implementation details of the PE interventions. The Participatory Ergonomics Framework (PEF) was designed by Haines and Wilson (1998) (17) and later validated and tested by Haines, Wilson and Koningsveld (2002) (14). Table 11 shows the proportion of documents that met the criteria for each of the categories of the PEF.

More documents (62%) reported that the PE interventions were permanent or planned to continue than those reporting temporary interventions (29%). The level of involvement was most often stated as direct representation, in which workers affected by implemented or planned changes were members of the team(s). The level of influence of the PE intervention was most often at the entire organization, however almost as many documents reported that the department or workgroup was targeted for change.

Decision-making was most often accomplished through group consultation. This approach allowed the teams to determine their preferred choice of action and then present it to senior management for approval. In rare instances, group delegation was reported, indicating that the group made decisions about changes and implementation without a separate step for implementation. Six per cent of the documents reported individual worker consultation for decision-making.

There was much variety in the mix of participants involved in the PE process. Workers were involved in all of the PE interventions in this review due to our relevance criteria. In 78% of documents, supervisors were also involved in the interventions. Many interventions also involved internal specialists/technical specialists (62%) as well as external advisors (65%). Senior management was involved in 44% of the interventions while union representatives were explicitly involved in less than 20% of the interventions. Cross-industry personnel and suppliers were very rarely involved in PE processes.

Table 11: Documents meeting the criteria for Participatory Ergonomics Framework (Haines et al, 2002) (14) categories.

PEF category	**Peer (n=33)**	**Grey (n=19)**	**Total (n=52)**
Permanence:			
Ongoing	54.5%	73.7%	61.5%
Temporary	36.4%	15.8%	28.8%
Unclear	9.1%	10.5%	9.6%
Level of involvement:			
Full direct	27.3%	5.3%	19.2%
Direct representative	72.7%	89.5%	78.8%
Delegated	0.0%	5.3%	1.9%
Level of Influence:			
Department/work group	45.5%	42.1%	44.2%
Entire organization	48.5%	57.9%	51.9%
Group of organizations	6.1%	0.0%	3.8%
Decision-making:			
Individual consultation	9.1%	0.0%	5.8%
Group consultation	75.8%	100%	84.6%
Group delegation	15.2%	0.0%	9.6%
Mix of participants*:			
Workers/operators	100%	100%	100%
Supervisors/ line mgmt	78.8%	78.9%	78.8%
Senior mgmt	48.5%	36.8%	44.2%
Internal/ technical specialist	63.6%	57.9%	61.5%
Union	24.2%	10.5%	19.2%
External advisor	66.7%	63.2%	65.4%
Supplier	6.1%	0.0%	3.8%
Cross-industry rep	0.0%	0.0%	0.0%
Requirement for participation:			
Compulsory	15.2%	10.5%	13.5%
Voluntary	45.5%	5.3%	30.8%
Not reported	39.4%	84.2%	55.8%

Focus of intervention*:			
Tools/equipment	90.9%	73.7%	84.6%
Work processes	69.7%	52.6%	63.5%
Workplace organization	15.2%	10.5%	13.5%
Remit (responsibilities)*:			
Set up/structure process	33.3%	26.3%	30.8%
Monitor/oversee process	36.4%	47.4%	40.4%
Identify problems	97.0%	100%	98.1%
Develop solutions	97.0%	100%	98.1%
Implement change	97.0%	73.7%	88.5%
Role of PE champions*:			
Initiates/guides process	72.7%	68.4%	71.2%
Acts as expert	60.6%	42.1%	53.8%
Trains members	51.5%	42.1%	48.1%
Available for consultation	45.5%	68.4%	53.8%
Not involved	12.1%	10.5%	11.5%
Who were PE champions*^:			
Ergonomists	60.6%	47.4%	55.7%
PT/OT	6.1%	0.0%	3.8%
Others	57.6%	52.6%	55.8%

* columns and rows not expected to add up to 100%
^ additional question not in PEF

Over 50% of the documents did not report the requirements for participation. When reported, it was most often voluntary. The interventions were most often focused on making changes to tools/equipment (85%). However there were many (64%) that reported a focus on work processes. Less than 15% reported a focus on changes to workplace organization. The team's remit (or responsibilities) were most often problem identification, solution identification and solution implementation. The teams were less often responsible for setting up or monitoring the PE process.

The roles of the PE champions varied, with most taking on multiple roles. They were most often responsible for initiating and guiding the PE process. The PE champions also took on roles of consultant, trainer and expert.

The PE champions were often reported to be ergonomists, other professionals, or ergonomic team members. Many times the discipline of the champion was not indicated though when noted the researcher involved in the intervention was often the champion.

Overall there weren't great differences between peer-reviewed and grey literature for most of the categories of the PEF. There were some differences in the category of permanence, with more grey literature documents reporting permanent or ongoing interventions than peer-reviewed documents. The level of involvement differed slightly with more peer-reviewed

documents reporting full direct involvement than grey literature documents. Also some differences in requirement for participation were seen. Peer-reviewed documents more often indicated voluntary participation whereas the grey literature documents often did not report this, perhaps reflecting the need for research publications to clearly report participation. Lastly there was some difference in the focus of intervention as the peer-reviewed documents tended to focus more often on tools/equipment and work processes than did the grey literature documents.

Changes implemented and effects noted

In addition to examining the focus of the intervention with the PEF, the changes that were *actually* implemented were noted. Table 12 illustrates that changes to tools/equipment were most often implemented, while somewhat fewer changes to work processes were implemented. Again, we noted a difference between peer-reviewed and grey literature for tools and equipment changes. The peer-reviewed documents reported more change implemented to tools and equipment than the grey literature. This may be related to the higher percentage of unclear documents in the grey literature.

Table 12: Percentage of documents indicating implemented changes and effect of intervention by literature type

	Peer-reviewed (n=33)	**Grey (n=19)**	**Total (n=52)**
Changes implemented:*			
Tools and equipment	90.9%	68.4%	82.7%
Work processes	51.5%	57.9%	53.8%
Workplace organization	15.2%	5.3%	11.5%
Unclear	6.1%	26.3%	13.5%
Effect of intervention:*			
Positive	93.9%	68.4%	84.6%
Negative	21.2%	10.5%	17.3%
No effect	27.3%	36.8%	30.8%

* Note that multiple changes and effects could be presented in each document

Many documents (85%) reported positive effects on our selected outcomes as a result of the PE intervention (Table 12). There were more peer-reviewed documents (94%) reporting positive effects than grey literature documents (68%). This may in part be due to publication bias effects in which non-positive results tend not to get published in peer-reviewed literature. Thirty-one percent of the documents that reported no effect from the intervention for one of our relevant outcome measures (Table 12). In addition, 17% of interventions reported a negative effect of the PE intervention.

Facilitators and barriers

Table 13 provides a list of potential facilitators and barriers and the number of documents that report them. These categories of facilitators and barriers were created *a priori* to data extraction; hence there were some categories with little information in the documents reviewed. We also included an "other" category to capture facilitators and barriers that would not fit into any other specific category.

When considering the categories in Table 13 please refer back to Table 1 for the definitions. Note also that any given category could be reported as either a facilitator or a barrier. For example a document could suggest that there was very good level of support from management which facilitated the PE process. Alternatively a document could suggest that support was not provided and therefore this was a barrier to the PE process.

The top rows of Table 13 present the categories most endorsed as facilitators/barriers. Those more often considered facilitators include: support of the PE intervention (28 of 39), ergonomic training (22 of 36) and communication (20 of 27), creating and following a detailed plan (17 of 18), creating appropriate teams (17 of 29), PE champion (15 of 16), resources (14 of 36), organizational training (14 of 21), and making easy changes first (11 of 12). Resources were more often listed as a barrier (22 of 36) than a facilitator. Similarly, lack of ergonomic training (14 of 36), not creating an appropriate team (12 of 29), lack of support of PE programs (11 of 39) and poor communication (7 of 27) were also frequently listed as barriers.

Table 13: Number of documents reporting specific facilitators and barriers to the PE process by type of literature, ranked by total frequency.

Facilitator/Barrier Category	Peer-reviewed	Grey	Total
Support of PE intervention	21	18	39
Ergonomic training	24	12	36
Resources	23	13	36
Create appropriate team	17	12	29
Communication	19	8	27
Organizational training	16	5	21
Detailed plan	9	9	18
PE champion	9	7	16
Working relations	10	5	15
Easy changes first	7	5	12
Climate of workplace	9	2	11
Production requirement	8	2	10
Personnel turnover	6	2	8
Research methods	5	2	7
Awareness of PE	1	6	7

Change resistance	6	0	6
Nature of work	1	0	1
Intervention history	1	0	1
Other**	28	19	47

** "Other" includes facilitator/barrier issues reported that we felt would not fit into the categories above.

In addition to listing the facilitators and barriers, specific questions about material resources and time for implementation were asked (see Table 14). Sixty per cent of documents addressed issues of material resources in the course of describing the intervention. The data extracted show that some (15%) of the documents reported that time was lacking for implementation. However, as noted above, for the most part this was not reported, or not reported clearly.

Table 14: Percentage of documents indicating material resources and time for implementation of solutions by literature type.

	Peer-reviewed (n=32)	**Grey (n=19)**	**Total (n=52)**
Material resources addressed:			
Yes	65.6%	52.6%	59.6%
No	15.6%	21.1%	17.3%
Not reported/Unclear	18.8%	26.3%	21.2%
Was there time to implement solutions:			
Yes	6.3%	0.0%	3.8%
No	21.9%	5.3%	15.4%
Not reported/unclear	71.9%	94.7%	78.8%

5.0 Discussion and Information Synthesis

This section presents a synthesis of the data from both peer-reviewed and grey literature documents. We first present an overview of the methodological details that are unique to this review, then we present a summary of the information we extracted from the documents. We also indicate where we feel that more research and better reporting is necessary. In this synthesis we discuss each aspect of the data extraction but we do not reproduce the specific data from the tables of the previous section (4.4). We recommend that you refer to the tables in section 4.4 if you require the relevant details. In addition, Appendix F contains a summary of each document that we included in data extraction. Please refer to this for specific details about each of the documents.

We expanded our stakeholder engagement process during this review. We felt that the topic of participatory ergonomics was well suited to this increased stakeholder/practitioner input. In fact the review itself was initiated in part as a response to our stakeholder feedback from our earlier review of the effectiveness of PE interventions. The stakeholders clearly indicated that a review of evidence on process and implementation was welcome.

In this review, we focused on documents from different literatures with rich descriptions of PE process and implementation. This focus on content and non-research documents required a novel approach to quality appraisal. Our quality appraisal was designed to identify some basic quality issues that the review team felt were important. The quality appraisal revealed some areas that require better methods and improved reporting in documents describing PE interventions. We discuss these below.

Context

The documents reviewed report on PE interventions from many different countries and industries/sectors. We consider it a strength of the review to include this variety. We feel that the findings reported here about process and implementation should apply to almost any workplace setting in Organization for Economic Cooperation and Development (OECD) nations (some adaptations may be necessary in low-income countries). The list below summarizes the main areas of context described in the documents with respect to implementing a PE intervention:

- Multiple sites of workplaces (or size of workplace/industry)
- Workplace culture
- Unionization
- Economic Context (including restructuring)
- Production changes
- Demographics of workforce

Origin and rationale for PE interventions
Ergonomic interventions generally are thought to have an impact on reducing risk factors of MSDs (22). The primary reason given for initiating/implementing a PE intervention was related to reducing injury rates (absenteeism or costs) or risk factors of musculoskeletal disorders. Almost three-quarters of the documents reported these as the rationale for adopting a PE approach.

Organizational structure
Various teams were described in the documents including steering committees, change teams or department/work group teams. There was often sufficient information about the team structure. Overall we thought that teams were important and well described, with multiple teams created for many of the interventions. The involvement of workers was also generally well documented. Workers were involved in the PE process most often in risk analysis, solution development and implementation tasks. Unfortunately involvement of a PE champion and issues of trust and cooperation were not well reported.

Disappointingly, the frequency and length of team meetings was not well reported. Also missing were details about whether there were time challenges for meeting attendance. These details would be immensely valuable to workplace parties planning such interventions or policy-makers considering mandating them.

Ergonomic training
Ergonomic training was a key element of PE interventions with 73% of documents reporting that training was provided. However, details about the length of training sessions or who provided the training were not described consistently. The nature of the training also varied greatly. Most of the documents described a type of general ergonomic training (including mechanisms of injury, risk factors, identification of hazards, and strategies for reducing hazards). Various other types of training were also mentioned, including training on problem-solving, team work and promoting awareness of ergonomics.

Once again there is a variety of training approaches possible for any given PE intervention. The length of the training sessions, nature of the training, and who provides the training can be tailored to the needs of the particular workplace. We emphasize however that better reporting of these training details would strengthen understanding of the implementation process and may provide direction on optimal training details.

Details about PE process and implementation
We used the Participatory Ergonomics Framework (PEF) (Haines et al, 1998 and 2002) (14; 17) to evaluate process and implementation details of the PE

interventions. This instrument provides details about various aspects of PE intervention implementation.

PE interventions can be either ongoing or temporary. The literature described more ongoing interventions than temporary ones. The concept of an ongoing PE intervention is similar to related concepts such as continuous quality improvement. An ongoing PE process suggests an emphasis on reducing risks and injuries within a workplace as part of continual improvement processes, and ultimately as a way to work more safely and productively.

The level of involvement was most often accomplished through direct representation in which workers who might be affected by changes were members of the team(s). This is likely the most efficient type of involvement, not requiring the entire workforce to be involved (as in direct involvement) yet also not resorting to delegation of representation.

The level of the influence of the PE interventions was either directed to the entire workplace or the departments/work group level. This suggests that PE interventions can be designed to meet the specific needs of departments or work groups but can also address issues across a workplace.

The vast majority of the documents described group consultation as the decision-making process. A consultation process seems most appropriate for PE interventions as workers (or representatives) are involved in much decision-making while senior management has control over resources and implementation issues (17).

The mix of participants shows the importance of workers and supervisors in the PE process. In our review, union personnel were much less often mentioned as part of the PE process. However we could not consistently determine if the workplaces were unionized. Our findings suggest that the voluntary involvement of workers, supervisors, specialists, senior management and union representatives (if present) is desired.

Most often, the interventions targeted changes to tools/equipment or work processes. Team composition and remit likely has an effect on the focus of changes. The PE teams were most often responsible for problem identification, solution identification and solution implementation. Since workers and supervisors were involved in the teams they would tend to focus on the aspects of the job they knew and performed most often. This may lead to less of a focus on change to workplace organization. Changes to tools/equipment or work processes may also be easier to identify and implement for PE teams.

The PE champions were often ergonomists or other professionals who took on a variety of roles. They were most often active in initiating and guiding the PE process, which may explain why the PE teams were less involved in this aspect of the process. The PE champions also took on roles of consultant, trainer and expert.

Overall the process of a PE intervention seems fairly robust and can involve quite a variety of personnel with various roles, responsibilities and decision-making methods. While there is no one best way to implement a PE intervention the literature does suggest certain key elements that are required (see recommendations in section 6.0).

Changes implemented and effects reported

In addition to examining the focus of the intervention from the PEF, we also looked at which changes that were actually implemented. Changes to tools/equipment were most often reported as implemented. The review team considers that changes to tools/equipment may represent the "low hanging fruit" or relatively easy issues to identify and change, compared with work processes and workplace organization changes. This may explain why tool/equipment changes were implemented more often.

The majority of documents reported positive effects as a result of a PE intervention. There were also some documents that reported no effect for one of our outcome measures. We were surprised to find that some of the documents reported a negative effect from a PE intervention.

Although the purpose of our review was to examine process and implementation, we decided to look further into the reported negative effects. In cases where negative effects were reported, documents always reported positive effects of the intervention as well. Thus it was not possible to examine specific facilitators/barriers for negative effects only. In some cases (6%) the negative effect was related to satisfaction with the intervention process, while in others greater risks (or perceived risks) were noted (8%). Only one document noted an increase in incidence of injury, and it was suggested that this was a result of increased reporting due to increased awareness (38). In one other document the negative effect pertained to team dynamics and function in an environment where teamwork was the focus of the intervention (51). In all cases where negative effects were reported, we note that they were not the primary findings of the document. We examined the facilitators and barriers for these documents to see if a different emphasis could be detected and found no indication of this. We conclude that the mix of positive and negative effects did not change the facilitator/barrier messages.

Facilitators and barriers

The information we extracted about facilitators and barriers from the documents in this review was quite rich. Our stakeholders also indicated that information about facilitators and barriers to PE process was essential to them. We examined 19 potential facilitators/barriers that we felt were important to the PE process and implementation of PE interventions. We created these categories of facilitators and barriers *a priori* so that we could report on those that were present as well as those that were not reported.

The list below represents the facilitator/barrier categories most often endorsed in the literature about PE interventions:

- support of PE intervention
- resources
- ergonomic training/knowledge
- creation of an appropriate team
- communication
- organizational training/knowledge

This endorsement suggests that these aspects are most important facilitators and barriers to consider in implementing a PE intervention. We do not suggest that these are the only aspects that are important to consider but they represent areas that have been frequently reported. To capture some of the richness of the data we examined, we present some of the facilitators/barriers in the text box below.

Support:

"A high level of 'buy in' from the supervisor was a factor that contributed to the successful and timely implementation of control measures." (Burgess-Limerick, 2006, 44)

"… top management should support the team" (May 1994, 31)

"… management commitment and support was a vital prerequisite for continuous improvement." (Motamedzade, 2003, 55)

"The support of co-workers was important for the operators in the working group." (St.Vincent, 1997, 59)

Resources:

"Time is needed for technical improvements, especially when the people at the shop themselves design and produce new equipment." (Laitinen, 1997, 10)

"Major obstacles were lack of time to devote to the project and an insufficient budget. Insufficient resources." (Rosecrance, 2000, 40)

"the program was seen as a drain on resources: 'Financially it's a huge commitment for the company. Further, the lack of specific budget lines for certain items (e.g. furniture, ergonomic upgrades) was a constraint on preventive spending.'" (Polanyi, 2005, 67).

Communication:

"continuous information and communication is critical…" (Kardborn, 1998, 63)

"Sharing information for change throughout the organization and equalizing access to information are both important features." (Mansfield, 1997, 41)

"broad based participation and communication with all employees is necessary to identify problem areas and increase the acceptance of solutions." (May, 1994, 31)

6.0 Key Messages/Recommendations

This review has summarized both the peer-reviewed and grey English-language literature about PE process and implementation. We have reviewed many types of documents (both research and non-research) that provided enough detail about context, process, and the barriers and facilitators to the implementation of participatory ergonomic interventions in workplaces. The peer-reviewed and grey literature documents we reviewed presented very similar information.

The recommendations are based on the information extracted and synthesized from 52 documents of peer-reviewed and grey literature. These documents were considered relevant, met our content/quality criteria and provided details about various elements of the PE process. Each of our recommendations is based on the endorsement and description from the documents we reviewed. With these recommendations, we take into account consistency across the documents and specific information presented about facilitators and barriers for each. When it was clear that more information was required we mention that as well. We feel that these recommendations will be applicable broadly as they are based on documents from multiple jurisdictions and different sectors/industries.

We make the following *recommendations* based on our review of the literature:

Involve the right people in the PE process
In addition to who is involved in the PE teams, it is important to establish who is involved in the PE process more broadly in the workplace. Our review found that workers, supervisors and specialists or advisors (internal or external to the workplace) were key actors in the PE process. Note that we required worker involvement for inclusion in the review based on various definitions of PE (3; 4). This array of participants likely represents the right mix of skills or knowledge to progress through the PE process. We make this recommendation based on the levels of endorsement for each participant. Additionally we note that the importance of facilitators such as support of PE interventions, communication and working relations support the need for a right mix of participants in the PE process.

An issue related to involving the right people is whether participation is compulsory or voluntary. This issue requires better reporting since we could not determine the requirement for participation in the majority of documents.

Involve a participatory ergonomic champion
An ergonomic champion was involved in the vast majority of PE interventions described. The role of this individual varied, but usually involved multiple tasks or duties emphasizing his or her importance. The champion was most often an ergonomist, but could also be another

professional or researcher. The PE champion was also an endorsed facilitator category and therefore an important aspect of the PE process.

We suggest there is a need for better reporting in the literature of who the PE champion is with regards to the background or profession.

Create teams with appropriate members

A team is an important aspect of PE interventions; the vast majority of the documents indicated that some type of team was formed as part of the PE process. Many, in fact, indicated that more than one type of team was created. The type of team seems flexible and adaptable to the particular circumstances. Teams could be categorized as steering committees, change teams (across departments), or department/workgroup teams.

It is clear that regardless of the type of team, having the appropriate members is important. The creation of an appropriate team was an often endorsed as a facilitator (and a barrier if not addressed). Issues of communication, support of PE interventions and inclusion of a PE champion in the process emphasizes the need to have appropriate people on the PE team.

However there are aspects of the teams that required better reporting or more information. Basic information about frequency and length of team meetings would be useful for those setting out to initiate a PE intervention. In addition more information about issues of trust or cooperation would help to better understand how the teams need to operate successfully. It is also not clear which type of team is *best* in a PE intervention at a particular location. It appears as if the type of team should be based on the people involved and the type of workplace.

Provide ergonomic training

Another important element of the PE process is ergonomic training, which was described in the majority of documents. Often, ergonomic training is specifically mentioned as a facilitator (or barrier if not sufficiently provided). Many other facilitators are related to aspects of the PE process that are usually addressed in ergonomic training. Specifically, having a detailed plan for the PE process, identifying easy changes to make first, as well understanding the nature of work and production requirements speak to the importance of training.

The nature of the training is flexible and can be tailored to the specifics of the workplace risks/hazards or the targeted solutions. The ergonomic training can be delivered by an ergonomist or other professional to workers PE team and supervisors.

Once again, more information in reports about frequency and length of training sessions would be helpful to those implementing a PE intervention. These details could help to create an appropriate plan for the resources required. Although there may be a great deal of variation in these aspects of training, even knowing the ranges more clearly, and the consequences of more or less training, would be helpful for planning.

Define participants' responsibilities (remit)
The documents in this review most often endorsed the following responsibilities to be central to the PE process for participants: problem identification, solution development, and implementation of change. The tasks of initiating/guiding and monitoring the PE process were less often considered the responsibility of the participants the documents in this review, perhaps because the PE champion was responsible for guiding and monitoring the PE process in many cases.

Make decisions using group consultation
Group consultation was the most frequently endorsed method of decision-making. This method as described by Haines et al (2002) (14) suggests that the group makes decisions but management becomes involved in decisions requiring resources and implementation. This appears to be a realistic way of progressing toward change in a workplace setting.

Facilitators such as communication, working relations and workplace climate were highly endorsed and are important to this type of decision-making method.

Address key facilitators/barriers
Awareness of potential facilitators and barriers is extremely important in the initiation and ongoing process and implementation of a PE intervention. The list below represents those that are most common in the literature and therefore should be considered in the PE process:

- support of PE intervention
- resources
- ergonomic training/knowledge
- creation of appropriate team
- communication
- organizational training/knowledge

It is important to be aware of the other potential facilitators and barriers, especially as PE interventions require adaptation to specific workplaces and associated risk factors.

Provide more information

There were some elements of the PE process that were not clearly endorsed by the documents reviewed. In some cases this suggests better reporting is required. In others it suggests that the PE process is flexible enough to allow different ways to accomplish the PE intervention successfully.

The contextual factors that were reported varied greatly across the documents. Despite this variation in context, the primary reason for engaging in a PE intervention was to reduce injuries (or associated costs) or risk factors for injuries. The use of PE for these purposes has previously been shown to be reasonably effective (21). This suggests that PE processes are flexible enough to address a variety of contextual factors.

We cannot comment on whether a PE intervention should be ongoing or temporary. There were more documents reporting ongoing interventions, and we feel that this would be desirable. However it may be that permanence should be based on the nature of the workplace, types of risk factors and workers involved.

The focus of the PE intervention is by nature something that should be defined by the PE team. While the interventions we reviewed showed more emphasis on tools/equipment and work processes, we do not feel that this is necessarily an endorsement to do so in all PE interventions. It may be that these types of changes are easiest to identify and change.

Overall we feel that more research or better reporting is required regarding some of the basic quality issues identified. Consistent reporting of details about the effect/impact of the intervention, and whether there were co-interventions (or other activities) during the PE intervention were required to determine quality. In addition more details about the intervention steps, duration and follow-up length would have strengthened the recommendations of this review. While this was not a review about intervention effectiveness, information that enables reviewers to judge quality is still important. The higher the quality of the documents the more confidence we have in making conclusions about the evidence for the PE process and implementation.

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