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Systematic review of the role of occupational health and safety interventions in the prevention of upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time

Institute for Work & Health
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sharing best evidence

About this report:

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Foreword

In recent years, the Institute for Work & Health has been actively engaged in building relationships with Prevention System agencies and organizations in Ontario. In these encounters, we often hear that potential research users want more evidence about the effectiveness of interventions aimed at protecting workers' health. We are also told that even when research evidence exists, it is often hard to access, difficult to understand and is not always presented in language and formats suitable to non-scientific audiences.

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

- Our systematic review team monitors developments in the international research literature on workplace health protection and selects timely, relevant topics for evidence review.

- Our group has the expertise to perform mixed method reviews of both qualitative and quantitative studies.

- 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 Institute staff members participated in this systematic review. External reviewers in academic and workplace leadership positions also 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
December, 2008

1.0 Introduction

Workers in many industries and sectors experience pain and symptoms of numbness and tingling in the neck, shoulder, arm, wrist and/or hand. Such symptoms may be warning signs of current or impending musculoskeletal disorders, such as peripheral nerve entrapments (e.g. carpal tunnel syndrome, ulnar tunnel syndrome), peripheral enthesopathies (e.g. shoulder tendinitis, lateral epicondylitis, hand-wrist tendinitis) and many other non-specific musculoskeletal pain disorders (1).

Collectively, these conditions are often referred to as *upper extremity musculoskeletal disorders*. Workers may also experience more acute traumatic injuries of their upper extremity, such as crushed fingers, tendon lacerations and burns (Statistical Supplement to Workplace Safety and Insurance Board [WSIB] Annual Report 2006) (http://www.wsib.on.ca/wsib/wsibsite.nsf/Public/AnnualReports). Together, upper extremity musculoskeletal disorders (MSDs) and traumatic injuries are a large burden to society and to workplaces because of lost productivity, reduced performance and lost-time claims among affected workers (2-4).

In 2006, upper extremity injuries accounted for about 30 per cent of lost-time claims in Ontario (Statistical Supplement to WSIB Annual Report 2006) (http://www.wsib.on.ca/wsib/wsibsite.nsf/Public/AnnualReports). From 1996-2005, 30 to 33 per cent of all claims among office workers were related to upper extremity and neck disorders (Institute for Work & Health [IWH] analyses of WSIB claims database by Marjan Vidmar). Recent analyses of the 2005 Canadian Community Health Survey show that seven per cent reported work-related repetitive strain injury (RSI) and 71 per cent of the RSIs were of the upper extremity (IWH analyses by Dr. Peter Smith). Data from the 2005 European Foundation for the Improvement of Living and Working Conditions Survey (based on fifteen countries) showed that 25 per cent of workers reported work-related neck/shoulder pain and 15 per cent reported work-related arm pain (5).

Upper extremity MSDs occur as a result of many factors. There are many known occupational risk factors including: physical (heavy physical load, awkward postures, working with arms above shoulder level, repetitive movements, same activity for prolonged periods, vibration); psychosocial (psychological demands at work, control at work, social support at work, job satisfaction); and personal (years of employment) factors (6,7).

A multicausal problem, such as with MSDs, most likely requires multiple solutions. In addition, current practices in the management of upper extremity MSDs are diverse. These include various interventions in the workplace (ergonomics training, workstation adjustments, work redesign), in the clinical setting (physiotherapy clinic at the worksite) and in disability

management programs (implemented by employers, insurers and jurisdictions).

Despite the frequency, high costs and the range of MSD prevention approaches, little is known about the most effective occupational health and safety (OHS) interventions. Other reviews have examined the effectiveness of interventions for reducing or preventing upper extremity musculoskeletal conditions, (8), but these reviews (9-22) differ in the following ways:

- Focused on clinically-based interventions and therefore are not specific to workplace-based interventions (9,11-13,16,23)\
- Included a broader range of musculoskeletal outcomes and therefore are not specific to upper extremity musculoskeletal signs, symptoms, disorders, injuries, claims or lost time (17-22)
- Restricted to specific clinical disorders and populations [e.g. persons with carpal tunnel syndrome (14)]
- Focused on a specific industry/sector [e.g. nursing (21), computer users (18,19)].

Furthermore, some reviews allowed a wide range of methodological quality to contribute to the evidence synthesis. Design criteria of previous reviews included:

- Single group designs (i.e. studies with no control or comparison group) (8,17,20)
- Studies ranking "low" in methodological quality (8,11,12,17).

Additionally, some reviews did not use a "best evidence synthesis" or other standard evidence synthesis approaches (9,14,20).

Thus, stakeholders such as occupational health and safety professionals, ergonomic consultants and others are faced with making decisions without one evidenced-based review that:

- Uses more rigorous systematic review methods
    - Comprehensive database searches
    - Best evidence synthesis
    - No language restrictions.
- Takes a more comprehensive approach
    - Continuum from acute to chronic disorders
    - Across all categories of workplace interventions (e.g. engineering solutions, administrative techniques, personal protective equipment, pre-placement screening & examinations)
- Across all industries/sectors
- Include a wide-range of outcomes.

The systematic review process provides a structured methodology for evaluating the literature and synthesizing evidence regarding a wide range of biomedical and epidemiological questions, including prevention strategies (18,24-27). Such reviews also identify knowledge gaps in the existing literature. Specifically, in the current review, we seek to answer the following question: Do occupational health and safety interventions prevent upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time? Further, we seek to identify which specific types of interventions are effective.

1.1 Organization of the report

Following this introduction, readers will find:

- A detailed description of the methods used to search for and select relevant studies.
- Detailed descriptions of the methods used for quality assessment, data extraction and best evidence synthesis of quantitative studies.
- Results of the systematic review, including information about the number of studies found; the methodological quality observed; the types of interventions examined; and study characteristics.
- Results of the synthesis of evidence according to intervention categories.
- Discussion about the levels of evidence and recommendations for future occupational health and safety intervention research and evaluation on this topic.
- Conclusions about the current state of the peer-reviewed literature.

2.0 Materials and methods

Occupational health and safety intervention studies were reviewed using a systematic review process that was developed by the Cochrane Collaboration www.cochrane.org/admin/manual.htm, and adapted by the Institute for Work & Health (IWH) systematic review program.

A review team comprised of 14 researchers from the United States, Canada and Europe participated. Reviewers were identified based on their expertise in conducting epidemiologic or intervention studies related to upper extremity musculoskeletal disorders among workers, their experiences in conducting systematic reviews or their clinical expertise. Review team members had backgrounds in epidemiology, ergonomics, kinesiology, occupational medicine, physical therapy, safety engineering and information science.

The basic steps of the systematic review process are listed below. The review team used a consensus process throughout the review:

1) Formulate the research question and search terms.
2) Convene a stakeholder meeting to review research question, definitions, search terms and relevancy criteria.
3) Conduct the literature search and pool articles with those submitted by experts, ensure a majority of review team members' key articles have been captured by the search.
4) Conduct the review to exclude non-relevant studies.
5) Conduct the review to assess methodological quality of relevant articles.
6) Conduct the review to extract data from relevant articles that were identified for evidence synthesis.
7) Complete the evidence synthesis.
8) Convene a stakeholder meeting to review evidence synthesis and develop key messages.

The research question addressed was: **"Do occupational health and safety interventions prevent upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time?"**

To answer this question, we reviewed primary, secondary and tertiary prevention intervention studies conducted at worksites. For the purposes of this review, we used prevention definitions from *Last's Dictionary of Epidemiology* (28):

> Primary prevention is aimed at reducing the incidence of disease and other departures from good health. The recipients of primary prevention are persons who are free of clinical or sub-clinical illness. The goal is to prevent (i.e., reduce the risk of) these persons

from experiencing any adverse outcomes associated with the illness (i.e., any known adverse consequence of exposure, from mild symptoms all the way to disability and, in conditions other than musculoskeletal disorders, mortality).

Secondary prevention aims to reduce prevalence by early detection and prompt and effective intervention to correct departures from good health. The recipients of secondary prevention are those who have subtle or sub-clinical evidence of disease (i.e., not overtly ill, but not fully healthy - this is usually found with some kind of testing or evaluation). The goal is to prevent these individuals from progressing to more severe forms of illness, including clinical illness, disability, or any other adverse consequence of the disease or condition.

Tertiary prevention is aimed at reducing the number or the impact of complications of illness. The recipients of tertiary prevention are those with clinically apparent disease. The goal of tertiary prevention is to minimize impairment, disability, lost time, etc. (any known adverse consequence of clinical illness).

The inclusion of secondary and tertiary intervention studies was based on the following three assumptions:

- There are too few primary prevention intervention studies to warrant a systematic review.
- Secondary and tertiary prevention interventions represent an important source of information on what works to improve upper extremity MSD health in worksite samples.
- There will be important commonalities to intervention approaches across prevention types that may indicate critical leverage points for stakeholders.

Stakeholders encouraged this broad inclusive perspective. In addition, the stakeholders encouraged the review team to include non-randomized trials that met our methodological quality criteria.

In order to perform a well-defined literature search, we created definitions of the terms "workplace or work setting," "occupational health and safety interventions," and "upper extremity musculoskeletal disorders and injuries."

Workplace or work setting was defined as any location where a worker is performing his or her assigned work.

Occupational health and safety interventions were defined as any primary, secondary or tertiary occupational health and safety interventions designed

to reduce musculoskeletal symptoms, signs, disorders, injuries, claims and lost time. Interventions were defined broadly initially by using the traditional hazard control tiers of engineering controls, administrative controls and personal protective equipment use. A broad definition allowed for a more comprehensive literature search to identify all approaches currently used for the purpose of "intervention."

We excluded violence prevention programs where the primary goal was preventing injury resulting from violence as opposed to other mechanisms of musculoskeletal injury/illness. However, biomechanical interventions designed to reduce assaults and consequently musculoskeletal injuries were included. For example, Collins, et al. (2004) found reductions in assaults on staff as a result of mechanical lift devices where the primary outcome was musculoskeletal injury (29).

Furthermore, we did not include interventions that were not delivered in the workplace. This excludes all off-site treatments (i.e. physiotherapy clinics, work-hardening programs, back schools). All interventions that occurred at a worksite were included.

We included screening programs as an intervention. Pre-placement screening and examinations (e.g. nerve conduction testing, genetic testing) are some of the most widely used interventions despite having limited information on effectiveness. However, these procedures were only included if they were required by the workplace. These examinations were included regardless of whether or not the medical examination occurred at the workplace or off-site. We recognize that not all off-site programs were easily identified as mandated by the workplace.

Studies designed to examine productivity were only included if upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost-time outcomes had been analyzed. We excluded productivity studies if they did not include health outcome data.

Upper extremity musculoskeletal disorders and injuries were defined, for consistency with regulatory requirements as well as insurance purposes, as "musculoskeletal symptoms and signs or clinical diagnoses." These included injuries to or disorders of the muscles, tendons, ligaments, joint, nerves, blood vessels or related soft tissue including sprains, strains and inflammation. We included workers' compensation claims data and employer reports despite the validity and reliability vulnerabilities of these data sources. These data sources are important to stakeholders who use them to evaluate intervention usefulness. We recognize the importance of physical risk factors, such as muscle loading, as a plausible pathway. However, we excluded studies where changes in exposure to these physical factors were the only primary outcome without considering changes in musculoskeletal disorders and injuries. This approach eliminates having to review a vast

literature of laboratory studies. We excluded surgeries, cancers and pregnancy-related musculoskeletal symptoms, signs, disorders and diagnoses.

Upper Extremity included the following body locations – neck, shoulder, upper arm, elbow, forearm, wrist and hand (30). Excluded regions included the thoracic spine, lower extremity (including hip, knee, ankle and foot), lumbar spine and low back. Also excluded were studies that only reported total symptoms (i.e. total body symptom count).

The review team considered published or in-press peer-reviewed scientific articles. There were no language restrictions. Book chapters, dissertations and conference proceedings were excluded.

Stakeholder engagement

Stakeholders from Ontario's health and safety system were invited to two meetings to provide direction to and feedback on the review. A first meeting was held to solicit input related to the specifics of the research question, the literature search terms and how the findings from this review ought to be presented. During this feedback session, the stakeholders also received a presentation on the systematic review process. Seven stakeholders representing the WSIB, the Ontario Ministry of Labour and two provincial health and safety associations attended the two-hour meeting (*see Appendix A for a list of stakeholders*). The second meeting was held to determine the types of messages that would emerge from the review and to determine appropriate communication channels.

2.1 Literature search

The literature search was based on the research question and our definitions of work setting (or workplace), occupational health and safety interventions and upper extremity musculoskeletal health disorders and injuries. Key terms were identified and combined to search the following databases: MEDLINE, EMBASE, CINAHL, PsycINFO and Business Source Premier.

Search terms were identified for three broad areas: work setting terms, intervention terms, and health/claim outcome terms (*see Table 1*). The search categories were chosen to be exclusive within each area. The terms within the work setting and intervention categories were combined using a Boolean OR operator. The terms within the health/claim outcome category were divided into three subcategories: upper extremity terms, injury/disease terms, and specific upper extremity injury/disease terms. The terms within each subcategory were combined using the Boolean OR operator. The upper extremity subcategory was combined with the injury/disease subcategory terms using a Boolean AND operator and the result was then combined with the specific upper extremity injury/disease terms using a Boolean OR operator. The three main categories were then combined using a Boolean AND operator. A simplified example of this search would be: computer

workers AND workstation adjustments AND cumulative trauma disorders. This would identify an article that describes workstation adjustment interventions among computer workers that focuses on cumulative trauma disorders as the upper extremity musculoskeletal health outcome.

Table 1: Search terms
Search strategy: combined the three areas using a Boolean AND operator, and combined terms within each category and subcategory using a Boolean OR operator.

Work setting terms	work, worker, work site, workplace, work environment, employee, employer, employment, personnel, industry, firm, company, plant, factory, office, accountant, apprentice, blue collar worker, computer user, contractor, laborer, operator, retail, supervisor, white collar worker, millwright, material handler, temperature, pronation, supination, flexion, rotation, overhead, above shoulder, twisting, reach, lift
Intervention terms	intervention studies, OHS program, OSH program, safety, health and safety, accident prevention, back school, training, protection, education, ergonomic, manual lifting, people based safety, safety climate, safety culture, safety incentive program, safety training, prevention, supervisor training, organizational policies, organizational practices, safety climate, safety culture, people-oriented culture, workplace organization, disability management, return to work, behavior based, employee assistance program, onsite treatment interventions, modified work, modified job, modified task, work hardening, engineering design/redesign, injury prevention, injury assessment, injury control, rest breaks, exercise, occupational accidents, organizational practice, organizational policy, posture/postural, chair, primary prevention, prevention, protective clothing, protective devices, workstation adjustment, alternate pointing device/mouse, keyboards, arm support, lighting, workplace surveillance, machine guard, pre-placement screening, genetic screening, nerve conduction testing, pre-employment screening, radiographic screening, gloves, personal protective equipment, cleaning regimes, vibration, anti-fatigue mat, participatory ergonomics, participatory process, participatory committee, wrist guards, foot stools

Health/claim outcome terms	Upper extremity terms Upper extremity, neck, cervical, shoulder, arm, rotator cuff, elbow, forearm, wrist, hand, fingers, thumb AND Injury/disease terms amputation, burns, dislocations, lacerations, pain, soft tissue injuries, sprains and strains, wounds and injuries OR Specific upper extremity injury/disease terms neck injuries, neck pain, shoulder dislocation, shoulder injuries, shoulder pain, arm injuries, forearm injuries, wrist injuries, hand injuries, finger injuries, tendon injuries, musculoskeletal injuries, musculoskeletal system, arthralgia, bursitis, brachial plexus neuritis, carpal tunnel syndrome, causalgia, pathologic constriction, cubital tunnel syndrome, cumulative trauma disorders, De Quervain, epicondylitis, ganglion cysts, hand-arm vibration syndrome, musculoskeletal diseases, myofascial pain syndromes, neuralgia, neuritis, osteoarthritis, polyradiculoneuropathy, radiculopathy, Raynaud Disease, shoulder impingement syndrome, synovitis, tendinopathy, tennis elbow, tenosynovitis, tenovaginitis, tension neck syndrome, thoracic outlet syndrome, ulnar nerve compression syndrome, work-related upper extremity

Before the literature search, the review team identified a list of 50 "must-have" articles to test the face validity of our search. We discovered that our initial search was missing some specific index terms for the upper extremity and intervention categories. Once these terms were added, we captured 41 of the 50 articles from the "must-have" list. Of the nine not captured, two were not indexed in any of the databases searched, three were excluded because we limited our search to human subjects only and these three had not been indexed as human, and four were not indexed with any upper extremity and/or intervention terms. The review team considered the search valid.

The review team also contacted 42 content experts to solicit relevant articles that might not be identified by the search. Six experts responded and three suggested articles. Three of these articles (two review articles and one intervention article) had been accepted for publication. One study was an intervention paper in press. One study was in the planning stages. Therefore, only the three articles accepted for publication were included. While

conducting the systematic review, two members from our review team identified two potentially relevant articles that were in press [(31), Conlon 2008] subsequently these articles were added to our literature search as coming from content experts.

2.2 Level 1 - Selection for relevance

The inclusive search strategy captured many studies not relevant to our research question. A relevance review was designed to identify and exclude non-relevant studies as efficiently as possible. To accomplish this goal, reviewers read only the article title and abstract (when available). Article relevance (Level 1a) was based on responses to five questions (*see Table 2*). Reviewers entered responses for all levels of the process on commercially available review software (Systematic Review Software [SRS] www.trialstat.com). SRS allowed centralized article tracking and access.

If reviewers did not know how to answer a question, they were instructed to mark it as "unclear" (*see Appendix B for reviewer guide for Level 1a*). In such cases, the article would move forward to Level 1b where the full paper was obtained to determine the study's relevancy.

Table 2: Level 1a – Screening questions and the response that leads to exclusion*

Level 1a	
1. Did an occupational health and safety intervention occur?	No
2. Did the intervention occur in a work setting?	No
3. Is the article from peer-reviewed publication (in press or accepted for publication)?	No
4. Is the article a review, commentary, letter to the editor, editorial or two pages or less in length?	Yes
5. Is the outcome upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims or lost time (including Occupational Safety and Health Administration (OSHA) log data and workers' compensation claims data)?	No
*the given response to any one question excluded the article from further review	

In addition to the questions in Table 2, the review team felt that single group designs (i.e. no control or comparison group) and studies with only post-intervention measures (i.e. no pre-intervention measures) were fatally flawed for evaluating intervention effectiveness and thus should be excluded. Therefore, full articles were obtained for all studies passing Level 1a review plus one additional relevancy criteria was assessed for all articles still considered relevant (*see Question 2, Table 3*). The review team felt that the level of information needed to evaluate the article for study design was not often available in the title and abstract of an article and therefore this

relevancy question was moved to Level 1b (*see Appendix B for Level 1b guide to reviewers*).

Table 3: Level 1b – Screening questions and the response that leads to exclusion*

Level 1b	
1. Should the article have been excluded in Level 1a (title and abstract) review for any of the following reasons (*Refer to criteria 1-5 listed in Table 2*)?	Yes
2. Is the design a single group or a post-only study?	Yes
*the given response to any one question excluded the article from further review	

Articles at Level 1a were reviewed by individual members of the team, while two reviewed each article at Level 1b.

Since a single reviewer conducted the Level 1a review, there was a possibility for error. Therefore, a quality control (QC) check was done with an independent reviewer (QC reviewer).

The QC reviewer assessed a randomly chosen set of one per cent of the articles that were subjected to Level 1a review (n=140). The quality control check contained 70 studies that were not included at Level 1a and 70 studies that would continue on to subsequent review levels.

QC reviewer responses were entered into SRS software so they could be directly compared to a team member's responses. The QC reviewer disagreed with the exclusion category selected by the original reviewer for 26 of the 140 articles. In 15 of 26 cases (58 per cent), the QC reviewer excluded the study while the original reviewer included it. Therefore, the original reviewer was more likely to be inclusive than the QC reviewer. We did not consider over-inclusion a problem since the article would be reviewed at the next level for relevance by two team members.

There were 11 articles in which the QC reviewer included the article and the original reviewer excluded it. In all cases, the QC reviewer responded with "unclear" about some or all of the criteria. The QC reviewer was not part of the review process, and therefore not privy to decisions and approaches that were not captured in the reviewer guide. This likely contributed to the choice of "unclear". All these articles were reviewed and none were inappropriately excluded. Therefore, we concluded that the quality of the Level 1a review was acceptable.

2.3 Level 2 - Quality assessment

Relevant articles were moved forward for methodological quality assessment at the Level 2 review. The team developed quality assessment

questions and pilot tested them using two relevant articles. This resulted in the identification of 16 methodological criteria questions for assessing quality, which are shown in Table 4. Each article was independently reviewed by two team members.
To reduce bias, the same two members did not review all of the same articles. Instead, each reviewer was randomly paired with other team members. Reviewer pairs were required to reach consensus on all criteria. Where review pairs disagreed in their assessment, they were encouraged to resolve their disagreement through discussion. In cases where agreement could not be reached, a third reviewer was consulted to ensure consensus was obtained (*see Appendix C for the Quality assessment (QA) guide for reviewers*). Team members did not review articles they had consulted on, authored or co-authored.

Because each methodological criterion was not considered to contribute equally to study validity, the review team assigned weights *a priori* for each criterion. The three-point weighting ranged from "somewhat important" (1 point) to "very important" (3 points) (*see Table 4*).

Table 4: Level 2 - Quality assessment questions and weights

Question	Weight
1. Is the research question clearly stated?	2
2. Were comparison group(s) used?	3
3. Was an intervention allocation described adequately?	3
4. Was recruitment (or participation) rate reported?	2
5. Were pre-intervention characteristics described?	2
6. Was loss to follow-up (attrition) less than 35 per cent?	2
7. Did the author examine for important differences between the remaining and drop-out participants after the intervention?	2
8. Was the intervention process adequately described to allow for replication?	3
9. Were the effects of the intervention on some exposure parameters documented?	1
10. Was the participation in the intervention documented?	2
11. Were the upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and/or lost time outcomes described at baseline and at follow-up?	3
12. Was the length of follow-up three months or greater?	2
13. Was there adjustment for pre-intervention differences (minimum threshold of three important covariates include age, gender and primary outcome at baseline)?	3
14. Were the statistical analyses optimized for the best results?	3
15. Were all participants' outcomes analyzed by the groups to which they were originally allocated (intention-to-treat analysis)?	2
16. Was there a direct between-group comparison?	3

Methodological quality scores for each article were based on a weighted sum of 16 quality criteria. The highest possible weighted score was 41. Each article received a quality ranking score by dividing the weighted score by 41 and then multiplying by 100. The quality ranking score was used to group articles into three categories: high (more than 85 per cent), medium (50 to 85 per cent) and low (less than 50 per cent). The categories were determined by team consensus with reference to the review methodology literature (18). The Cochrane Manual http://www.cochrane.org/admin/manual.htm and AHRQ Guidelines http://www.ahrqu.gov/ were also used.
The quality ranking represents the review team's assessment of the internal, external, construct and statistical conclusion validity of each study (32). Each validity type is important in determining how much weight to give to any one study's reported effects. A lower overall quality ranking reflected greater uncertainty among the review team members in that the results were attributable to the intervention and not other on-going activities in the workplace or more broadly in society. Therefore, data extraction and evidence synthesis were only completed on the high and medium quality studies. This decision had the added benefit of comparability to other IWH systematic reviews.

2.4 Level 3 – Data extraction

Studies that moved forward to data extraction create the evidence base used for evidence synthesis. Prior to conducting the data extraction to build the evidence base, the review team considered issues that arose during the review. The review team agreed to:

- Look at studies where the methodological quality score placed the study in the high or medium category, but the reviewers who assigned quality scores indicated that it should not proceed (*see Appendix C, Quality assessment guide for reviewers, Question 17*).
- Look at studies that have been reviewed in previous IWH systematic reviews for large differences in quality ranking in this review compared to an earlier review.

The review team agreed to conduct sensitivity analyses of the evidence base for studies with small sample sizes and studies that did not control for covariates/confounders in the analyses, recognizing these were consistent concerns expressed by reviewers of methodological quality.

Following earlier reviews, any study that had a control group and did not do a direct statistical comparison between the intervention and the control groups would be excluded. A "direct statistical comparison" required a description of a statistical test (e.g. a chi square value) with a p-value, or presentation of confidence intervals. A statistical test was needed to provide statistical confidence that the observed intervention was not likely due to chance.

The problem resulting from single group studies (i.e. no control or comparison group) was discussed and it was noted that the analyses of such studies could not include between-group statistical comparisons. It was observed that studies with no comparison or control group had methodological quality scores of 50 to 60 per cent or less. Therefore, following other reviews, the team decided any study that did not have a control or comparison group would not be brought forward for data extraction.

The team developed standardized data extraction forms based on existing forms and data extraction procedures (18,19,33,34) (*see Appendix D for the data extraction guide for reviewers*). Extracted data were used to build summary tables to inform evidence synthesis and to develop our overall conclusions.

Data extraction was performed independently by two reviewers. Again, reviewer pairs were rotated to reduce bias. Team members did not review articles they had consulted on, authored or co-authored. Differences in data extracted between reviewers were identified and resolved by discussion. In cases where agreement could not be reached, a third reviewer was consulted to ensure consensus was obtained.

Reviewers extracted data on: year of study; type of work setting; study design; sample characteristics; length of follow-up; intervention characteristics; upper extremity MSD outcomes and whether those outcomes were self-reported, administrative or clinically-based; statistical analyses; covariates/confounders; and study findings (*see Table 5 for the complete list of data extraction questions*). The review team decided to record the effects reported for the longest follow-up period when considering study findings.

During the data extraction, reviewers reconsidered the methodological quality rating scores recorded in the Level 2 review. Any quality rating changes that the reviewer identified were proposed to the full team for consensus. Final ratings are documented in the methodological quality assessment table (*see Table 7*).

Initially, we planned to calculate the effect sizes for each article to evaluate the strength of associations uniformly (35-38). However, this approach was abandoned early in the process once we realized the amount of heterogeneity in outcome measures and study methods, and the lack of data necessary to calculate effect size in some studies.

Table 5: Data extraction (DE) items

1. Name of first author and year of publication.
2. State the research question(s)/objective(s).
3. List the jurisdiction where the study was completed.
4. Describe in what type of work setting(s)/workplace(s) that the study was conducted.
5. List the job titles/classification of those who participated in the study.
6. List the inclusion criteria for participants described in the study.
7. List the exclusion criteria described in the study.
8. What is the study design?
9. Was the study protocol reviewed and approved by a REB (Research Ethics Board)?
10. What type of prevention intervention did the study investigate?
11. Describe all interventions in the study.
12. Categorize the intervention.
13. Describe the process by which the intervention was selected/developed.
14. Was participation in the intervention documented?
15. Indicate the time period between the baseline measurement and all subsequent follow-up measurements.
16. Describe the overall study group.
17. Describe the intervention group(s).
18. Describe the referent group(s).
19. Were covariates/confounders evaluated for inclusion in the final analysis?
20. Did the investigators describe or characterize differences in covariates/confounders for those that participated in the study versus those that were invited but did not participate, if possible, by experimental group?
21. Did the investigators describe or characterize differences in covariates/confounders for those that participated in the study versus those that were lost to follow-up, if possible, by experimental group?
22. Were outcomes "actively" assessed by the investigators or "passively" assessed through administrative data sources?
23. Does the study use "administrative" records to collect measurements of upper extremity musculoskeletal health outcomes?
24. Does the study use self-report questionnaire records as completed by the employee to collect measurements of upper extremity musculoskeletal health outcomes?
25. Does the study use clinical exams or clinical records or clinical diagnoses as completed by the clinician to collect measurements of upper extremity musculoskeletal health outcomes?
26. Was the population studied "fixed" or "open"?
27. What sources were used to "count" employee injuries?
28. How were employee hours collected?
29. Indicate at what level employee hours were ascertained and/or estimated.
30. Did the study discuss how researchers handled any of the following special issues related to administrative record keeping: temporary or contract employees; employees who floated between units/departments; turnover rate; re-injury to the same employee?
31. Were injury rates calculated?
32. If outcome rates were calculated, list the equation(s).
33. Check all upper-extremity regions where symptoms were ascertained by questionnaire.
34. Check all upper-extremity regions where specific clinical disorders were ascertained by physical examination or laboratory test.
35. Was blinding of physical assessment done?
36. Was a standard protocol used for the clinical exams?
37. Please check the types of final analyses done for testing observed effects of the

intervention.
38. Describe for each outcome (upper extremity musculoskeletal) the observed intervention effect.
39. Were additional statistical analyses conducted to increase your confidence in the observed effects?
40. Remark on the findings or enter information that is unique about the study that may not be adequately captured in the other data extraction questions.

The following general guidelines were used to present findings:

- Present findings as the authors did
- When only one global statistical test of the impact of multiple interventions on upper extremity musculoskeletal (MSK) effects was conducted, this was presented as "all interventions"
- If a reviewed study did not have an upper extremity MSK primary outcome but an upper extremity MSK outcome data was reported, we included the evidence in the synthesis
- When specific upper extremity MSK outcome data values were not reported, values were abstracted from figures.

Decision rules were developed to present findings when more than one outcome was used to evaluate the intervention:

- Upper extremity MSK outcome effects described as improvements were noted as "positive"
- Upper extremity MSK outcome effects described as deteriorations were noted as "negative"
- Upper extremity MSK outcome effects described as not significant were noted as "no effect" and the direction of change, if any, was indicated
- Between-group upper extremity MSK outcome effect comparisons (e.g. intervention versus control) were presented where study design allowed
- Where no statistical tests were presented for the observed upper extremity MSK outcome effects, this was noted in parentheses
- If there was a discrepancy about upper extremity MSK outcome effects between statements or tests in the abstract and results, the reviewers relied on the results.

2.5 Evidence synthesis

The heterogeneity in methodological quality required the use of a synthesis approach adapted from Slavin and others (24,33,39,40) known as "best evidence synthesis." This approach allows consideration of the article's quality, the quantity of articles using the same prevention strategy and the consistency of the findings (*see Table 6*). "Quality" refers to the methodological strength of the studies as determined in quality assessment. "Quantity" refers to the number of studies that provides evidence on the

same intervention category. “Consistency” refers to the similarity of results observed across the studies. A strong level of evidence exists when there are three high quality studies with convergent results.

Our evidence synthesis guidelines were adapted from other IWH prevention intervention reviews (18,33,40). While the review team first used the evidence synthesis to answer the fundamental question posed: “Do occupational health and safety interventions have an effect on upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time among workers?”, evidence synthesis was also conducted for specific prevention and disability management programs and practices represented in the literature.

In synthesizing evidence, we needed to develop decision rules for use with studies that used more than one outcome to evaluate an intervention. A study with any positive results and no negative results on a single intervention was classified as a *positive effect* study. A study with both positive effects and no effects was also classified as a *positive effect* study (e.g. there was a positive effect on one outcome such as shoulder pain, but no effect on another outcome, such as neck pain). A study with only no effects was classified as a *no effect* study. A study with any negative effects was classified as a *negative effect* study.

Synthesis of the reviewed evidence on a particular intervention category was ranked on the following scale: strong evidence; moderate evidence; limited evidence; mixed evidence; insufficient evidence (*see Table 6*). In all cases, the review team reached consensus on the evidence synthesis conclusions.

Working with our stakeholders, the following terminology for messages was agreed upon. These messages correspond to the particular levels of evidence (*see Table 6*). A strong level of evidence results in “recommendations” for practical workplace application. A moderate level of evidence leads to “practice considerations” or practices to be considered for workplace application.

Table 6: Best evidence synthesis guidelines

Level of Evidence	Minimum quality	Minimum quantity	Consistency	Terminology for messages
Strong	High (>85%)	Three	Three high quality studies agree. If more than three studies, ¾ of the medium and high quality studies agree.	Recommendations
Moderate	Medium (50-85%)	Two high quality OR Two medium quality and one high quality	Two high quality studies agree. OR Two medium quality studies and one high quality study agree. If more than three studies, more than □ of the medium and high quality studies agree.	Practice Considerations
Limited	Medium (50-85%)	One high quality OR Two medium quality OR One medium quality and one high quality	If two studies (medium and/or high quality), agree. If more than two studies, more than ½ of the medium and high quality studies agree.	
Mixed	Medium and high	Two	Findings from medium and high quality studies are contradictory.	
Insufficient	No high quality studies, only one medium quality study, and/or any number of low quality studies.			

3.0 Results

3.1 Literature search and selection for relevance

We identified 20,100 articles using the search terms listed in Table 1. After different databases were merged, duplicate articles were removed and the articles from content experts were included, 15,279 articles remained (*Figure 1*).

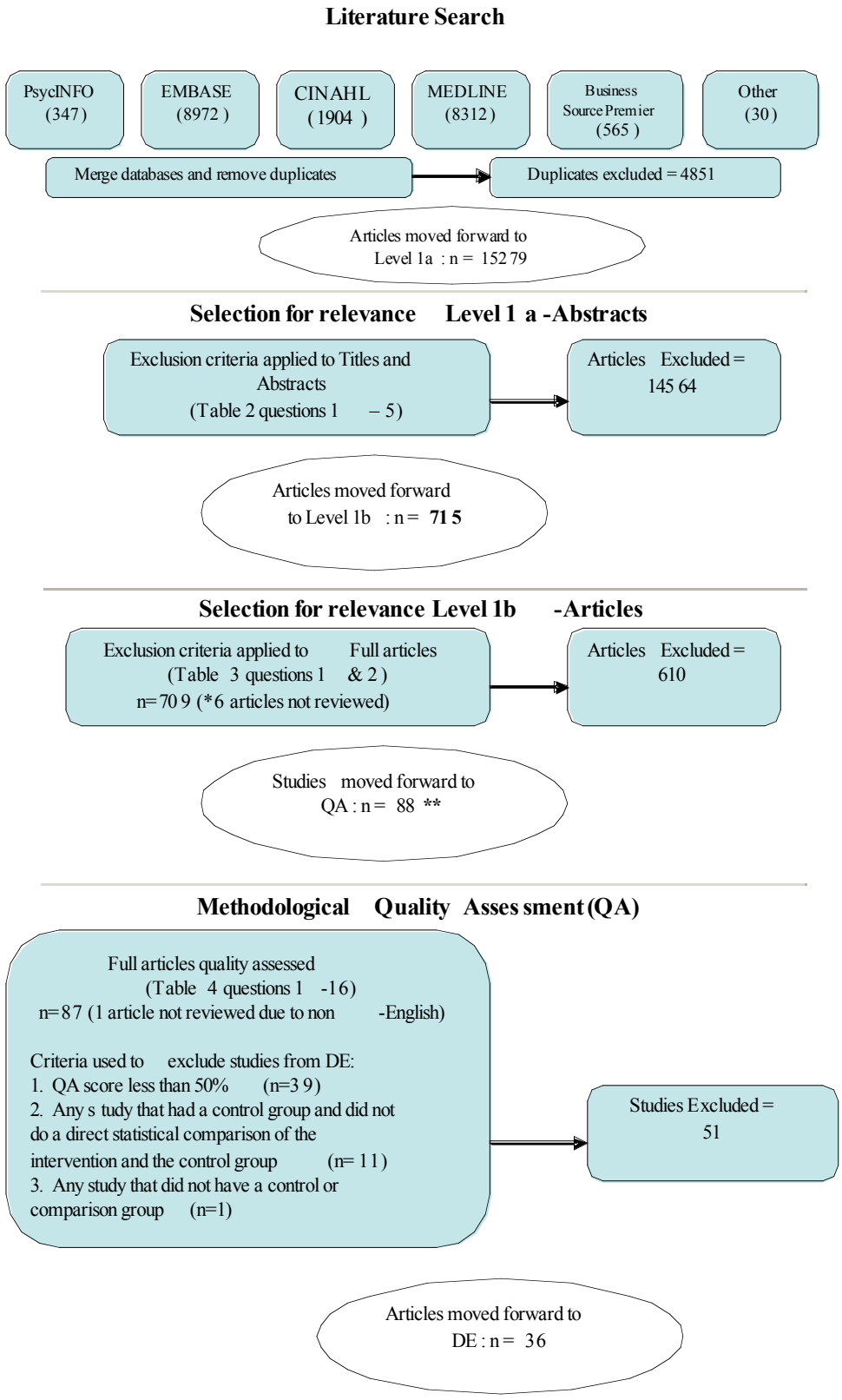
A total of 14,564 articles were excluded during the Level 1a review for not meeting the inclusion criteria (*refer to Table 2 for criteria*).

A total of 715 articles proceeded to Level 1b review. Using the exclusion criteria in Tables 2 and 3, 610 additional articles were dropped (*for more details about articles excluded by Level 1 criteria, see Appendix E*). Six articles* were not reviewed because we were unable to find a reviewer for these non-English articles.

Consequently, 88 studies (99 articles) proceeded to Level 2 methodological quality assessment. Eleven articles** were grouped with other articles that described results from the same study. Eighty-seven studies were reviewed by two reviewers using the quality assessment questions in Table 4. One non-English study (Czech language) was not reviewed for methodological quality (Hladky 1998).

** Aaras 2001 (Primary reference) with Aaras 1998; Aaras 1999 (Primary reference) with Aaras 2001 and Aaras 2002; Horgen 2005 (Primary reference) with Konarska 2005, Dainoff 2005 and Aaras 2005; Bohr 2000 (Primary reference) with Bohr 2002; Martin 2003 (Primary reference) with Gatty 2004; Lagerstrom 1998 (Primary reference) with Lagerstrom 1997; Laing 2007 (Primary reference) with Laing 2005; Vink 1997 (Primary reference) with Vink 1995

Figure 1: Flowchart of systematic review process



3.2 Methodological quality assessment

The 87 studies that met our relevance criteria were assessed for methodological quality using 16 quality criteria (*see Table 7*). Studies that met the following criteria were included in evidence synthesis: 1) rank of high or medium quality; and 2) studies that had a control group/comparison group and had a direct statistical comparison of the intervention and the control/comparison group.

High quality studies

Fourteen studies were of high quality (more than 85 per cent) (Conlon 2008, Faucett 2002, Feuerstein 2004, Gerr 2005, Horneij 2001, Ketola 2002, Lundblad 1999, Martin 2003, Pillastrini 2007, Rempel 1999, Rempel 2006, Rempel 2007, Sjogren 2005, Voerman 2007). The high quality studies were quite consistent in the quality scores meeting between 13 and 16 of the 16 criteria.

The studies did not consistently document the effects of the intervention on some exposure parameters (seven of 14). The studies also did not consistently examine for important differences between remaining and drop-out participants after the intervention; and loss to follow-up was greater than or equal to 35 per cent (four of 14 for both criteria).

Medium quality studies

We classified 34 studies as medium quality (range 50 to 85 per cent) (Aaras 1999, Aaras 2001, Alexandre 2001, Bohr 2000, Brisson 1999, Cook 2004, Coury 1998, Fredriksson 2001, Galinsky 2000, Galinsky 2007, Greene 2005, Hedge 1999, Kamwendo 1991, Laing 2007, Leclerc 1997, Lemstra 2003, Lin 2007, Lintula 2001, Luijsterburg 2005, McLean 2001, Mekhora 2000, Nevala-Puranen 2003, Peper 2004, Ripat 2006, Takala 1994, Thomas 1993, Tittiranonda 1999, Tsauo 2004, van den Heuvel, van der Molen 2004, Veiersted 2007, Wahlstedt 2000, Whysall 2006, Yassi 2001). These studies generally scored well on the following criteria: stating the research question (34/34); using comparison (control) group(s) (33/34); describing pre-intervention characteristics (31/34); describing the intervention process adequately to allow for replication (30/34); and describing upper extremity musculoskeletal outcomes at baseline and follow-up (34/34).

However, fewer of these studies met the following criteria: reporting recruitment (or participation) rate (13/34); examining for important differences between the remaining and drop-out participants after the intervention (13/34); optimizing statistical analyses for the best results (12/34); and adjusting for pre-intervention differences (minimum threshold of three important covariates include age, gender and primary outcome at baseline) (8/34).

Studies not moving forward to data extraction

We classified 39 studies as quality not sufficient to continue to data extraction (less than 50 per cent) (Aaras 1987, Aaras 1994, Aiba 1999, Bayeh 1999, Bernacki 1999, Bru 1994, Caple 2001, Chatterjee 1992, Christmansson 1999, Cole 2006, Daerga 2004, Dalkilinc 2002, Demure 2000, Evanoff 1999, Fernstrom 1999, Feuerstein 2000, Grunert 1990, Haig 1990, Herbert 2001, Horgen 2005, Jensen 2007, Jones 1997, Lagerstrom 1998, Lewis 2001, Li 2004, McKenzie 1985, Moore 1994, Nelson 1998, Orgel 1992, Ronald 2002, Shute 1984, Silverstein 1988, Stevenson 2000, Torma-Krajewski 2007, Trevelyan 2001, Vasseljen 1995, Vink 1997, Vink 1997, Wergeland 2003).

All of these studies described upper extremity musculoskeletal outcomes at baseline and follow-up. Most of these studies had a length of follow-up that was three months or greater (35/39). Few of these studies had a comparison (control) group(s) (8/39), of which only one study used random allocation (Bru 1994).

Table 7: Methodological quality assessment (QA) (n=87)

	Methodological Criteria: Quality Assessment Question #																Quality Score	Percentage Quality Score
	Research Question	Comparison group	Intervention allocation	Recruitment rate reported	Pre-intervention characteristics	Loss to follow-up < 35%	Differences between remaining & drop out	Intervention described for replication	Intervention on some exposure parameters documented	Participation in intervention	Upper extremity outcomes described at baseline & follow-up	Length of follow-up 3 months or greater	Adjustment for pre-intervention differences	Statistical analyses optimized	Intention-to-treat analysis	Direct between-group comparison		
Criteria code*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Weight	2	3	3	2	2	2	2	3	1	2	3	2	3	3	2	3		
Max score	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	41	
Author, year																		
High Quality Ranking (H) (14 studies)																		
Pillastrini, 2007	1	1	2	1	1	1	1	1	1	1	1	1	1	1	1	1	41	100%
Rempel, 2006	1	1	2	1	1	1	1	1	0	1	1	1	1	1	1	1	40	98%
Faucett, 2002	1	1	2	1	1	1	0	1	1	1	1	1	1	1	1	1	39	95%
Horneij, 2001	1	1	2	1	1	0	1	1	1	1	1	1	1	1	1	1	39	95%
Ketola, 2002	1	1	2	1	1	1	1	1	1	1	1	1	1	1	0	1	39	95%
Rempel, 1999	1	1	2	1	1	1	1	1	0	1	1	1	1	1	0	1	38	93%
Rempel, 2007	1	1	2	1	1	1	0	1	0	1	1	1	1	1	1	1	38	93%
Gerr, 2005	1	1	2	1	1	0	0	1	1	1	1	1	1	1	1	1	37	90%
Sjogren, 2005	1	1	2	1	1	1	1	1	0	1	1	1	0	1	1	1	37	90%
Feuerstein, 2004	1	1	2	1	1	1	1	1	1	0	1	1	0	1	1	1	36	88%
Lundblad, 1999	1	1	2	1	1	0	1	1	1	1	1	1	0	1	1	1	36	88%
Martin, 2003	1	1	2	0	1	1	1	1	0	1	1	0	1	1	1	1	36	88%
Voerman, 2007	1	1	2	0	1	1	1	1	0	0	1	1	1	1	1	1	36	88%
Conlon, 2008	1	1	2	1	1	0	0	1	0	1	1	1	1	1	1	1	36	88%
Criteria met	14	14	14	12	14	10	10	14	7	12	14	13	11	14	12	14		
Per cent criteria met	100%	100%	100%	86%	100%	71%	71%	100%	50%	86%	100%	93%	79%	100%	86%	100%		

Medium Quality Ranking (M) (34 studies)																		
Cook, 2004	1	1	2	1	1	1	1	1	1	1	1	0	0	0	1	1	33	80%
Luijsterburg, 2005	1	1	1	1	1	1	0	1	1	1	1	1	0	1	1	1	33	80%
Leclerc, 1997	1	1	0	1	1	1	0	1	0	1	1	1	1	1	1	1	32	78%
Galinsky, 2007	1	1	2	1	1	0	0	1	0	1	1	0	0	1	1	1	31	76%
Greene, 2005	1	1	2	0	1	0	1	1	1	1	1	1	0	0	1	1	31	76%
Lin, 2007	1	1	1	0	1	1	1	1	1	0	1	1	0	1	1	1	31	76%
Ripat, 2006	1	1	2	0	1	1	1	1	1	1	1	1	1	0	0	0	31	76%
Kamwendo, 1991	1	1	1	1	0	1	1	1	1	1	1	1	0	0	1	1	30	73%
Lintula, 2001	1	1	2	0	1	0	0	1	1	1	1	0	0	1	1	1	30	73%
Takala, 1994	1	1	2	1	1	1	0	1	0	1	1	0	1	0	1	0	30	73%
Galinsky, 2000	1	1	1	0	1	1	0	1	1	1	1	0	0	1	1	1	29	71%
Tittiranonda, 1999	1	1	2	0	1	1	0	1	1	1	1	1	0	0	0	1	29	71%
Brisson, 1999	1	1	2	1	1	1	0	1	1	0	1	1	0	0	1	0	28	68%
McLean, 2001	1	1	2	0	0	0	1	1	1	1	1	0	0	1	0	1	28	68%
Lemstra, 2003	1	1	1	0	1	0	0	1	0	0	1	1	1	1	0	1	27	66%
Veiersted, 2007	1	1	2	1	1	0	0	1	1	0	1	0	0	0	1	1	27	66%
Aaras, 1999	1	1	2	0	1	0	1	1	0	0	1	1	1	0	0	0	26	63%
Bohr, 2000	1	1	2	0	1	1	0	0	1	0	1	1	0	0	1	1	26	63%
Hedge, 1999	1	1	2	0	1	1	0	1	1	1	1	0	0	0	1	0	26	63%
van den Heuvel, 2003	1	1	2	0	1	1	0	1	0	1	1	0	0	0	0	1	26	63%
Van Der Molen, 2004	1	1	2	0	1	0	0	1	1	0	1	0	0	1	0	1	26	63%
Alexandre, 2001	1	1	1	0	1	1	1	1	0	0	1	0	1	0	1	0	25	61%
Peper, 2004	1	1	0	0	1	0	0	1	1	1	1	0	1	1	0	1	25	61%
Wahlstedt, 2000	1	1	1	1	1	1	0	0	1	0	1	1	1	0	1	0	25	61%
Whysall, 2006	1	1	1	0	1	1	1	1	1	0	1	1	0	0	1	0	25	61%
Laing, 2007	1	1	1	1	1	0	0	1	1	0	1	1	0	0	0	1	24	59%
Aaras, 2001	1	1	1	0	1	0	1	1	1	0	1	1	0	0	1	0	23	56%
Mekhora, 2000	1	1	1	1	1	1	0	1	0	0	1	1	0	0	0	0	22	54%
Thomas, 1993	1	1	0	0	1	1	1	0	0	0	1	0	0	1	1	1	22	54%
Tsauo, 2004	1	1	1	0	1	1	1	1	0	0	1	0	0	0	1	0	22	54%
Yassi, 2001	1	1	1	0	0	1	0	1	1	0	1	1	0	0	0	1	22	54%
Coury, 1998	1	0	0	1	1	1	1	1	0	1	1	0	0	1	0	0	21	51%
Fredriksson, 2001	1	1	0	1	1	0	0	1	1	0	1	1	0	0	0	1	21	51%
Nevala-Puranen, 2003	1	1	1	0	1	1	0	0	1	0	1	1	0	0	0	1	21	51%
Criteria met	34	33	30	13	31	22	13	30	23	16	34	19	8	12	20	22		
Per cent criteria met	100%	97%	88%	38%	91%	65%	38%	88%	68%	47%	100%	56%	24%	50%	59%	65%		

Quality not sufficient to continue to data extraction (39 studies)																		
Herbert, 2001	1	0	0	1	1	1	0	1	1	0	1	1	0	1	0	0	20	49%
Lewis, 2001	1	0	0	1	1	0	1	1	1	0	1	1	0	1	0	0	20	49%
Li, 2004	1	0	0	1	0	0	1	1	1	1	1	1	0	1	0	0	20	49%
Nelson, 1998	1	1	0	1	0	0	0	1	0	0	1	1	0	1	1	0	20	49%
Vasseljen, 1995	0	0	1	0	1	1	1	1	0	1	1	0	0	0	0	1	20	49%
Wergeland, 2003	1	1	0	0	1	1	0	0	1	1	1	1	0	0	0	1	20	49%
Bru, 1994	1	1	1	1	1	1	0	0	0	0	1	1	0	0	0	0	19	46%
Jensen, 2007	1	0	0	1	1	1	0	1	1	1	1	1	0	0	0	0	19	46%
Aaras, 1987	1	1	0	0	1	0	0	0	1	1	1	1	0	0	0	1	18	44%
Demure, 2000	1	0	0	1	1	1	1	0	1	1	1	1	0	0	0	0	18	44%
Silverstein, 1988	1	0	0	1	1	1	0	1	0	1	1	1	0	0	0	0	18	44%
Bayeh, 1999	0	1	0	0	1	1	0	1	0	0	1	1	0	0	1	0	17	41%
Fernstrom, 1999	1	0	0	0	1	1	1	0	1	0	1	1	0	1	0	0	17	41%
Trevelyan, 2001	0	0	0	1	1	1	0	1	1	1	1	1	0	0	0	0	17	41%
Christmansson, 1999	1	0	0	1	1	1	0	1	0	0	1	1	0	0	0	0	16	39%
Orgel, 1992	0	0	0	1	1	1	0	0	0	1	1	1	0	1	0	0	16	39%
Stevenson, 2000	1	0	0	1	1	0	0	1	0	1	1	1	0	0	0	0	16	39%
Vink, 1997	1	1	0	1	0	0	0	1	1	0	1	1	0	0	0	0	16	39%
Evanoff, 1999	1	0	0	0	1	0	0	1	0	0	1	1	0	1	0	0	15	37%
Cole, 2006	1	0	0	1	1	0	0	0	1	1	1	1	0	0	0	0	14	34%
Lagerstrom, 1998	1	0	0	1	1	0	0	1	0	0	1	1	0	0	0	0	14	34%
Torma-Krajewski, 2007	1	0	0	1	1	0	0	1	0	0	1	1	0	0	0	0	14	34%
Daerga, 2004	1	0	0	1	1	1	0	0	0	0	1	1	0	0	0	0	13	32%
Feuerstein, 2000	1	0	0	0	1	0	0	1	1	0	1	1	0	0	0	0	13	32%
Grunert, 1990	1	1	0	0	0	0	0	1	0	0	1	1	0	0	0	0	13	32%
Shute, 1984	0	1	0	1	0	1	1	0	1	0	1	0	0	0	0	0	13	32%
Vink, 1997	1	0	0	0	1	0	0	1	1	0	1	1	0	0	0	0	13	32%
Haig, 1990	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	12	29%
Ronald, 2002	1	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	12	29%
Horgen, 2005	1	0	0	0	1	1	0	0	1	0	1	1	0	0	0	0	12	29%
Aiba, 1999	1	0	0	0	0	0	0	1	1	0	1	1	0	0	0	0	11	27%
Dalkilinc, 2002	1	0	0	0	1	0	0	0	1	0	1	0	0	1	0	0	11	27%
Caple, 2001	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	10	24%
Jones, 1997	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	10	24%
McKenzie, 1985	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	10	24%
Moore, 1994	1	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	10	24%

Aaras, 1994	1	0	0	0	1	0	0	0	1	0	1	0	0	0	0	0	8	20%
Bernacki, 1999	0	0	0	0	0	0	0	1	0	0	1	1	0	0	0	0	8	20%
Chatterjee, 1992	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	5	12%
Criteria met	30	8	2	18	29	15	6	26	18	11	39	35	0	8	2	3		
Per cent criteria met	77%	21%	5%	46%	74%	38%	15%	67%	46%	28%	100%	90%	0%	21%	5%	8%		

*Refer to Table 4 for the quality assessment criteria

Note: highlighted in grey are studies that were excluded from data extraction for the following reasons: 1) no control or comparison group or 2) had a control group and did not do direct statistical comparison of the intervention and the control group.

3.3 Data extraction

Data extraction and evidence synthesis were completed on studies that: 1) were ranked as high or medium in quality; 2) had a control or comparison group; and 3) had a direct statistical comparison of the intervention and the control group.

One medium quality study did not have a control or comparison group (Coury 1998). Eleven medium quality studies had a control or comparison group, but did not include a direct statistical comparison of the intervention and control group (Aaras 1999, Aaras 2001, Alexandre 2001, Brisson 1999, Hedge 1999, Mekhora 2000, Ripat 2006, Takala 1994, Tsauo 2004, Wahlstedt 2000, Whysall 2006). In total, 36 studies were included in data extraction and evidence synthesis.

Intervention categories

The review team reached consensus on the intervention categories shown in Table 8.

There were 19 distinct intervention categories examined in the 36 studies.

- Exercise – four studies
- Ergonomics training & exercise – three studies
- Biofeedback training – three studies
- Cognitive behavioural training – one study
- Job stress management training – two studies
- Workstation adjustment – four studies
- Ergonomics training – four studies
- Ergonomics training and workstation adjustment – one study
- Alternative keyboards – two studies
- Alternative pointing devices – two studies
- Arm supports – three studies
- New chair – one study
- Rest breaks – four studies
- Rest breaks and exercise – one study
- Participatory ergonomics – one study
- Broad-based MSK injury prevention program – one study
- Miscellaneous work redesign – four studies
- Multi-component patient handling – one study
- Prevention strategies and physical therapy – one study

Fifteen studies examined the effectiveness of more than one intervention (Lundblad 1999, Kamwendo 1991, Faucett 2002, Horneij 2001, Gerr 2005, Ketola 2002, Bohr 2000, Tittiranonda 1999, Conlon 2008, Rempel 2006, Lintula 2001, Rempel 2007, McLean 2001, van den Heuvel 2003, Yassi 2001). Seven of these studies included interventions that were classified in different intervention categories (Lundblad 1999, Kamwendo 1991, Faucett 2002, Horneij 2001, Conlon 2008, Rempel 2006, van den Heuvel 2003). Many intervention categories included only one study (n=7). Therefore, this

explains the overall number of studies across the intervention categories being greater than the number of included studies (n=36).

Study designs

Our final set of studies included 23 randomized trials, eight non-randomized trials and five cross-over or delayed intervention designs. All of the high quality studies (n=14) and 13 (of 22) medium quality studies were randomized trials.

Type of injury prevention

Nine studies were primary prevention trials and eight were secondary prevention trials. Fifteen studies were both primary and secondary prevention trials. Two studies were both secondary and tertiary prevention trials. Two studies were primary, secondary and tertiary prevention trials.

Table 8: Description of interventions used in data synthesis
(Note: Intervention category column – Intervention categories with more than one aspect to the intervention, the intervention characteristics are connected with the "&" symbol. In studies with more than one intervention category, the intervention categories are separated by a comma.)
(I = Intervention, C = Control)

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
Ergonomics training & exercise, Exercise	Lundblad 1999	High	I_1: physiotherapy: 50 minutes twice a week (5 to 8 per group) for 16 weeks. Included training on postural awareness, stabilization exercises, relaxation techniques, lifting techniques and exercise training (included strength, coordination, endurance and flexibility training). Also received home exercise program. I_2: exercises according to Feldenkrais methods (includes sensory awareness of pattern of movement, aim to increase body awareness, coordination and control). Individual instruction four times and in a group (7 to 8 subjects/group) 12 times. Also received audiotapes with a total of eight exercises. Intervention lasted 50 minutes/week and subjects performed home exercises. C: no intervention.	Randomized trial	Secondary
Exercise	Sjogren 2005	High	I: physical exercise "progressive light resistance training" in department's own training facilities under the guidance of a physiotherapist in group sessions (20 minutes duration) over 15 weeks. Training sessions (about six minutes per session) in three five-week intervals – first interval: training once per workday, second and third intervals: one to two times per workday, or about seven to eight times per week). C: no intervention There were two groups. One group underwent the 15-week intervention followed by the 15-week non-intervention (I_1C). The other group underwent the process in the reverse order (I_2C).	Randomized cross-over	Secondary
Exercise, Ergonomics training & exercise	Kamwendo 1991	Medium	I_1: traditional neck school (four hours): four trainings by a physiotherapist on active and stretching exercises and muscle relaxation. I_2: traditional neck school plus reinforcement (two hours): physiotherapist visited the workplace to discuss ergonomic changes and provided written instructions, plus a psychologist interviewed the user to develop a personal coping strategy. C: no intervention.	Randomized trial	Secondary
Biofeedback training, Cognitive behavioural training	Faucett 2002	High	I_1: muscle learning therapy (MLT) that used sEMG (Electromyographic) feedback and operant conditioning to decrease muscle tension. I_2: education (by an occupational health nurse) using adult learning and cognitive behavioural techniques in small group discussions to advance worker's capabilities for symptom and stress management and problem	Randomized trial	Primary

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
			solving. C: no intervention.		
Biofeedback training	Thomas 1993	Medium	I: biofeedback training (audible EMG biofeedback using Pocket Ergometer™ Model PE102 with electrodes placed on forearm extensor and flexor muscles) to discourage awkward hand postures and exertion of excessive force with fingers. Used device for one hour per day. C: no intervention.	Non-randomized trial	Primary and secondary
Biofeedback training	Voerman 2007	High	I: ergonomic counseling on workstation adjustments via weekly visits by therapist (physiotherapist, health scientists) for four weeks. First visit comprised an ergonomic workplace investigation of risk inventory and discussions with the worker about possible improvements. Workstation adjustments focused on modifying the existing workstation (no new equipment). Remaining visits used to further discuss the ergonomic aspects and consequences of ergonomic adjustments. In addition, workers received ambulant myofeedback training (consisted of shoulder/neck relaxation methods to reduce the amount of EMG inactivity recorded and training in a muscle reset procedure). C: ergonomic counseling on workstation adjustments via weekly visits by therapist (physiotherapist, health scientists) for four weeks. First visit comprised an ergonomic workplace investigation of risk inventory and discussions with the worker about possible improvements. Workstation adjustments focused on modifying the existing workstation (no new equipment). Remaining visits used to further discuss the ergonomic aspects and consequences of ergonomic adjustments.	Randomized trial	Secondary
Job stress management training	Feuerstein 2004	High	I: worksite checklist evaluation by a health professional, workstation adjustments (no new equipment), stretching exercises and access to an ergonomics information website (ErgoClinic). In addition, they received an interactive job stress management education during two 70-minute meetings held two weeks apart followed by an email with a healthy computing tip every two weeks. C: worksite checklist evaluation by health professional, workstation adjustments (no new equipment), stretching exercises and access to the ErgoClinic website.	Randomized trial	Secondary
Job stress management training, Exercise	Horneij 2001	High	I_1: individually designed physical training program based on the results of a baseline screening physical examination. Exercises included: posture, balance, muscular endurance (for back, neck, abdominal, shoulder), functional exercises, stretching exercises, cardiovascular fitness exercises. Advised to perform as often as possible and at least twice a week. I_2: Stress management program based on group instruction sessions focused on "perceived stress induced by lack of social support, low decision latitude/work control, and perceived high psychological work load." Each group, consisting of five to 12 subjects, met seven times over seven weeks, each time for 1.5 hours. In addition, two follow-ups	Randomized trial	Primary and secondary

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
			were carried out at three and six months. Meetings "covered both theory and practice." C: no intervention.		
Workstation adjustment	Gerr 2005	High	I_1: training and workstation adjustments based on protective factors identified from prior studies. I_2: training and workstation adjustments based on OSHA, NIOSH and private industry standards. C: no instruction, but received the same visits from the study staff.	Randomized trial	Primary
Workstation adjustment (high I_2 & low I_1 intensity)	Ketola 2002	High	I_1: ergonomic checklist and evaluated and adjusted their workstations with a physical therapist. New forearm and wrist rests were provided if needed. I_2: same ergonomic checklist and attended a one-hour group training session (two to six persons) on ergonomics and rest breaks. C: leaflet on musculoskeletal health and VDT use.	Randomized trial	Secondary
Workstation adjustment	Pillastrini 2007	High	I: individual workstation adjustments by trained/expert physical therapist, 30 minutes per individual at baseline and five to 10 minutes twice a month for five months. Also received an informative brochure about VDT and MSDs. C: informative brochure about VDT and MSDs.	Randomized trial	Primary and secondary
Workstation adjustment	Cook 2004	Medium	I: education about workstation set-up and working posture and workstations were adjusted to support the forearm on the desk surface (no new equipment). Participants were monitored for the first few hours to ensure that they were not adopting postures of trunk flexion, shoulder elevation or increased wrist extension. C: education about workstation set-up and working posture and, where required, adjustments to desk, chair and monitor height were made according to Australian standards.	Randomized trial	Primary and secondary
Ergonomics training (Traditional ergonomics training I_1, Participatory ergonomics training I_2)	Bohr 2000	Medium	I_1: one-hour training session consisting of lecture and handouts about office ergonomics. I_2: two-hour participatory training session with problem solving. C: no intervention.	Randomized trial	Primary and/or secondary (In the absence of stated inclusion and exclusion criteria, it is not possible to determine. If the majority of participants were not clinically ill, then it was primary and/or

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
					secondary prevention.)
Ergonomics training	Greene 2005	Medium	I: active ergonomics training consisting of two, three-hour training sessions in one week. IC: delayed intervention after two weeks of follow-up. Note: "After participants were randomly assigned to [intervention] groups, the physical proximity of participant work location in the intervention and control groups was assessed. To minimize diffusion of treatment effects, participants from the same work location were assigned to the same [intervention] group." So, although the word "randomly" was used, it appears that some kind of cluster grouping was then established with methods that are not provided.	Randomized trial with delayed intervention (*see note in intervention description section*)	Primary and secondary
Ergonomics training	Peper 2004	Medium	I: training of six weekly two hour group sessions in ergonomic principles, psychophysiological awareness and control, sEMG practice at the workstation. C: no intervention.	Randomized trial	Primary
Ergonomics training	Veiersted 2007	Medium	I_1: written information on ergonomic recommendations formulated in cooperation with experienced hairdressers (take breaks, relax neck and shoulders, reduce work with elevated arms, check arm position in a mirror, use helping devices). This was followed by a visit by an occupational therapy student who provided education on the background of the five recommendations and gave them a pamphlet. I_2: written information (same as I_1) plus personal follow-up with a demonstration and discussion of each recommendation (10 minutes).	Randomized trial	Primary and secondary
Ergonomics training & workstation adjustment	Martin 2003 (and Gatty 2004)	High	I: individual training for one hour per week for four weeks in body mechanics, workstation adjustments and task modification. C: no intervention	Randomized trial	Primary
Ergonomics training & exercise	Nevala-Puranen 2003	Medium	I_1: redesign of workstations (included placing the VDU workstation in the corner of the room, new worktables allowing support to entire forearms and hands-on table, new adjustable chair, more free table space, screens placed below the worker's eye level, holder for papers set beside the screen, heights of tables and chairs adjusted for each subject to fit their anthropometric dimensions and taught to use the various possibilities for adjustment, new mice and standard flat keyboards were acquired if old ones were not in good condition). I_2: redesign of workstations (same as I_1) plus training on work technique (included the use of the mouse with both hands, use of earphones for telephone communications and instruction on daily stretching exercises (for 2 minutes at regular intervals when sitting at	Non-randomized trial	Primary and secondary

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
			workstation) for upper extremity).		
Alternative keyboards	Rempel 1999	High	I: keyboard with a keyswitch force-displacement profile having a greater travel distance until the key is "made" and greater "dampening" when the key reaches the bottom of its travel. C: conventional keyboard.	Randomized trial	Secondary and teriary
Alternative keyboards	Tittiranonda 1999	Medium	I_1: Apple Adjustable Keyboard™ plus one-hour ergonomics training. I_2: Comfort Keyboard System™ plus one-hour ergonomics training. I_3: Microsoft Natural Keyboard™ plus one-hour ergonomics training. C: conventional keyboard plus one-hour ergonomics training.	Randomized trial	Secondary
Alternative pointing devices, Arm supports	Conlon 2008	High	I_1I_2: alternative mouse with forearm support board. I_1C_2: alternative mouse without forearm support board. C_1I_2: conventional mouse with forearm support board. C_1C_2: conventional mouse without forearm support board.	Randomized trial	Primary
Alternative pointing devices, Arm supports	Rempel 2006	High	I_1: trackball and ergonomics training. I_2: forearm support board and ergonomics training. I_3: forearm support board, trackball and ergonomics training. C: only the ergonomics training.	Randomized trial	Primary and secondary
Arm supports	Lintula 2001	Medium	I_1: one Ergorest® arm support with a mouse pad for the hand that operated the mouse. I_2: Ergorest® arm supports for both hands and a mouse pad for the mousing hand. C: no arm supports and instructed not to change their workstations during the study period.	Randomized trial	Primary
New chair	Rempel 2007	High	I_1: curved seat pan chair (new chair) and miscellaneous items. I_2: flat seat pan chair and miscellaneous items. C: miscellaneous items (footrest, small table-top storage box for items, scissors, side table, task lamp and reading glasses).	Randomized trial	Secondary and teriary
Rest breaks	Galinsky 2007	Medium	IC: Workers alternated between an intervention and a control rest break schedule every four weeks. The control/conventional (C) schedule involved a break every two hours (15-minute breaks in morning and afternoon and 30- minute break for lunch). The intervention (I) schedule involved a break every hour (conventional schedule plus four five-minute breaks). Workers were prompted to take breaks by electrical timers. Note: Described mixed design with stretching exercise as a between-subject factor and rest-break schedule as a within-subject repeated measures with randomized order. However, no results presented on stretching group, therefore this review only reports on rest break	Within-subject repeated measures with randomized order	Primary and secondary

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
			intervention.		
Rest breaks	Galinsky 2000	Medium	IC: Workers alternated between an intervention and a control rest break schedule every four weeks. The control/conventional (C) schedule involved a break every two hours (15-minute breaks in am and pm and a 30-minute break for lunch). The intervention (I) schedule involved a break every hour (conventional schedule plus four five-minute breaks). Workers were prompted to take breaks by electrical timers.	Within-subject repeated measures with randomized order	Primary, secondary and tertiary
Rest breaks	McLean 2001	Medium	I_1: workstation assessment and adjustments. Ergobreak™ software prompted users to take 30-second breaks every 40 minutes. I_2: workstation assessment and adjustments. Ergobreak™ software prompted users to take 30-second breaks every 20 minutes. C: workstation assessment and adjustments. Ergobreak™ software installed but provided no prompting; subjects told to take breaks whenever they wanted to.	Randomized trial	Primary
Rest breaks, Rest breaks & exercise	van den Heuvel 2003	Medium	I_1: break reminder software. Software prompted user to take a five-minute break after 35 minutes of continuous computer usage and a seven-second break after five minutes of continuous computer usage. Also, workstation adjustment and training were provided. I_2: break reminder software plus exercise. Same as I_1 plus software prompted user to do exercises during the breaks. C: only workstation adjustment and training.	Randomized trial	Secondary
Participatory ergonomics	Laing 2007	Medium	I: detailed participatory ergonomic approach (consisted of a project steering committee, an ergonomic change team and an ergonomic program implementation blueprint). Aimed at improving communication and psychosocial exposures. C: no intervention.	Non-randomized trial	Primary
Broad-based Musculoskeletal Injury Prevention Program (MIPP)	Leclerc 1997	Medium	I: training with exercise and ergonomic changes following a site visit by an ergonomist. C: usual injury prevention policies.	Non-randomized trial	Primary and secondary
Prevention strategies & physical therapy, Early intervention	Lemstra 2003	Medium	I_1: prevention strategies and physical therapy that included: a) primary prevention strategies designed to change the work, not the worker (e.g. worker rotation schedules, reduced lifting loads, and ergonomic redesign of tasks), b) secondary prevention strategies consisted of independent on-site management with a physical therapist (included reassurance of a good prognosis, encouragement to resume normal	Non-randomized trial	Primary, secondary and tertiary

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
program (EIP)			activities, simple exercises, and recommendations to resume work as soon as safely possible on either full duties or time-limited modified or light duties). The neutral return-to-work arrangements were based on physical and functional information from the physical therapist and medical information from the family physician. Company management, union leadership, and the workers themselves fully supported the independent occupational management approach and were, at all times, encouraged to participate in its development. I_2: Early intervention program (EIP) - WCB initiated with the intention of providing rapid and expanded rehabilitation services to injured workers to facilitate their return to the workplace. Injured workers are required to immediately participate in expanded physical therapy and work-hardening programs. If not at work at six weeks, broader secondary or tertiary treatment protocols are initiated that last up to four hours a day and include psychosocial intervention. The decision for secondary or tertiary rehabilitation is based on 28 "red flags" considered important by the WCB. (*Note: see table 16: study reports descriptive comparison only of results, therefore this review does not report this intervention in the evidence synthesis.*) C: standard care - standard medical and physical therapy care, which included long waiting lists for physical therapy.		
Miscellaneous work redesign (VDT workstation)	Lin 2007	Medium	I: redesigned workstations (mainly to reduce shoulder loadings), according to the specification of workstation design by Occupational Safety and Health Administrations of Oregon State (OR-OSHA, 2004) for computers in semiconductors. C: original workstations (matched by their similarity of age, height, weight, employment duration, working practice, and MSK risk factors and symptoms).	Non-randomized trial	Primary and secondary
Miscellaneous work redesign (raised bricklaying)	Luijsterburg 2005	Medium	I: bricklayers that implemented raised bricklaying C: bricklayers that did not implement raised bricklaying	Non-randomized trial	Primary and secondary
Miscellaneous work redesign (change from lineout to line production in car body sealing)	Fredriksson 2001	Medium	I: change from lineout to line production in car body sealing. The cars were placed on "palettes," which moved ahead slowly along the line and work was performed on these moving platforms. The ''palettes'' allowed individually adjustable heights on the sides of cars, but not in front of or behind them. The height of the car was also adjustable. Along the line, the work was divided into workstations and a worker did certain tasks at every station, the same on every car. The operators worked in teams of seven to eight individuals, and each team was responsible for three to four workstations. Four times a day the workers changed stations. This meant that they performed the same task during two consecutive hours. The duration of the individual work tasks was	Non-randomized trial	Primary

Intervention category	Author, year	Quality rating	Intervention description	Study design	Prevention type
			between 15 and 90 seconds. The operators could not leave the line without anyone else to take his/her place. Even if the line was halted due to an error, the workers had to remain in their places so as to be able to begin working immediately when the line started again. C: no change in work process (another car-body department with most similar working conditions to intervention group). Lineout system - all cars were sealed in workstations where a fixed pair of workers carried out all the work on the car, usually sealing either the left or the right side of the car. The estimated time for sealing one car was approximately 20 minutes (mean time about 15 minutes, which gave operators the freedom to take longer breaks). It was possible to adjust the height of the car, but not to make any individual adjustments of the workplace.		
Miscellaneous work redesign (mechanical assist for materials transport)	van der Molen 2004	Medium	I: mechanical with a crane (adjusted method), transporting materials with a crane (bricks and mortar). C: manual (conventional method). I_1C: cross-over with intervention first. I_2C: cross-over with intervention second. Order of I and C was varied across participants (each participant took part in both conditions (I and C), order of condition and time of observation am/pm was randomly assigned).	Randomized cross-over design	Primary and secondary
*Multi-component patient handling	Yassi 2001	Medium	I_1: "safe-lift" policy; lifting and transfer equipment; three hours of education on back care, patient assessment and handling techniques. I_2: "no strenuous lifting" policy; new mechanical patient lifts and transfer equipment on each ward; three hours of education on back care, patient assessment and handling techniques. C: no policy changed; one mechanical total body lift available on the ward and access to sliding devices from a central equipment depot on request only; no training provided.	Randomized trial	Primary and secondary

*Multi-component patient handling - an intervention that included three components: policy change, equipment purchase and training on equipment usage and patient handling
MIPP = MSK Injury Prevention Program

Characteristics of studies used in data synthesis
Study characteristics important to consider when examining comparability and generalizability are shown in Table 9.

Countries of origin
The studies reviewed originated in different parts of the world: 15 from the United States, 15 from European countries, four from Canada, one from Asia and one from Australia.

Types of industry/jobs
A variety of industries and job titles were represented; no single industry or job title was dominant. However, the primary job duties of most study participants involved office work (22 of 36 studies).

Sample sizes and numbers lost to follow-up
The sample sizes in the studies tended to be small but varied from 10 (van der Molen 2004, Thomas 1993) to 602 (Leclerc 1997). Six studies (van der Molen 2004, Thomas 1993, Martin 2003, Nevala-Puranen 2003, Rempel 1999, McLean 2001) had samples sizes of 20 or less. Lost to follow-up details were often lacking in the study descriptions (n=10). When reported, the numbers lost to follow-up tended to be small but varied from 0 to 52 per cent.

Length of observation
The length of observation also varied greatly, from one day (van der Molen 2004) to
18 months (Horneij 2001).

Overall, there was a great deal of heterogeneity supporting the best evidence synthesis approach. Additional information about each study can be found in Appendices F to I, Tables 13 to 16. We summarize the tables below.

Table 9: Study description
(I = Intervention, C = Control, np = not provided)

Intervention category	Author year and QA rating	Country	Industry/sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Ergonomics training & exercise (I_1), Exercise (I_2)	Lundblad 1999, High	Sweden	Auto manufacturing	Industrial workers	Randomized trial	I_1 n=32 I_2 n=33 C n=32	I_1 n=17 I_2 n=13 C n=9	One year
Exercise	Sjogren 2005, High	Finland	Administrative office	Office workers	Randomized cross-over design	I_1C n=36 I_2C n=17	n=2	30 weeks
Exercise, Ergonomics training & exercise	Kamwendo 1991, Medium	Sweden	Health care	Medical secretaries	Randomized trial	I_1 n=25 I_2 n=28 C n=26	Total n=3	Six months
Biofeedback training, Cognitive behavioural training	Faucett 2002, High	USA	Electronics manufacturing	Professional engineers, non-professional telemarketers (both intensive VDU use) Assembly workers (assembled small electronic devices using microscopes and other hand held tools)	Randomized trial	I_1 n=46 I_2 n=46 C n=47	I_1 n=14 I_2 n=9 C n=8	32 weeks
Biofeedback training	Thomas 1993, Medium	USA	Hardware manufacturing	Light weight hardware assembly workers	Non-randomized trial	I n=5 C n=5	Not provided	Eight weeks
Biofeedback training	Voerman 2007, High	Sweden and Nederlands	Not provided	Computer workers (e.g., job counselors and medical secretaries)	Randomized trial	I n=42 C n=37	I n=9 C n=5	Six months

Intervention category	Author year and QA rating	Country	Industry/sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Job stress management training	Feuerstein 2004, High	USA	Financial	Multinational, professional, knowledge office workers (e.g. economists, computer specialists)	Randomized trial	I n=36 C n=34	I n=12 C n=11	12 months
Job stress management training, Exercise	Horneij 2001, High	Sweden	Health care (Municipal home-care services)	Nursing aids and assistant nurses	Randomized trial	I_1 n=90 I_2 n=93 C n=99	I_1 n=43 I_2 n=43 C n=37	18 months
Workstation adjustment	Gerr 2005, High	USA	Financial, insurance and food industries, education	Computer workers (in financial companies, insurance companies, food product producers, and universities)	Randomized trial	I_1 n=122 I_2 n=125 C n=115	I_1 n=7 I_2 n=6 C n=4	Six months
Workstation adjustment (high & low intensity)	Ketola 2002, High	Finland	Public administration	Secretaries, technicians, architects, engineers, draftspersons.	Randomized trial	I_1 n=39 I_2 n=35 C n=35	I_1 n=2 I_2 n=2 C n=3	10 months
Workstation adjustment	Pillastrini 2007, High	Italy	Local government office (town hall)	Administrative personnel	Randomized trial	I n=100 C n=100	I n=1 C n=3	Five months
Workstation adjustment	Cook 2004, Medium	Australia	Newspaper call centre	Call centre staff	Randomized trial	I n=30 C n=29	Total n=11	12 weeks

Intervention category	Author year and QA rating	Country	Industry/sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Ergonomics training (Traditional ergonomics training, Participatory ergonomics training)	Bohr 2000, Medium	USA	Centralized reservation centre for transportation company	Call centre employees	Randomized trial	I_1 n=51 I_2 n=50 C n=53	I_1 n=12 I_2 n=12 C n=6	12 months
Ergonomics training	Greene 2005, Medium	USA	Education services	Library, continuing education, computer networking, family/consumer science	Randomized trial with delayed intervention	I n=43 IC n=44	No provided	Two weeks
Ergonomics training	Peper 2004, Medium	USA	Education services	Not provided	Randomized trial	I n=16 C n=12	Not provided	Six weeks
Ergonomics training	Veiersted 2007, Medium	Norway	Hairdressing	Hairdressers	Randomized trial	I_1 n=18 I_2 n=20	Not provided	Four weeks (approx)
Ergonomics training & workstation adjustment	Martin 2003 (and Gatty 2004), High	USA	Education services	Clerical/Office workers	Randomized trial	I n=7 C n=8	I n=0 C n=1	16 weeks
Ergonomics training & exercise	Nevala-Puranen 2003, Medium	Finland	Newspaper	Not provided	Non-randomized trial	I_1 n=8 I_2 n=9	I_1 n=2 I_2 n=1	Seven months

Intervention category	Author year and QA rating	Country	Industry/sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Alternative keyboards	Rempel 1999, High	USA	Professional, scientific or technical services	Administrative assistants or technical writer/editors	Randomized trial	I n=10 C n=10	I n=2 C n=2	12 weeks
Alternative keyboards	Tittiranonda 1999, Medium	USA	Professional, scientific or technical services	Laboratory workers	Randomized trial	I_1 n=20 I_2 n=20 I_3 n=20 C n=20	I_1 n=1 I_2 n=9 I_3 n=1 C n=0	24 weeks
Alternative pointing devices, Arm supports	Conlon 2008, High	USA	Aerospace engineering	Engineers and professional positions supporting engineering (computer programming, graphic design, financial planning, project developers)	Randomized trial	I_1I_2 n=51 I_1C_2 n=52 C_1I_2: n=51 C_1C_2 n=52	Not provided, but more subjects dropped out from the I_1C_2 and I_1I_2 than C_1C_2 and C_1I_2	One year
Alternative pointing devices, Arm supports	Rempel 2006, High	USA	Health care	Registered nurses, health-care specialists (operating as customer service operators)	Randomized trial	I_1 n=45 I_2 n=46 I_3 n=45 C n=46	I_1 n=4 I_2 n=1 I_3 n=4 C n=1	52 weeks
Arm supports	Lintula 2001, Medium	Finland	Not provided	Office employees and researchers	Randomized trial	I_1 n=7 I_2 n=7 C n=7	I_1 n=0 I_2 n=0 C n=0	Six weeks
New chair	Rempel 2007, High	USA	Garment	Sewing machine operators	Randomized trial	I_1 n=72 I_2 n=100 C n=105	I_1 n=30 I_2 n=27 C n=11	Four months

Intervention category	Author year and QA rating	Country	Industry/sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Rest breaks	Galinsky 2007, Medium	USA	IRS (Internal Revenue Service)	Seasonal data entry operators	Within-subject repeated measures with randomized order	n=90	n=12/51 (24 per cent) (12 incomplete data/51 available for f/u (note: n=27 attrition due to release of employment and resignation)	Eight weeks
Rest breaks	Galinsky 2000, Medium	USA	IRS (Internal Revenue Service)	Seasonal data entry operators	Within-subject repeated measures with randomized order	n=101	n=21/63 (33.3 per cent) (21 incomplete data/63 available for f/u (note: n=38 attrition due to release of employment and resignation)	Eight weeks
Rest breaks	McLean 2001, Medium	Canada	Education services	Not provided	Randomized trial	I_1 n=np I_2 n=np C n=np Total n=15	Not provided	Two weeks
Rest breaks, Exercise	van den Heuvel 2003, Medium	Netherlands	Public administration	Not provided	Randomized trial	I_1 n=97 I_2 n=81 C n=90	I_1 n=18 I_2 n=15 C n=16	Three months
Participatory ergonomics	Laing 2007, Medium	Canada	Automotive manufacturing	Not provided	Non-randomized trial	I n=45 C n=21	Not provided	10 months
Broad-based MSK Injury Prevention Program (MIPP)	Leclerc 1997, Medium	France	Hospital, warehouse, office	Not provided	Non-randomized trial	Total n = 620	Not provided	12 months

Intervention category	Author year and QA rating	Country	Industry/sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Prevention strategies & physical therapy	Lemstra 2003, Medium	Canada	Meat industry	Not provided	Cross-over	I_1=285 C=185	Not provided	Crossover design using administrative data over two years (Company A, 1999 (C) & 2000 (I_1)
Miscellaneous work redesign (VDT workstation)	Lin 2007, Medium	Taiwan	Semiconductor manufacturing	Semiconductor fabrication workers	Non-randomized trial	I n=20 C n=20	I n=0 C n=0	Five months
Miscellaneous work redesign (raised bricklaying)	Luijsterburg 2005, Medium	Netherlands	Construction	Bricklayers	Non-randomized trial	I n=44 C n=158	I n=14 C n=91	10 months
Miscellaneous work redesign (change from lineout to line production in car body sealing)	Fredriksson 2001, Medium	Sweden	Automobile assembly	Operators from sealing and car-body departments.	Non-randomized trial	I n=78 C n=45	I n=21 C n=24	12 months
Miscellaneous work redesign (Mechanical assist for materials transport)	van der Molen 2004, Medium	Netherlands	Construction	Bricklayers' assistants	Randomized cross-over design	Total n=10	Total n=0	Repeat measures (Time1-4) over 4.5 hours on same day.
*Multi-component patient handling	Yassi 2001, Medium	Canada	Health care	Nurses, unit assistants	Randomized trial	I_1 n=116 I_2 n=127 C n=103	I_1 n=not provided I_2 n=not provided C n=not provided	12 months

*Multi-component patient handling - an intervention that included three components: policy change, equipment purchase and training on equipment usage and patient handling

Research question
All 36 studies presented some form of research question (*Appendix F, Table 13*). The clarity and detail of these questions varied in both the high and medium quality studies.

Inclusion/exclusion criteria
All 14 of the high quality studies and 19 of the 22 medium quality studies provided some inclusion/exclusion criteria (*Appendix F, Table 13*). The inclusion and exclusion criteria presented were often insufficient to clearly determine whether the intervention was primary, secondary or tertiary (i.e. the injury status of the participants was not indicated). The heterogeneity of worker samples made comparisons across studies a challenge.

Confirmation of the intervention
The review team considered whether the intervention was confirmed during the course of the study (Appendix G, Table 14). Confirmation of the intervention helps to establish whether the effects noted were actually related to the intervention. This is particularly important when researchers are comparing several different types of interventions (*see Table 8*). Thirteen of the 14 high quality studies and 18 of the 22 medium quality studies confirmed that the intervention was implemented and was being used during the course of the study. Five studies did not confirm the intervention (Thomas 1993, Feuerstein 2004, Veiersted 2007, Leclerc 1997, Lemstra 2003).

Covariates and confounders
In Table 15 (Appendix H), we list covariates/confounders that were examined in each study and covariates/confounders that were included in the final analysis of each study. Thirteen of the 14 high quality studies examined for covariates/confounders in the analysis (or in design by careful matching); 12 of 22 medium quality studies examined for covariates/confounders. The variables considered in these analyses varied greatly with little consistency across the studies. Nine of the 14 high quality studies included covariates/confounders in the final analysis (Voerman 2007, Gerr 2005, Ketola 2002, Pillastrini 2007, Conlon 2008, Rempel 2006, Rempel 2007) or controlled by design (matched design Rempel 1999 and cross-over design Sjogren 2005). Only four of the 22 medium quality studies (Kamwendo 1991, Greene 2005, van den Heuvel 2003, Fredriksson 2001) included covariates/confounders in the final analysis.

Outcomes of interest
The outcomes of interest for this systematic review were upper extremity musculoskeletal (MSK) symptoms, signs, disorders, injuries, claims and lost time outcomes (*see Appendix I, Table 16*). These outcomes were ascertained from employer records [e.g. injury, LWD (lost work days), WC (workers' compensation)], worker self-report and clinical measures (includes clinical exams, clinical records or clinical diagnoses). Thirty studies examined only

worker self-report outcomes (Lundblad 1999, Sjogren 2005, Kamwendo 1991, Horneij 2001, Nevala-Puranen 2003, Thomas 1993, Voerman 2007, Feuerstein 2004, Gerr 2005, Ketola 2002, Pillastrini 2007, Cook 2004, Bohr 2000, Greene 2005, Peper 2004, Veiersted 2007, Martin 2003, Lintula 2001, Rempel 2007, Galinsky 2007, Galinsky 2000, McLean 2001, van den Heuvel 2003, Laing 2007, Leclerc 1997, Lin 2007, Luijsterburg 2005, Fredriksson 2001, van der Molen 2004, Yassi 2001). Four studies examined both worker self-report and clinical outcomes; three of these were high quality (Faucett 2002, Conlon 2008, Rempel 2006) and one medium quality (Tittiranonda 1999). One study examined only clinical outcomes (Rempel 1999). One study examined only employer record outcomes (Lemstra 2003). Blinding of clinical/physical assessment was employed in four studies (Conlon 2008, Rempel 2006, Tittiranonda 1999, Rempel 1999) and in one study it was not clear if blinding was used (Faucett 2002).

3.4 Evidence synthesis

A summary of the intervention effects is presented in Table 10. More details about the intervention effects can be found in Appendix I, Table 16. Details regarding the interventions for each study are described in Table 8. Since effect sizes could not be consistently calculated for the studies reviewed, we present the effects as they were reported by study authors.

Using the effects reported for each study and grouping them according to the intervention categories, we use the algorithm presented in Table 6 to determine the level of evidence for effects of interventions on upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time outcomes.

Table 11 is a summary of the effects by type of outcome measurement for studies in evidence synthesis. Also included is an overall best evidence synthesis by intervention category using the algorithm from Table 6 (Best evidence synthesis guidelines). In no case did the review team find a negative or adverse intervention effect. The evidence synthesis is summarized overall and for each intervention category below.

Overall, these 36 studies provided **mixed** evidence that occupational health and safety interventions have an effect on upper extremity MSK outcomes. Fifteen studies examined the effectiveness of more than one intervention (Lundblad 1999, Kamwendo 1991, Faucett 2002, Horneij 2001, Gerr 2005, Ketola 2002, Bohr 2000, Tittiranonda 1999, Conlon 2008, Rempel 2006, Lintula 2001, Rempel 2007, McLean 2001, van den Heuvel 2003, Yassi 2001) and thus explain the number of interventions being greater than the number of included studies. We found 20 interventions with positive effects and 32 with no effect. When only high quality studies were considered, we found nine interventions with positive effects and 13 with no effect.

Table 10: Intervention effects on upper extremity MSK health outcomes as reported in the studies. Studies are ordered by intervention category.
For greater detail on intervention effects see Appendix I, Table 16.
(I = Intervention, C = Control, VAS = Visual Analogue Scale)

Intervention category	Author, year	QA	Effect (positive, no, negative) on: upper extremity MSK outcomes
Ergonomics training & exercise (I_1), Exercise (I_2)	Lundblad, 1999	High	Positive (I_2 vs I_1 and C) on prevalence of neck pain in the previous seven days. No effect (I_1 and I_2 vs C) on prevalence of shoulder pain in the previous seven days, complaint indices (neck-index, shoulders-index, neck-shoulders-index), VAS (neck and shoulder) Note for discussion: Potential for problems with multiple comparisons. 1/7 upper extremity MSK outcomes was significant [1/7 = 14% therefore greater than chance alone (5%)].
Exercise	Sjogren, 2005	High	Positive (I vs C) on intensity of neck symptoms. No effect (I vs C) on intensity of shoulder symptoms.
Exercise (1_1), Ergonomics training & exercise (I_2)	Kamwendo, 1991	Medium	No effect (1_1 and I_2 vs C) on neck and shoulder pain.
Biofeedback training (1_1), Cognitive behavioural training (I_2)	Faucett, 2002	High	No effect (I_1 and I_2 vs C) on symptom severity (composite symptom severity score - mean of pain, stiffness & numbness) in upper extremity, neck or shoulders. No effect (I_1 and I_2 vs C) on number of incident cases (diagnosed with upper extremity work-related musculoskeletal disorders during the course of the study)
Biofeedback training	Thomas, 1993	Medium	No effect (I vs C) on subjective discomfort scores (body part discomfort scores - forearm & hands).
Biofeedback training	Voerman, 2007	High	No effect (I vs C) on shoulder/neck pain.
Job stress management training	Feuerstein, 2004	High	No effect (I vs C) on level of pain (VAS) in neck and upper extremity. No effect (I vs C) on upper extremity symptom severity (subscale of Disabilities of the Arm, Shoulder and Hand [DASH]).
Job stress management training (I_2), Exercise (I_1)	Horneij, 2001	High	No effect (I_1 and I_2 vs C) on neck and shoulder pain (Nordic Musculoskeletal Questionnaire).
Workstation adjustment	Gerr, 2005	High	No effect (I_1 and I_2 vs C) on incidence of musculoskeletal symptoms in arm/hand or neck/shoulder.
Workstation adjustment (high I_2 & low intensity I_1)	Ketola, 2002	High	No effect (I_1 and I_2 vs C) on neck, area between neck and shoulders, shoulders, forearms, wrists, or fingers discomfort.

Intervention category	Author, year	QA	Effect (positive, no, negative) on: upper extremity MSK outcomes
Workstation adjustment	Pillastrini, 2007	High	No effect (I vs C) on prevalence of shoulder, hand/wrist, and neck discomfort.
Workstation adjustment	Cook, 2004	Medium	No effect (I vs C) on neck, shoulder, forearm, andwrist discomfort.
Ergonomics training (Traditional ergonomics training I_1, Participatory ergonomics trainging I_2)	Bohr, 2000	Medium	Positive (I_1 and I_2 vs C) on upper body pain/discomfort.
Ergonomics training	Greene, 2005	Medium	No effect (I vs IC) on symptoms of upper extremities.
Ergonomics training	Peper, 2004	Medium	Positive (I vs C) on neck/shoulder, arms and wrists/hands symptoms.
Ergonomics training	Veiersted, 2007	Medium	No effect (I_1 vs I_2) on neck and shoulder complaints.
Ergonomics training & workstation adjustment	Martin, 2003 (and Gatty, 2004)	High	Positive (I vs C) on elbow/forearm symptoms. No effect on neck, shoulder and wrist/hand symptoms.
Ergonomics training & exercise	Nevala-Puranen, 2003	Medium	Positive (I_2 vs I_1) on neck, shoulder, and elbow symptoms. No effect (I_1 vs I_2) on wrist symptoms.
Alternative keyboards	Rempel, 1999	High	Positive (I vs C at 12 weeks) on reducing Phalen's test time. No effect (I vs C at 12 weeks) on nerve conduction.
Alternative keyboards	Tittiranonda, 1999	Medium	Positive (I_3 vs C) on arm/hand symptoms and change in overall pain severity. No effect (I_1 and I_2 vs C) on arm/hand symptoms and change in overall pain severity. No effect (I_1 and I_3 vs C) on prevalence of the Phalen's test, Tinel's sign, and Finkelstein's test.

Intervention category	Author, year	QA	Effect (positive, no, negative) on: upper extremity MSK outcomes
Alternative pointing devices, arm supports	Conlon, 2008	High	Positive effect I_2 (forearm support board) vs C_2 (no support board) on change in discomfort in right upper extremity. No effect I_2 (forearm support board) vs C_2 (no support board) on incident musculoskeletal disorders in neck/shoulder, right and left upper extremity. No effect I_2 (forearm support board) vs C_2 (no support board) on change in discomfort in neck/shoulder and left upper extremity. No effect I_1 (alternative mouse) vs C_1 (conventional mouse) on change in discomfort in neck/shoulder, right and left upper extremity. No effect I_1 (alternative mouse) vs C_1 (conventional mouse) on incident musculoskeletal disorders in neck/shoulder, right and left upper extremity.
Alternative pointing devices, Arm supports	Rempel, 2006	High	Positive effect armboard vs no armboard on neck/shoulder pain and right upper extremity pain. No effect armboard vs no armboard on left upper extremity pain. Positive effect armboard vs no armboard on incident musculoskeletal disorders in neck/shoulder. No effect armboard vs no armboard on incident musculoskeletal disorders in right and left upper extremity. Positive effect trackball vs no trackball on left upper extremity pain. No effect trackball vs no trackball on neck/shoulder and right upper extremity pain. Positive effect trackball vs no trackball on incident musculoskeletal disorders in left upper extremity. No effect trackball vs no trackball on incident musculoskeletal disorders in neck/shoulder and right upper extremity.
Arm supports	Lintula, 2001	Medium	No effect (I_1 vs I_2 vs C) on perceived MSK strain in neck/shoulder/arm region.
New chair	Rempel, 2007	High	Positive effect (I_1 and I_2 vs C) on neck and shoulder pain severity.
Rest breaks	Galinsky, 2007	Medium	Positive effect I vs C on symptoms in the neck, right shoulder/upper arm, right forearm/wrist/hand and left shoulder/upper arm. No effect (I vs C) on symptoms in the left forearm/wrist/hand.

Intervention category	Author, year	QA	Effect (positive, no, negative) on: upper extremity MSK outcomes
Rest breaks	Galinsky, 2000	Medium	Positive effect (I vs C) on symptoms in neck, right shoulder/upper arm, right elbow, right forearm/wrist/hand, left shoulder/upper arm and left elbow. No effect (I vs C) on symptoms in the left forearm/wrist/hand.
Rest breaks	McLean, 2001	Medium	Positive effect (I_2 q20 min vs C) forearm/wrist discomfort. No effect (I_2 q20 min vs C) on neck or shoulder discomfort. No effect (I_1 q40 min vs C) on neck, shoulder and forearm/wrist discomfort.
Rest breaks (I_1) , Rest breaks & exercise (I_2)	van den Heuvel, 2003	Medium	No effect (I_1 and I_2 vs C) on frequency of neck/shoulder and upper arm/forearm/wrist/hands/fingers. No effect (I_1 and I_2 vs C) on severity of complaints in neck/shoulder and upper arm/forearm/wrist/hands/fingers. No effect (I_1 and I_2 vs C) on sick leave for neck/shoulder and upper arm/forearm/wrist/hands/fingers.
Participatory ergonomics	Laing, 2007	Medium	No effect (I vs C) on pain severity of shoulder/upper arm and forearm/hand.
Broad-based MSK Injury Prevention Program (MIPP)	Leclerc, 1997	Medium	No effect (I vs C) on neck symptoms. Positive effect (I vs C) on shoulder symptoms.
Prevention strategies & physical therapy	Lemstra, 2003	Medium	Positive effect I_1 (prevention strategies and physical therapy company A) versus C (standard care company A) for incidence of upper extremity time-loss claims, time-loss days and time-loss costs.
Miscellaneous work redesign (VDT workstation)	Lin, 2007	Medium	No effect (I vs C) in percentage of musculoskeletal shoulder symptoms.
Miscellaneous work redesign (raised bricklaying)	Luijsterburg, 2005	Medium	No effect (I vs C) in shoulder and hand-wrist complaints. No effect (I vs C) sick leave due to shoulder problems.
Miscellaneous work redesign (change from lineout to line production in car body sealing)	Fredriksson, 2001	Medium	No effect (I vs C) on prevalence of neck, shoulders and hand/wrist disorders.
Miscellaneous work redesign (mechanical assist for materials transport)	van der Molen, 2004	Medium	No effect I (mechanization-crane) vs C (manual handling-conventional) on local discomfort of the shoulders.

Intervention category	Author, year	QA	Effect (positive, no, negative) on: upper extremity MSK outcomes
*Multi-component patient handling	Yassi, 2001	Medium	Positive effect (I_1 "Safe Lifting" versus C) on shoulder pain. No effect (I_2 "No Strenuous Lifting" versus C) on shoulder pain.

*Multi-component patient handling - an intervention that included three components: policy change, equipment purchase and training on equipment usage and patient handling

Table 11: Effects summary by type of outcome measurement (n=36 studies) and the best Evidence Synthesis by intervention category (n=19)
QA (Quality assessment), sh (shoulder), wr (wrist), R (right), L (left), RUE (right upper extremity), LUE (left upper extremity), + (Positive effect), ∅ (No effect), +/∅ (both positive and no effect found)

Author, year	Industry/sector	Outcome		QA	Evidence
		Worker self-report	Clinical		
Exercise					**MIXED**
Lundblad, 1999 (I_2)	Auto manufacturing	+/∅ (neck) ∅ (sh)		H	Positive
Sjogren, 2005	Administrative office	+ (neck) ∅ (sh)		H	Positive
Kamwendo, 1991 (I_1)	Health care (medical secretary)	∅ (neck/sh)		M	No effect
Horneij 2001 (I_1)	Health care (Nursing aides/assistant nurse)	∅ (neck, sh)		H	No effect
Ergonomics training & exercise					**MIXED**
Lundblad, 1999 (I_1)	Auto manufacturing	∅ (neck, sh)		H	No effect
Nevala-Puranen, 2003 (I_2)	Newspaper	+ (neck, sh, elbow) ∅ (wrist)		M	Positive
Kamwendo, 1991 (I_2)	Health care (medical secretary)	∅ (neck/sh)		M	No effect
Biofeedback training					**MODERATE NO EFFECT**
Faucett, 2002 (I_1)	Electronics manufacturing	∅ (UE/neck/sh)	∅	H	No effect
Thomas, 1993	Hardware manufacturing	∅ (forearm/hands)		M	No effect
Voerman, 2007	Not provided	∅ (sh/neck)		H	No effect
Cognitive behavioural training					**LIMITED NO EFFECT**
Faucett, 2002 (I_2)	Electronics manufacturing	∅ (UE/neck/sh)	∅	H	No effect

Author, year	Industry/sector	Outcome		QA	Evidence
		Worker self-report	Clinical		
Job stress management training					**MODERATE NO EFFECT**
Feuerstein, 2004	Financial	⌀ (neck/UE)		H	No effect
Horneij, 2001 (I_2)	Health care (Nursing aides/assistant nurse)	⌀ (neck, sh)		H	No effect
Workstation adjustment					**STRONG NO EFFECT**
Gerr, 2005 (I_1 & I_2)	Financial, insurance, food industries, education	⌀ (I_1 & I_2) (arm/hand, neck/sh)		H	No effect
Ketola, 2002 (high I_2 & low I_1 intensity)	Public administration	⌀ (I_1 & I_2) (neck, R&Lneck/sh, R&L sh, R&L forearm, R&L wr, R&L fingers)		H	No effect
Pillastrini, 2007	Local government	⌀ (sh, hand/wr, neck)		H	No effect
Cook 2004	Newspaper call centre	⌀ (neck, sh, forearm, wr)		M	No effect
Ergonomics training					**MIXED**
Bohr 2000 (Traditional ergonomics training I_1, Participatory ergonomics training I_2)	Transportation (centralized reservation centre)	+ (I_1 & I_2) (neck/upper back/shoulder/upper arm/forearm/wrist/hand)		M	Positive
Greene, 2005	Education services	⌀ (sh/upperarm/elbow/ forearm/wr/hand)		M	No effect
Peper, 2004	Education services	+ (neck/sh, arms, wr/hand)		M	Positive
Veiersted, 2007 (I_2)	Hairdressing	⌀ (neck, sh)		M	No effect
Ergonomics training & workstation adjustment					**LIMITED POSITIVE**
Martin, 2003 (and Gatty, 2004)	Education services	+ (elbow/forearm) ⌀ (neck, sh, wr/hand)		H	Positive

Author, year	Industry/sector	Outcome		QA	Evidence
		Worker self-report	Clinical		
Alternative keyboards					**LIMITED POSITIVE**
Rempel, 1999 (alternative keyboard switch design)	Professional, scientific or technical services		+/⌀	H	Positive
Tittiranonda, 1999 I_1 & I_2 (adjustable split) I_3 (fixed split)	Professional, scientific or technical services	+ (I_3) (arm/hand) ⌀ (I_1 & I_2) (arm/hand)	⌀ (I_1 & I_3)	M	Positive (I_3) No effect (I_1 & I_2)
Alternative pointing devices					**MIXED**
Conlon, 2008 (vertical mouse)	Aerospace engineering	⌀ (neck/sh, R&LUE)	⌀ (neck/sh, R&LUE)	H	No effect
Rempel, 2006 (trackball)	Health care (customer service operators)	+ (LUE) ⌀ (neck/sh, RUE)	+ (LUE) ⌀ (neck/sh, RUE)	H	Positive
Arm supports					**MODERATE POSITIVE**
Conlon, 2008	Aerospace engineering	+ (RUE) ⌀ (neck/sh, LUE)	⌀ (neck/sh, R&LUE)	H	Positive
Rempel, 2006	Health care (customer service operators)	+ (neck/sh, RUE) ⌀ (LUE)	+ (neck/sh) ⌀ (R&LUE)	H	Positive
Lintula, 2001 (I_1 one hand, I_2 both hands)	Not provided	⌀ (I_1 & I_2) (neck/sh/arm)		M	No effect
New chair					**LIMITED POSITIVE**
Rempel, 2007 I_1 (curved) and I_2 (flat)	Garment	+ (I_1 & I_2) (neck/sh)		H	Positive

Author, year	Industry/sector	Outcome		QA	Evidence
		Worker self-report	Clinical		
Rest breaks					**LIMITED POSITIVE**
Galinsky, 2007	Federal government (Internal Revenue Service)	+ (neck, Rsh/upper arm, Rforearm/wr/hand, Lsh/upper arm) ⌀ (Lforearm/wrist/hand)		M	Positive
Galinsky, 2000	Federal government (Internal Revenue Service)	+ (neck, Rsh/upper arm, Relbow, Rforearm/wr/hand, Lsh/upper arm, Lelbow) ⌀ (Lforearm/wrist/hand)		M	Positive
McLean, 2001 (I_1 q40 min, I_2 q20 min)	Education services	+ (I_2 forearm/wr) ⌀ (I_1 neck/sh/forearm/wr) & I_2 neck, sh)		M	Positive (I_2) No effect (I_1)
van den Heuvel, 2003	Public administration	⌀ (neck/sh, arms/elbows/ forearms/wr/hands/ fingers)		M	No effect
Rest breaks & exercise					**INSUFFICIENT**
van den Heuvel, 2003	Public administration	⌀ (neck/sh, arms/elbows/ forearms/wr/hands/ fingers)		M	No effect
Participatory ergonomics					**INSUFFICIENT**
Laing, 2007	Automotive manufacturing	⌀ (sh/upper arm, forearm/hand)		M	No effect
Broad-based MSK Injury Prevention Program (MIPP)					**INSUFFICIENT**
Leclerc, 1997	Hospital, warehouse, office	+ (sh) ⌀ (neck)		M	Positive
Miscellaneous work redesign					**LIMITED NO EFFECT**
Lin, 2007	Semiconductor manufacturing	⌀ (sh)		M	No effect
Luijsterburg, 2005	Construction	⌀ (sh, hand/wr)		M	No effect
Fredriksson, 2001	Automobile assembly	⌀ (neck, sh, hand/wr)		M	No effect

Author, year	Industry/sector	Outcome		QA	Evidence
		Worker self-report	Clinical		
van der Molen, 2004	Construction	∅ (sh)		M	No effect
Multi-component patient handling					**INSUFFICIENT**
Yassi, 2001 (I_1 "Safe Lifting", I_2 "No Strenuous Lifting")	Health care (Nurses, unit assistants)	+ (I_1) (sh) ∅ (I_2) (sh)		M	Positive (I_1) No effect (I_2)

Blanks = outcome measurement not used.
Note: Study by Lemstra (2003) Intervention category: **Prevention strategies & physical therapy**
Not shown in table because only used employer record outcome.
(Industry/Sector: Meat industry, QA:Medium, Outcome: + LWD (Lost work days) and + WC (Workers'compensation, Evidence: Insufficent).

Exercise

Four studies evaluated exercise programs: two high quality studies (Lundblad 1999, Sjogren 2005) found positive effects for the neck and no effect for the shoulder, one high (Horneij 2001) and one medium quality study (Kamwendo 1991) found no effect on neck and shoulder outcomes. The exercise interventions were similar; initial training on exercises (by a physical therapist, Feldenkrais instructor) followed by an independent exercise program done either during work hours or at home. The four exercise programs included a variety of activities including strengthening, stretching, coordination, relaxation and/or stabilization exercises. Overall, these studies provide **mixed** evidence that exercise programs have an effect on upper extremity MSK outcomes.

Ergonomics training and exercise

Three studies evaluated ergonomics training combined with exercise programs: one high quality study (Lundblad 1999) found no effects on neck and shoulder outcomes, one medium quality study (Nevala-Puranen 2003) found either positive (neck, shoulder, elbow outcomes) or no effects (wrist outcome), depending on the outcome variable, and one medium quality study (Kamwendo 1991) found no effect on neck/shoulder outcome. The study by Kamwendo 1991 also included a limited contribution from an interview by a psychologist to develop a personal coping strategy. Overall, these studies provide **mixed** evidence that ergonomics training combined with an exercise program have an effect on upper extremity MSK outcomes.

Biofeedback training

Three studies evaluated biofeedback training: two high quality studies (Faucett 2002, Voerman 2007) found no effect on upper extremity outcomes and one medium quality study (Thomas 1993) found no effect on forearm/hands outcome. Together these studies provide **moderate** evidence that biofeedback training has **no effect** on upper extremity MSK outcomes.

Cognitive behavioural training

One high quality study (Faucett 2002) found no effect on upper extremity outcomes with an intervention that used adult learning and cognitive behavioural techniques in small group discussions to advance workers' capabilities for symptom and stress management and problem-solving. This single study provides **limited** evidence that cognitive behavioural training has **no effect** on upper extremity MSK outcomes.

Job stress management training

Two high quality studies (Feuerstein 2004, Horneij 2001) reported no effect on upper extremity MSK outcomes. In both studies, the intervention was delivered in a group setting and the intensity varied in duration (from 70 to 90 minute sessions over three to seven weeks). These studies provide **moderate** evidence that job stress management training alone has **no effect** on upper extremity MSK outcomes.

Workstation adjustment
Three high quality studies (Gerr 2005, Ketola 2002, Pillastrini 2007) and one medium quality study (Cook 2004) examined the effect of an array of workstation adjustments. The individual workstation adjustments were performed by a therapist or technician with the goal of reducing a range of specific postural stresses. The control groups received either ergonomics training or no intervention. All studies found no effect of workstation adjustments on upper extremity MSK outcomes. These studies provide **strong** evidence that workstation adjustments alone have **no effect** on upper extremity MSK outcomes.

Ergonomics training
Four studies examined ergonomics training: all studies were medium quality (Bohr 2000, Greene 2005, Peper 2004, Veiersted 2007). Two studies (Greene 2005, Veiersted 2001) found no effect, and two had positive effects (Bohr 2000, Peper 2004). The four studies implemented different types of training programs ranging from a single session to multiple participatory training sessions. The duration of the training varied from a 10-minute personal follow-up after receiving an information pamphlet to a one-hour lecture on ergonomics. Together, these studies provide **mixed** evidence that ergonomics training has an effect on upper extremity MSK outcomes.

Ergonomics training and workstation adjustment
One high quality study (Martin 2003) found a positive effect on the elbow/forearm and no effect on the neck, shoulder and wrist/hand. This single high quality study provides **limited** evidence that ergonomics training plus workstation adjustments have a **positive** effect on upper extremity MSK outcomes.

Alternative keyboards
One high quality study (Rempel 1999) and one medium quality study (Tittiranonda 1999) examined the effect of alternative keyboards on upper extremity MSK outcomes. One study (Rempel 1999) found either positive (Phalen's test time) or no effect (nerve conduction), depending on the outcome variable for a keyboard with a new keyswitch force displacement. The other study (Tittiranonda 1999) found positive effects for one fixed split keyboard and no effect for two other adjustable split keyboards when compared to a conventional keyboard. Together, these studies provide **limited** evidence that alternative keyboards have a **positive** effect on upper extremity MSK outcomes.

Although positive effects were found in both studies, the Tittiranonda study found no effect for two keyboards in independent comparisons with a placebo keyboard. Therefore, we have a situation where two alternative keyboards in two different studies were shown to have positive effects and two keyboards from a single study were shown to have no effect. As a result, the team felt these inconsistent results represented a **mixed** level of evidence.

Further, these interventions are biomechanically very different and the team felt that the review should also address findings from the individual studies. A single high quality study provides **limited** evidence that a keyboard with a new keyswitch force displacement has a **positive** effect on upper extremity MSK outcomes. A single medium quality study provides **insufficient** evidence whether an adjustable split keyboard or a fixed split keyboard have an effect on upper extremity MSK outcomes.

Alternative pointing devices

Two studies examined the effect of alternative pointing devices on upper extremity MSK outcomes. One high quality study (Rempel 2006) found positive effects on some upper extremity MSK outcomes (and no effect on others) for a trackball compared to a conventional mouse. One high quality study (Conlon 2008) found no effect on upper extremity MSK outcomes for a vertical mouse compared to a conventional mouse. Together, these studies provide **mixed** evidence that alternative pointing devices have an effect on upper extremity MSK outcomes. While our findings suggest mixed evidence exists for alternative pointing devices on upper extremity outcomes, the team considers the devices (a trackball and vertical mouse) very different input technologies. While both are designed to reduce wrist pronation, Rempel 2006 found only positive effects for the left side of the body. Given right-handed dominance of the study population and society in general, the team does not consider the health effects as strongly as if they were on the right side of the body.

Arm supports

Three studies evaluated arm supports: two high quality studies (Conlon 2008, Rempel
2006) found positive and no effect and one medium quality study (Lintula 2001) found no effect. Positive effects were found in both high quality studies for right upper extremity self-report outcomes. Given the right-handed dominance, the team considers these health effects as important. These studies provide **moderate** evidence that arm supports have a **positive** effect on upper extremity MSK outcomes.

New chair

One high quality study (Rempel 2007) found a positive effect on upper extremity MSK outcomes with the introduction of a curved seat pan chair (new chair) and a flat seat pan chair (modified chair) in garment workers. This single high quality study provides **limited** evidence that both a new chair and a modified chair have a **positive** effect on upper extremity MSK outcomes.

Rest breaks

Four studies evaluated the effects of rest breaks: all studies were medium quality (Galinsky 2007, Galinsky 2000, Mclean 2001, van den Heuvel 2003). One study (van den Heuvel 2003) found no effect. The break pattern

evaluated in this study was a five-minute break every 35 minutes. The three other medium quality studies (Galinsky 2007, Galinsky 2000, McLean 2001) found positive or no effect, depending on the time between rest breaks and the upper extremity outcome. For the positive findings, the break patterns were as follows: a five-minute break every hour (Galinsky 2007, Galinsky 2000) and a 30-second break every 20 minutes (McLean 2001). Two studies used software to prompt breaks (van den Heuvel 2003 and McLean 2001), while two studies used timers (Galinsky 2007 and Galinsky 2000). Taken together, there was **limited** evidence that rest breaks have a **positive** effect on upper extremity MSK outcomes.

Rest breaks & exercise

A single medium quality study (van den Heuvel 2003) evaluated rest breaks combined with stretching exercises during the break. This study reported no effect on upper extremity outcomes. With a single medium quality study, there is **insufficient** evidence to determine whether rest breaks combined with exercise has an effect on upper extremity MSK outcomes.

Participatory ergonomics

A single medium quality study (Laing 2007) evaluated a participatory ergonomic approach that was aimed at improving communication and psychosocial exposures. This study reported no effect on upper extremity outcomes. With a single medium quality study, there is **insufficient** evidence to determine whether a participatory ergonomics program has an effect on upper extremity MSK outcomes.

Broad-based MSK Injury Prevention Program (MIPP)

A single medium quality study (Leclerc 1997) evaluated a broad-based MSK injury prevention program. This study found either positive (shoulder outcome) or no effect (neck outcome), depending on the outcome. With a single medium quality study, there is **insufficient** evidence to determine whether broad-based MSK injury prevention programs have an effect on upper extremity MSK outcomes.

Prevention strategies & physical therapy

A single medium quality study (Lemstra 2003) evaluated an occupational management approach involving prevention strategies plus physical therapy compared to standard care (standard medical and physical therapy). This study found positive effects for upper extremity employer outcomes (i.e. lost work days and workers' compensation outcomes). With a single medium quality study, there is **insufficient** evidence to determine whether the prevention strategies combined with physical therapy have an effect on upper extremity MSK outcomes.

Miscellaneous work redesign

Four studies evaluated the effects of some type of work redesign: all studies were medium quality (Lin 2007, Luijsterburg 2005, Fredriksson 2001, van

der Molen 2004). Taken together, there was **limited** evidence that work redesign has **no** effect on upper extremity MSK outcomes. However, these four studies included disparate work redesign interventions that occurred under a wide set of circumstances with no replication. Given this, the team felt that the review should also address findings from the individual studies. With only single medium quality studies, there is **insufficient** evidence to determine whether work redesign [under various circumstances i.e. redesign of VDT workstations in semiconductor manufacturing (Lin 2007), change from line out to line production in car body sealing (Fredriksson 2001), raised bricklaying (Luijsterburg 2005), mechanical assist for bricks/mortar transport (van der Molen 2004)] has an effect on upper extremity MSK outcomes.

Multi-component patient handling

Multi-component patient handling includes three components: policy change, equipment purchase and training on equipment usage and patient handling. A single medium quality study (Yassi 2001) evaluated this intervention and found positive effects on shoulder outcomes for the "safe-lift policy" intervention (lifting & transfer equipment) and no effect for the "no strenuous lifting" intervention (new mechanical patient lifts). With a single medium quality study, there is **insufficient** evidence to determine whether either multi-component patient handling intervention had an effect on upper extremity MSK outcomes.

3.5 Further examination of the evidence base

Consensus was reached by the review team to explore whether studies with small samples and studies where there was no adjustment for covariates/confounders in the analyses could distort the evidence synthesis conclusions. The team felt that well-designed studies with small samples may not show a positive effect for the intervention when, in fact, a positive effect exists. This would lead to an understatement of the level of evidence for an intervention.

The team also felt that studies where no covariates or confounders were controlled for in the analysis could show a positive effect for the intervention when, in fact, there is no effect of the intervention on upper extremity MSK outcomes. This would lead to an overstatement of the level of evidence for the intervention.

Overall, we found small sample sizes did not lead to null findings (33 to 50 per cent had no effect findings) and the lack inclusion of covariates/confounders did not lead to positive findings (48 to 57 per cent of the studies showed no effect). What follows details this exploration. In summary, the team did not consider these two important methodological issues to influence our evidence synthesis.

Small sample size: Do small sample sizes (defined as n <= 20) lead to null (or no effect) findings?
We identified six studies (of 36 studies) in data extraction with total samples sizes of 20 subjects or less (van der Molen 2004, Thomas 1993, Martin 2003, Nevala-Puranen 2003, Rempel 1999, McLean 2001). Only two of the six studies had no effect findings (van der Molen 2004, Thomas 1993) and the remaining had positive findings (Martin 2003, Nevala-Puranen 2003, Rempel 1999, McLean 2001).

In addition, we looked at studies where reviewer pairs raised concerns about small sample sizes at either quality assessment and/or data extraction phases. This added two additional studies (Cook 2004, Lintula 2001) and increased the number of no effect studies to four of eight studies (Thomas 1993, van der Molen 2004, Cook 2004, Lintula 2001).

Together, these explorations increase our confidence that the evidence synthesis statements we made above are representative of the full literature and not biased by inclusion of studies with small sample sizes.

Analysis of covariates/confounders: Do studies that lacked adjustment for covariates/confounders in final analysis lead to positive findings?
To examine this, we looked at three conditions: 1) studies that adjusted for three important covariates (age, gender and primary outcome) as identified in quality assessment (Q#13, *Table 4*) or showed no baseline differences in these three variables and thus did not need to adjust; 2) studies that adjusted for any covariates or confounders in the final analysis or controlled for covariates through study design; 3) studies that minimally controlled for baseline musculoskeletal health either through statistical analysis or design (e.g. matching).

1. Twenty-three studies did not adjust for pre-intervention differences **or** demonstrate no baseline differences. Ten found a positive effect (Lundblad 1992, Sjogren 2005, Nevala-Puranen 2003, Bohr 2000, Tittiranonda 1999, Galinsky 2007, Galinsky 2000, McLean 2001, Yassi 2001, Lemstra 2003), and 13 studies had no effect findings (Kamwendo 1991, Thomas 1993, Feuerstein 2004, Cook 2004, Greene 2005, Veiersted 2007, Lintula 2001, van den Heuvel 2003, Laing 2007, Lin 2007, Luijsterburg 2005, Fredriksson 2001, van der Molen 2004).

2. Twenty-three studies did not adjust for any covariates/confounder(s) or control for covariates through study design. Twelve of the 23 studies had positive effects (Lundblad 1992, Nevala-Puranen 2003, Bohr 2000, Peper 2004, Martin 2003, Tittiranonda 1999, Galinsky 2007, Galinsky 2000, McLean 2001, Leclerc 1997, Yassi 2001, Lemstra 2003), and 11 studies had no effect findings (Horneij 2001, Faucett 2002, Thomas 1993, Feuerstein 2004, Cook 2004, Veiersted 2007, Lintula 2001, Laing 2007, Lin 2007, Luijsterburg 2005, van der Molen 2004).

3. Twenty-four studies did not evaluate or adjust for pre-intervention differences in baseline health or control by design. Eleven of the 24 studies had positive findings (Lundblad 1992, Nevala-Puranen 2003, Bohr 2000, Peper 2004, Tittiranonda 1999, Galinsky 2007, Galinsky 2000, McLean 2001, Leclerc 1997, Yassi 2001, Lemstra 2003), and 13 studies had no effect findings (Kamwendo 1991, Faucett 2002, Thomas 1993, Feuerstein 2004, Cook 2004, Veiersted 2007, Lintula 2001, van den Heuvel 2003, Laing 2007, Lin 2007, Luijsterburg 2005, Fredriksson 2001, van der Molen 2004).

Taken together, these three explorations suggest our evidence synthesis is not being influenced by the heterogeneity of the research design and analyses.

4.0 Discussion

4.1 Main findings from this review

This systematic review sought to answer the question: "Do occupational health and safety interventions prevent upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time?" and to consider the evidence for the effectiveness of specific interventions.

From an initial pool of more than 15,000 articles, we identified 36 studies that were included in our data synthesis. Across all intervention categories, the results suggest a **mixed level of evidence** for the effect of **occupational health and safety interventions** on upper extremity MSK outcomes. A mixed level of evidence means there were medium to high quality studies with inconsistent findings.

Importantly, no evidence was found that any occupational health and safety intervention had a negative or harmful effect on upper extremity musculoskeletal health. The above conclusions do not change when considering only high quality studies. The mixed level of evidence finding may be due to the heterogeneity of intervention types grouped together where some interventions were effective and others not. Consequently, the review team further considered the level of evidence for each specific intervention category.

Strong level of evidence

We found a **strong** level of evidence for **NO** effect on upper extremity MSK outcomes in one intervention:

- **Workstation adjustments alone**

All workstation adjustment interventions were conducted in office environments and focused on computer workstations. It is recommended that readers of this review examine the specific workstation adjustments evaluated in the studies. We found no strong evidence for any other occupational health and safety interventions.

The review team strongly discourages an approach to prevention where only workstation adjustments are made to computing workstations. We recommend that worksites not engage in a program of workstation adjustments alone. Furthermore, the review team considers it of limited utility for further studies to be conducted that only test the effectiveness of workstation adjustments on upper extremity MSK outcomes in office environments when there are a series of practices described below that may have positive benefits.

Moderate level of evidence
A **moderate** level of evidence for a **positive** effect on upper extremity MSK outcomes was found for one intervention:

- **Arm supports**

The review team considers the use of arm supports an important **practice consideration**. The results from these interventions were localized in the right side of the body and, given the right-handed dominance of the majority of the population, the team considers these health effects as important. All interventions were conducted in office environments, but the review team considers the use of arm supports a practical design strategy to reduce muscle loading in the upper extremity and potentially useful in a range of work environments.

A **moderate** level of evidence for **NO** effect on upper extremity MSK outcomes was found for two interventions:

- **Biofeedback training**
- **Job stress management training**

As both of these interventions occurred in a range of work environments, we consider the results generalizable to a broad range of workplace settings.

Limited level of evidence
A **limited** level of evidence for a **positive** effect on upper extremity MSK outcomes was found for four interventions:

- **Ergonomics training plus workstation adjustment**
- **Alternative keyboards**
- **New chair**
- **Rest breaks**

We found limited evidence that ergonomics training combined with workstation adjustment had a positive effect on upper extremity MSK outcomes. This is significant because, when initiated as separate interventions, there was strong evidence that workstation adjustments alone had NO effect on upper extremity MSK outcomes and mixed evidence on ergonomics training alone. Even though the workstation adjustments varied across all the studies, the review team felt the evidence is emerging and until new research is conducted and available, that workstation adjustment combined with training appears to be more effective when used together compared to using either intervention independently.

A **limited** level of evidence for **NO** effect on upper extremity MSK outcomes was found for two interventions:

- **Cognitive behavioural training**
- **Miscellaneous work redesign strategies**

The review team considers the interventions with a limited level of evidence to be of particular importance to researchers, funders, labour and employers participating in research. For several specific interventions, the addition of one or two high quality studies could shift the level of evidence from limited to moderate or strong. Thus, we have identified those interventions with positive effects as practices where evidence is emerging.

These results should not discourage researchers and practitioners from continuing to develop different cognitive behavioural training or work redesign interventions. The specific work redesigns studied and the workplace settings should be reviewed by the reader. From a hazard control perspective, work redesign strategies that remove the hazard from the workplace are an important injury prevention strategy. Practitioners should be careful not to make generalizations about the role for cognitive behavioural training in improving upper extremity musculoskeletal health.

Mixed level of evidence

The review team concluded there was a **mixed** level of evidence (medium and high quality studies with inconsistent findings) on upper extremity MSK outcomes for a range of interventions:

- **Exercise programs**
- **Ergonomics training plus exercise**
- **Ergonomics training**
- **Alternative pointing devices**

In order to advance the field and shift the level of evidence from mixed to positive, further research of these interventions should be of high methodological quality (*see Table 4 for quality criteria*). While mixed evidence exists for alternative pointing devices, the synthesis aggregates quite different pointing devices (a vertical mouse and a trackball). The review team is cautious in making any recommendations about specific alternative pointing devices.

The team also considers the interventions with a mixed level of evidence to be of particular importance to researchers, funders, labour and employers participating in research. For several specific interventions, the addition of one or two high quality studies could have shifted the level of evidence from mixed to limited or moderate. Thus, these interventions require further study.

Insufficient level of evidence

There was **insufficient** evidence to determine an effect on upper extremity MSK outcomes for any of the following interventions:

- **Rest breaks plus exercise**
- **Participatory ergonomics**
- **Broad-based MSK Injury Prevention Program**
- **Multi-component patient handling**
- **Prevention strategies and physical therapy**

These occupational health and safety interventions have not been evaluated in studies using more rigorous designs. Such single studies of medium methodological quality provide an insufficient level of evidence for us to make general assertions about intervention effectiveness.

4.2 Comparison with other systematic reviews

We identified two recent systematic reviews that have examined a comparable research question with our review (8,18,19). Although one would hope that multiple systematic reviews addressing the same questions would provide greater clarity on the effectiveness for upper extremity MSDs, we found some discordance among the reviews. Here we highlight some of the reasons for the discrepancies in the messages from recent reviews compared with our review.

In this review, we used similar methods to an earlier IWH prevention systematic review of workplace interventions in computer users (18,19). There was considerable overlap between these reviews with 16 of the 36 studies (44 per cent) common across the two reviews. However, there were some differences in the final messages that can be explained by:

1. Additional articles published since the 2004 search by Brewer (2006);
2. Our review included all sectors/industries whereas the Brewer (2006) review was restricted to computer users;
3. Our review was specific to upper extremity MSK outcomes whereas Brewer (2006) included a range of musculoskeletal outcomes (including upper and lower extremity, neck, thoracic or upper back and low back);
4. Our review included studies with employer reports and workers' compensation reports of upper extremity MSK outcomes whereas Brewer (2006) excluded these outcomes;
5. Evolution in developing quality assessment criteria and criteria weighting that occasionally led to discordance in the quality assessment ranking (high versus medium or medium versus low) in a few studies (Tittiranonda 1999, van den Heuvel 2003, Martin 2003, Nelson 1998);
6. Evolution of the best evidence guidelines from a more recent IWH systematic review on economic evaluations (27) such that one high quality study resulted in a "limited level of evidence" whereas in Brewer (2006), this would have been considered an "insufficient level of evidence."

Another recent systematic review by Boocock (2007) summarized the evidence on the effectiveness of interventions for the prevention and management of neck and upper extremity musculoskeletal conditions (8). They searched multiple databases from 1999 to 2004 and identified 31 relevant studies. Our review searched multiple databases from inception to 2007 and identified 36 studies that met our relevancy criteria.

Despite both reviews having similar inclusion criteria (related to population, intervention and outcomes), only six studies were common across the two reviews (Nevala-Puranen 2003, Ketola 2002, Tittiranonda 1999, van den Heuval 2003, Faucett 2002, Bohr 2000). Some of these differences can be explained by our broader search strategy (i.e. search terms used, time frame of search). However, much of this variation is the result of the inclusion of more heterogeneous study designs in the Boocock (2007) review.

Almost 50 per cent (15/31) of the studies included in their evidence synthesis were described as having "no control group." These single group study designs were excluded in the quality assessment phase of our review. In addition, our review excluded any study that had a control or comparison group and did not do a direct statistical comparison between the intervention and the control group. In the absence of a direct between-group statistical comparison, we could not make any inferences about the effect of the intervention. Studies such as these (Aaras 2001, Mekhora 2000) were included in the Boocock (2007) review.

Furthermore, Boocock (2007) allowed a wider range of methodological quality (low, medium and high quality ratings) to contribute to their evidence synthesis. Our review used a best evidence synthesis guideline (*see Table 6*) in which only studies rated as high and medium quality moved forward to evidence synthesis.

Our review team recognized that one of the important results of the methodological quality assessment was an ability to speak about a large part of the research. However in evidence synthesis, we aimed to focus on those studies where we had confidence in their conclusions. Lower overall methodological quality reflects a greater uncertainty among the review team as to whether the findings were the result of chance or some other program or practice on-going in the workplace or jurisdiction and not the intervention. Another review has shown that the inclusion of studies with lower methodological quality were more likely to find positive effects (41).

Generally, the Boocock (2007) review combined more diverse interventions in grouping their intervention categories for evidence synthesis. The following are examples of the intervention classifications used: *work environment/workstation adjustments* (included new workplaces +/-

ergonomics training, workstation adjustment +/- ergonomics training) and *ergonomic equipment* (included new chair, new tools, gloves).

Our review team felt that these interventions were too different to combine and thus chose to split many of these intervention categories in our evidence synthesis. We found that combining heterogeneous interventions led to mixed levels of evidence and the loss of messages that emerge from more specific intervention categories.

4.3 Strengths of this systematic review

The review team included members with varied backgrounds and specializations (e.g. expertise in the systematic review process, occupational health and safety, clinical treatment of persons with MSK problems and epidemiology). We believe this broad expertise contributed to the internal validity of our review.

Also, our broad and exhaustive literature search strengthens our review. We contacted external experts to request potentially relevant published articles, along with articles in press. This provided another way to ensure that as much relevant literature as possible was reviewed.

In addition, at our methodological quality assessment phase, we asked reviewers to identify other relevant studies included in the reference list of the article. Our experience with previous reviews has found that this step is important for us to identify studies that might have been missed in the search and to bring together multiple articles that might have been written for one study.

The review was not limited to articles published in the English language. Several non-English articles were reviewed during relevance (Level 1a & Level 1b) before methodological quality assessment. Only one study (Hladky 1998, Czech language) moved forward to quality assessment. However, it was not possible to include the study in our quality assessment and data synthesis since we were unable to identify two reviewers to assess the article.

The review team used a quality control process to assess the early phase of article exclusion. We also used a process of randomly pairing reviewers at each phase to improve independent assessment by at least two team members. Review teams used a transparent approach for making decisions and all decisions were made using consensus. At the data extraction phase of the review, review team pairs examined the quality assessment results to determine if they agreed. Discrepancies were resolved by team consensus. The review team was impressed with the importance of having many people examining each study.

Additional quality control processes included exploring for discrepancies in methodological quality assessment scores in similar studies that have been reported in previous IWH systematic reviews (18,19,26,34). We found that the differences in quality scores could be explained by a different set of criteria being used in the quality assessment and in the weighting of the criteria.

Our review included studies with a range of upper extremity MSK outcomes to include: 1) worker self-report; 2) clinical; and 3) employer records and workers' compensation reports. While a number of studies used worker self-report and clinical outcomes, the review team was surprised by the lack of studies using employer records and workers' compensation reports. Engagement with our stakeholder groups has identified these as critical outcomes in the implementation of programs and practices.

Our evidence synthesis focused on studies using designs in which we had confidence in their conclusions. As such, our evidence synthesis only included studies that: 1) ranked high and medium quality; 2) had a control or comparison group; and 3) did a direct statistical comparison between the intervention and the control/comparison group.
Study quality is important and it has been shown that lower quality studies are more likely to find positive effects (41).

4.4 Limitations of this systematic review

A broader search of the grey literature, conference proceedings and dissertations might have yielded further relevant evidence on the effectiveness of occupational health and safety interventions on upper extremity MSK health outcomes. However, the review team believes that most high quality research will be published in peer-reviewed literature, and thus is not a substantial limitation to leave out the grey literature.

Because of time constraints, the review team was unable to clarify specific questions about a study with the study authors. For example, contacting authors for additional information related to the intervention description might lead to a better understanding of the characteristics of effective interventions.

Although a quantitative synthesis (or meta-analysis) was considered in this review, it was not appropriate due to differences among comparison/control groups, the use of different outcome measures and insufficient data reported. Similarly, comparable systematic reviews (8,18,19) have not been able to use quantitative syntheses due to the heterogeneity of the included studies.

4.5 Implications for further research

Many interventions could provide fertile ground for additional high quality studies. However, researchers, funders, employers and organized labour should attend to the effects (*Table 10*) and study quality (*Table 4*) when

determining interest and investment in further research. Clearly, high quality studies are necessary to achieve the strong level of evidence we desire for recommending programs and practices.

As more research is being conducted and supported by employers, labour and government, we have summarized some issues to consider before embarking on new projects:

- Researchers should use concurrent worksite control groups as opposed to study designs with simulated controls, statistical controls or cross-over designs. True concurrent controls contribute results that are more generalizable across industrial sectors.
- Researchers should include a "no intervention" control group. We identified several studies where the control/comparison group received "training only" while the intervention group received "training plus new equipment." The effects of an intervention may be reduced by the control/comparison group receiving a component of the treatment received by the intervention group.
- Field studies should have adequate sample sizes to reduce the risk of mistakenly concluding an intervention has no effect, simply because the sample is too small.
- Rather than testing three or more treatment arms, if the sample size is limited, it is more valuable to test an intervention and a control.
- For upper extremity musculoskeletal disorders, the review team recommends that studies be four to 12 months in duration to allow for examining the sustained effects. This time period appears adequate to observe changes; there is evidence that musculoskeletal symptoms may take weeks or months for change following an intervention. However, longer duration studies require more attention to other ongoing workplace changes that are potentially confounding.
- In addition to worker self-report outcomes, researchers should consider using workers' compensation, injury records or other regulated injury reporting systems using standard approaches that are common to the reporting requirements demanded of stakeholders.
- Covariates and confounders should be measured and adjusted for using multivariate statistical models. This is especially true when the researchers are unable to randomize workers into either intervention or control groups.
- Single interventions (i.e. training only, equipment only) tend to lead to no effect outcomes. A common characteristic of interventions showing positive effects is the multi-component nature of the intervention (i.e. training combined with addressing issues in the environment).
- There is a lack of work-based intervention studies on the management of upper extremity MSDs in non-office based sectors. Of the articles that proceeded to evidence synthesis, studies in the

office sector accounted for 61 per cent (22 of 36 studies) of the evidence base.
- No studies were identified that looked at the prevention of acute traumatic upper extremity injuries.

As a result of these concerns, one potential action that stakeholders could take is to convene a conference or series of position papers advocating standards for occupational health and safety intervention research.

4.6 Next steps

The review team believes that the systematic review process should continue to develop in several ways when considering the occupational health and safety literature:

- It is important to include non-English articles.
- Depending on the research question, the grey literature should be explored to determine if it would add value to the evidence synthesis.
- If necessary, article authors should be contacted to clarify findings in the published studies.
- When possible, studies where between-group comparisons were not made should be re-analyzed to provide evidence that can be included in data synthesis.

Most studies have used either worker self-report and/or clinical outcomes. Researchers should be including outcomes that are important to their stakeholders such as workers' compensation, injury records or other regulated injury reporting systems.

Many of the well-conducted, randomized controlled studies have been done in the office sector. The overwhelming message from our review is that more high quality research across industries and sectors is needed. The team was surprised and somewhat frustrated by the lack of work-based intervention studies evaluating upper extremity musculoskeletal disorders in non-office based sectors. Furthermore, the office sector is known for frequency of injuries but not necessarily for severity (e.g. amputations, lacerations).

We did not identify any studies that looked at the prevention of acute traumatic upper extremity injuries. This review proved fertile ground for discovering knowledge gaps in this literature. It is vital that we begin to generate the amount and quality of evidence required so decision-makers can make evidence-informed decisions about preventing and managing upper extremity musculoskeletal disorders.

5.0 Messages

Based on the evidence from this review, the following messages have been extracted.

We **recommend** that worksites NOT engage in health and safety activities that include workstation adjustments alone. However, when combined with ergonomics training, there is limited evidence that workstation adjustments are beneficial for preventing upper extremity MSDs.

We note that a **practice to consider** is that using arm supports may reduce upper extremity MSDs.

Another **practice to consider** is that the research evidence does NOT support adopting biofeedback and job stress management as training programs to reduce upper extremity MSDs.

More research is needed of high quality studies, including a comparison no intervention group (control), sufficient study sample, and a follow-up duration of four to 12 months. Research should specifically focus on the effectiveness of combined interventions (e.g. training and adjustment), alternative keyboards, chairs and rest breaks, and on non-office workers and acute traumatic upper-extremity injuries.

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Appendices A - I

Appendix A

List of stakeholders who attended the first meeting

Toronto (May 2007)

Attendees:

Jonathan Tyson	Pulp and Paper Health & Safety Association
Anne Duffy	Ontario Ministry of Labour
Andrea Duncan	Workplace Safety & Insurance Board, Return To Work Branch
Starly Catli	Workplace Safety & Insurance Board, Medical and Occupational Disease Policy Branch
Alice Peter	Workplace Safety & Insurance Board, Occupational Disease Policy and Research
Gary Doig	Workplace Safety & Insurance Board, Ergonomist
David Mijatovic	Occupational Health Clinics for Ontario Workers

List of stakeholders who attended the follow-up meeting

Toronto (July 2008)

Attendees:

Anne Duffy	Ontario Ministry of Labour
Lucy Hart	The Global Company
Jamie Williamson	Workplace Safety & Insurance Board, Return To Work Branch
Deborah McBride	Workplace Safety & Insurance Board, Occupational Disease Policy and Research

Appendix B

Reviewer guide for Level 1a and Level 1b

Level 1a Guide for Reviewers

The guide is designed to provide all reviewers with the same information. Each reviewer should become thoroughly familiar the guide prior to conducting a review. Inter-rater variability should be minimized by each rater's familiarity with the guide. The bolded materials below are included in the table in Memo 1 and in the SRS on-line form.

Questions 1–5 are designed to remove articles not relevant to our research questions. All questions should be answered so we can collect the totals regarding why articles were excluded.

Please do not interpret or vary from the definitions supplied in the guide. Please contact Carol if you are unclear or have problems using the guide as written. We are trying to minimize differences between reviewers by strictly following the definitions as outlined in Memo 1.

Level 1a (Title & Abstract) Review

Q1. Did an occupational health and safety intervention occur?
The reviewer is first asked to determine if the paper should be excluded because an occupational health and safety intervention did not occur. Occupational health and safety interventions will be defined as any occupational health and safety primary, secondary or tertiary intervention designed to reduce musculoskeletal symptoms, signs, disorders, injuries, claims and lost time. Interventions will be defined broadly initially by utilizing the traditional hazard control tiers of engineering controls, administrative controls and personal protective equipment use. Excluded are interventions that are designed to only meet regulatory requirements (e.g., respiratory, needlestick, blood-borne pathogens and violence prevention), violence prevention programs where the primary outcome is violence reduction and not musculoskeletal injury reduction (note: biomechanical interventions designed to reduce assaults and consequently musculoskeletal injuries are included), office interventions designed to improve visual health status [since this intervention has been reviewed in another one of our prevention systematic reviews of computer-related office interventions (18) and worksite health promotion or clinical interventions that are not delivered in the workplace (i.e. off-site treatments such as physiotherapy clinics, work hardening programs and back schools). Pre-placement screening and examinations (e.g. nerve conduction testing, genetic testing) will only be included if they are required by the workplace (regardless of whether or not the medical examination occurs at the workplace or off-site). Studies designed to examine productivity will only be included if they have been analyzed to yield information of relevance to prevention (i.e. studies which clearly indicate that health effects were included among the study outcomes and were evaluated for an effect of the intervention). Excluded are case reports and case series that describe an OHS intervention but are not clearly investigating a specific OHS intervention in a study.

a) **Yes**
b) **Unclear**
c) **No**

Q2. Did the study occur in a work setting?
The reviewer is asked to determine if the paper should be excluded because it did not occur in a work setting. *Work setting (or workplace)* considered complaints to be work-related when stated in text of the study, or when people are selected from a specific working population. Occupational health and safety interventions delivered to students working at a workplace as part of their student curriculum will not be included as workplace training.

a) **Yes**
b) **Unclear**
c) **No**

Q3. Is the article from a peer-reviewed publication (in press or accepted for publication)?
The reviewer is asked to determine if the article should be excluded because it is not from a peer-reviewed publication. A list of known peer-reviewed journals has been provided to each team member and should be referenced as needed. The peer-reviewed list is included as Attachment 4 in Memo 1.

a) **Yes**
b) **Unclear**
c) **No**

Q4. Is article a review, commentary, letter to the editor, editorial or two pages or less in length?
These articles are being excluded as the review is focusing on original studies. The information needed to answer this question is often found in the title. Please note (by flagging in SRS) if a systematic review of occupational health and safety and upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims or lost time is found. Unless it explicitly says in the title or keywords that the article is a review, commentary or letter to the editor then error on being inclusive (i.e. answer No or Unclear). Unless it explicitly lists the page numbers (i.e. 121-122) then err on being inclusive (i.e. No or Unclear).

a) **Yes**
b) **Unclear**
c) **No**

Q5. Is the outcome an upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims or lost time?
The reviewer is asked to determine if the paper should be excluded because it did not include an upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims or lost time outcome. *Musculoskeletal disorder* will be defined as musculoskeletal

symptoms, signs, or clinical diagnoses. These are injuries to or disorders of the muscles, tendons, ligaments, joints, nerves, blood vessels or related soft tissue including a sprain, strain and inflammation. We include workers' compensation claims data, employer reports and OSHA log data. Both individual health data (i.e. injuries at an individual level) and grouped data (i.e. rates at workplaces - rates between an intervention and control worksite) will be included. We recognize the importance of physical risk factors, such as muscle loading, as a plausible pathway; however, we exclude studies where changes in exposure to these physical factors are the only primary outcome without considering changes in musculoskeletal disorders and injuries. We exclude surgeries, cancers and pregnancy related musculoskeletal symptoms, signs, disorders and diagnoses. *Upper extremity* will include the following involved zones – neck, shoulder or upper arm, elbow or forearm, wrist or hand (Beaton et al, 2007 Scand J Work Environ Health). Excluded regions include the thoracic spine, lower extremity, lumbar spine and low back. Also excluded are studies that only report total symptoms (i.e. total body symptom count). Studies that look at the outcome "comfort" (i.e. scale assessing only level of comfort) will be excluded and studies that look at the outcome "discomfort" (i.e. scale with anchors from level of comfort to level of discomfort) will be included.

a) Yes
b) Unclear
c) No

Level 1b Guide for Reviewers

The guide is designed to provide all reviewers with the same information. Each reviewer should become thoroughly familiar the guide prior to conducting a review. Inter-rater variability should be minimized by each rater's familiarity with the guide. The bolded materials below are included in Table 2 and Table 3 in Memo 1 and in the SRS on-line form.

Question 1 is designed as a Quality Control Check to remove articles not relevant to our research questions (based on Criteria 1 to 5 in Table 2). Question 2 is designed to remove articles not relevant to our research question based on relevancy of the study design. Both questions should be answered so we can collect the totals regarding why articles were excluded.

Please do not interpret or vary from the definitions supplied in the guide. Please contact Carol if you are unclear or have problems using the guide as written. We are trying to minimize differences between reviewers by strictly following the definitions as outlined in Memo 1.

Level 1b (Full Article) Review

Quality Control Check

Q1. Should the article have been excluded in Level 1a (Title & Abstract) review for any of the following reasons (Refer to criteria 1 to 5 listed below)?

Remember to use the definitions for work setting (or workplace), occupational health and safety interventions, musculoskeletal disorder and upper extremity stated in Memo 1.

1. Occupational health and safety intervention did <u>not</u> occur
2. Did <u>not</u> occur in a work setting
3. Article is <u>not</u> from a peer-reviewed publication (in press or accepted for publication)
4. Article <u>is</u> a review, commentary, letter to the editor, editorial or two pages or less in length
5. Outcome <u>not</u> an upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims or lost time (including OSHA log data and workers' compensation claims data)

a. **Yes, article is NOT relevant based on one or more Criteria (1 to 5) (specify, _____)**

The study does NOT meet one or more of our relevance criteria (1 to 5). Please specify by listing the numerical criteria to which the study is NOT relevant.

b. **No, article is relevant based on Criteria (1 to 5)**

The study meets our relevance criteria (1 to 5).

Study Design Relevancy

Q2. Is the design a single group or a post-only study?

The reviewer is asked to determine if the paper should be excluded because it is a single group or a post-only study. A single group has no control or comparison group. It is a single group design. Participants could have different pre-intervention characteristics that could account for change. Additionally, secular changes to the workplace could explain observed changes in workplaces. A post-only design has no pre-intervention measures. In combination, if a study doesn't include comparisons with pre-intervention measurements as well as no control group then the study can't account for the two biggest threats to validity of workplace research: pre-intervention differences and secular changes. If the study is a single group or a post-only study, it will be excluded.

a) **Yes (article is NOT relevant and should NOT proceed to QA)**
b) **Unclear**
c) **No**

Appendix C

Quality assessment guide for reviewers

The quality assessment will be conducted on the studies that remain following the exclusion steps – Level 1a and Level 1b review. The quality assessment process involves a review of the full article to evaluate the overall quality of the article and provide a quality ranking. The ranking determines if the article should continue to the data extraction step of the review.

The guide is designed to provide all reviewers with the same information. Each reviewer should become thoroughly familiar with the guide prior to conducting a quality assessment review. Inter-rater variability should be minimized by following the guide. The bolded materials below are included in the SRS on-line form.

Design and Objectives

Q1. Is the research question clearly stated?

If the aim of the study is not clearly stated then results are likely of limited value. A clear, explicit statement of objectives should be included in the study. Consider if the question is "focused" in terms of: the population studied, the intervention given and the outcomes considered.

a) **Yes**
b) **Unclear**
c) **No**

Q2. Were comparison group(s) used? (choose only one answer)

A comparison group is important to document and account for the potential effects of unexpected secular changes. Having a closely analogous comparison group, with similar exposure to causal risk factors as the intervention subjects is a major strength of a workplace intervention study. A comparison group can receive a "placebo" and thus be considered a comparison.

By "concurrent," it is expected the information on the comparison group is collected at the same times as the treatment group. The crossover design would be considered a concurrent control as this method compares two or more interventions in which subjects, upon completion of the course of one treatment, are switched to another. However, a criticism of the crossover design is that the effects of the first intervention may carry over into the period when the second is given.

By "historical," it implies that the comparison group for whom data were collected was at a time preceding that at which the data are gathered on the group being studied (e.g. clinical example of historical comparison is study which compares length of stay, cost and complications after the introduction of a clinical care pathway in total joint replacement to the same measures in patients cared for a couple of years before the introduction of the clinical care pathway). The time series design would be included as a type of historical comparison. The problem with using historical controls is the potential for bias due to secular trends in cost and resource use (i.e. length of stay and costs had

generally decreased). Therefore, the reductions in length of stay and cost in the clinical pathway patients compared to the historical controls could simple reflect these secular trends and not a direct effect of the clinical pathway.

"Single group" implies one comparison group was used against which the intervention's effect was evaluated. "Multiple groups" implies more than one comparison group was used to evaluate the intervention's effects. Comparison groups can be within the same plant (such as different departments), or outside the intervention plant (such as a similar company in the same industry, etc.) and may have received no interventions, or some interventions that differ from those of the study group. Comparison groups are actual groups of individuals; *statistically generated references created for comparison do not constitute a control*.

a) Yes, concurrent comparison; single group

One concurrent comparison group was used against which the intervention's effect was evaluated.

b) Yes concurrent comparison; multiple groups

More than one concurrent comparison group was used to evaluate the intervention's effects. Comparison groups can be within the same plant (such as different departments), or outside the intervention plant (such as a similar company in the same industry, etc.) and may have received no interventions, or some interventions that differ from those of the study group.

c) Yes, historical comparison; single group

One historical comparison group was used against which the intervention's effect was evaluated.

d) Yes historical comparison; multiple groups

More than one historical comparison group was used to evaluate the intervention's effects. Comparison groups can be within the same plant (such as different departments), or outside the intervention plant (such as a similar company in the same industry, etc.) and may have received no interventions, or some interventions that differ from those of the study group.

e) Unclear

f) No comparison group

No comparison groups were used in the study.

Q3. Was an intervention allocation described adequately?

Inadequate description of the exposure/intervention allocation strategy makes it impossible to reproduce the intervention allocation strategy in another population. This should be clearly stated to be reproducible by others. However, random allocation of treatment/intervention conditions (by study participants, work units or organizations described as randomly receiving the intervention) is the preferred scientific method as it is most likely to control for confounding.

a) **Well described; random**
b) **Well described; not random**
c) **Not well described; random**
d) **Not well described; not random**
e) **Unclear**

Level of Recruitment

Q4. Was recruitment (or participation) rate reported?

Recruitment (or participation) rate is the ratio of those workers/departments/organizations who agreed to participate in the study over those workers/departments/organizations who were approached to participate in the study but chose not to participate based on various reasons (e.g. worker refused to participate in study). Sometimes the information to calculate a recruitment (or participation rate) must be abstracted from information reported in tables.

a) **Yes**
b) **Unclear**
c) **No**

Q5. Were pre-intervention characteristics described? (if yes, then check all that apply)

Indicate if pre-intervention characteristics are described, these may include job related factors, individual characteristics, and factors related to exposures and outcomes (for example baseline pain levels across groups, gender). A description of pre-intervention characteristics allows us to identify any important pre-intervention characteristics that could potentially confound the relationship between the intervention and the outcome. It is important to measure potential confounders/effect modifiers as they could mask any true associations that may be present and therefore threaten interval validity of a given study. In turn, statistical methods can be used to adjust or control for these factors. Possible adjustment methods include stratifying based on the difference (for example if gender is different one can do separate analyses for males and females).

a) **Employees/workers**

Individual level information – for example years on job

b) **Department/supervisors**

Information on department level – for example per cent female

c) **Organizations/workplace**

Information at site level – for example the per cent of workers in each department could also include per cent females and males

d) **Unclear**
e) **Not Described**
f) **Not Applicable**

One example of a circumstance where not applicable would apply – a randomized trial conducted in which the author(s) asserted that randomization works but did not confirm it by measuring pre-intervention characteristics.

Q6. Was the loss to follow up (attrition) less than 35 per cent? (please report for the primary level of analysis)

There should be adequate follow up rate for each of the levels of recruitment identified above. The amount lost to follow up introduces the potential for exclusion bias, reduces the available sample size and reduces the confidence in the results obtained.

Note: Reviewers asked for further clarification when answering this question. We asked reviewers to use follow-up (attrition) rate for the longest follow-up period since in summarizing the results we will be using the longest follow up.

a) **Employees/workers (Specify: _____)**
b) **Department/supervisors (Specify: _____)**
c) **Organizations/workplace (Specify: _____)**
d) **Unclear**
e) **≥ 35%**
f) **Not reported**

Q7. Did the author examine for important differences between the remaining and drop out participants after the intervention? (if yes, then check all that apply)

Differential attrition of subjects poses a major threat to internal validity. Exclusion bias can result if certain subjects are systematically more likely to be lost to follow-up than others. Comparisons should be made for drop-outs and remaining participants on pre-intervention characteristics or other demographic variables, as available. When there are no statistical differences between these groups, one can be more confident that attrition bias did not occur.

a) **Yes**
b) **Unclear**
c) **No**
d) **Not applicable, high follow up rate makes this not necessary (consider less than 5 per cent attrition as high follow-up or use your own discretion)**

Intervention Characteristics

Q8. Was the intervention process adequately described to allow for replication? (choose only one answer)

Inadequate description of the intervention strategy makes it impossible to reproduce the intervention in another population. The setting of the intervention, (i.e., where it was carried out) what was changed and how, are important aspects to document.

a) **Yes**

All or most aspects of the intervention are clearly described.

b) **Unclear**

There is not enough information provided, the intervention process is not clearly described.

c) **No**

The intervention process is not described.

Q9. Were the effects of the intervention on some exposure parameters documented?

Another way the intensity of an intervention can be assessed is by looking at the extent to which ergonomic changes were actually implemented because of the intervention process. Do the researchers report process outcomes? For example did muscle loading change or did behaviours change because of training? These are a few of the process outcomes. For this reason documenting the changes is of key importance, particularly if one wishes to understand the pathway leading from the intervention to changes in health outcomes. Most importantly, if the process outcomes don't reflect the hypothesized changes then health effects may be due to other factors and not the intervention.

a) Yes
b) Unclear
c) No

Intervention Intensity

Q10. Was the participation in the intervention documented?

Examining the intensity with which the intervention is implemented within the organization is an important part of an evaluation, which has not been extensively documented in the literature. One way the intensity of an intervention can be assessed is by looking at the extent to which the workplace parties actually participate in the intervention process. We are not valuing the extent of the participation, rather that the researchers document it. This is intervention fidelity – was the intervention sustained for a period that could produce an effect? i.e. treatment logs, documentation on compliance with exercise.

a) Yes
b) Unclear
c) No

Outcomes

Q11. Were the upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and/or lost time outcomes described at baseline and follow-up? (check all that apply)

Our primary outcomes are employee upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims and lost time outcomes. Baseline is defined as 'at the time of the intervention OR information retrieved from/for years prior to the intervention (for example, intervention started in 2000 and OSHA records from 1997 were reported as "pre-intervention" data)'. Follow-up is defined as 'the period of time that the individual, group or initially defined population is observed following the completion of the intervention'.

a) Yes, described at baseline and follow-up
b) No, only described at baseline
c) No, only described at follow-up
d) Unclear
e) Not measured
f) Not applicable

One example of not applicable would be a randomized trial where the researchers asserted that randomization would equally distribute persons pre-intervention.

Q12. Was the length of follow-up 3 months or greater?
Length of follow-up refers to the period of time that the individual, group or initially defined population is observed following the completion of the intervention. An adequate follow-up period needs to occur for the intended effects of the intervention to occur.

a) **Yes**
b) **Unclear**
c) **No**

Analysis
Q13. Was there adjustment for pre-intervention differences (minimum threshold of three important covariates include age, gender and primary outcome at baseline)?
Statistical adjustment allows the researchers to control for factors that may potentially confound the relationship between the intervention and outcome. Possible adjustment methods include stratifying based on the difference (for example if sex is different one can do separate analyses for males and females). Another method is including the variable in the statistical model, this does not allow for the variable to vary, which eliminates its effect on the association of interest. The group reached consensus that a minimum threshold of three important covariates (age, gender, primary outcome at baseline) must be assessed in any given study.

a) **Yes, baseline differences were observed and adjusted for the three important covariates (age, gender and primary outcome at baseline)**
b) **Unclear**
c) **No, baseline differences were observed but not adjusted for the three important covariates (age, gender and primary outcome at baseline)**
d) **No, baseline differences were not reported for the three important covariates (age, gender and primary outcome) so no adjustment was performed**
e) **Not applicable, no baseline differences were observed for the three important covariates (age, gender and primary outcome) so no adjustment was necessary**
f) **Not applicable, only one group**

Q14. Were the statistical analyses optimized for the best results?
For example: Did the investigators use all the information that was available/collected when they did their analysis? Did they reasonably collect all that they could have in order to perform an optimal analysis?

a) **Yes**

Statistical methods are described sufficiently, and the methods used were appropriate and properly applied.

b) **Unclear**
c) **No**

An example where the statistical methods would be inappropriate is if the design has a control group and no between-group statistical comparisons are made. Similarly, if there are pre/post measures of the outcome the statistical analyses would be inappropriate if the pre-intervention measures are not considered in the analysis or if they did not demonstrate an absence of pre-intervention differences.

Q15. Were all participants' outcomes analysed by the groups to which they were originally allocated (intention-to-treat analysis)?
An estimated treatment effect may be biased if some randomised participants are excluded from the analysis. Intention-to-treat analysis aims to include all participants randomized into a trial irrespective of what happened subsequently.

a) **Yes**
b) **Unclear**
c) **No**
d) **Not applicable**

The study design did not use random allocation to the intervention(s).

Q16. Was there a direct between-group comparison?
The direct between-group comparison could be a statistical test, an estimate of effect size or expressed as a magnitude of effect. There MUST be a clear direct comparison between the intervention group and the control group to determine the extent to which the intervention produces an effect.

a) **Yes**
b) **Unclear**
c) **No**
d) **Not applicable, only one group**

Q17. Should this article proceed to data extraction?
Using all the information you have gathered on the article and after critically appraising its quality, please assess how confident you are that the results are valid, reliable and that bias in the results was minimal. If certain issues pertaining to the study quality have reduced your confidence in the results, please summarize these in the space provided (e.g. Study did not have enough participants to minimize the play of chance, Design was not adequate to answer question about the outcome, Contamination between groups was a problem).

a) **Yes**
b) **No (specify why?, _____)**

Q18. Are there other studies listed in this reference list which should be retrieved for consideration? (if yes, please include reference ID or author/year/publication etc.)
The primary authors will be the ones focusing on this question. However, if in your role as a general reviewer you discover a reference you think is important – please identify it. Often, the search will pick up Part I of a two part publication and we want to ensure we

are rating "studies" not articles. It is important for us to both identify studies that might have been missed in the search and to bring together multiple articles that might have been written for one study.

a) **Yes (specify, _____)**
b) **No**

Appendix D

Data extraction guide for reviewers

This guide must be read before beginning the data extraction. Print this guide (on a colour printer if possible) and have it available to refer to while doing the data extraction. Please extract the data from the articles you review by completing the form on SRS and entering text in the provided areas. Please read the questions carefully - especially the instructions in italics - which provide details on how to enter the data. Red text provides examples to illustrate specific responses.

All of the questions in the SRS form should have an answer. If an article lacks the information necessary to answer a particular question then the reviewer should enter "**not provided**" in the text box. It is important that all questions have answers because we will not know if an article did not have the information or a reviewer forgot to enter it if we allow blank answers. Remember, do not extrapolate just provide the information that is presented in the article. You may need to get information out of tables or figures (e.g., to calculate participation rates).

Data Extraction Questions:

Study design and setting:

1. **Name of first author and year of publication.** Write the last name of the first author and the year of publication (Author's last name, yyyy).

2. **State the research question(s)/objective(s).** If the research question(s)/objective(s) are well-stated then use the exact wording (in quotations) OR if not well stated then the wording – appears to say. If more than one objective; then list all objectives. Be clear to only include *the objectives tested* not broader objectives described.

3. **List the jurisdiction where the study was completed.** Provide information regarding the country, region, province, city, etc. where the study was carried out - enter "NP" where information is not available.

4. **Describe what type of worksetting(s)/workplace(s) that the study was conducted in.** Please use the language from the article to describe succinctly. Describe the organization and the unit as it is part of the setting. For example, the organization may be a hospital but the units are only surgical units in the hospital.

5. **List the job titles/classification of the participants that participated in the study.** Provide the level of detail given in the study or enter "NP" where information is not available.

6. **List the inclusion criteria for participants described in the study. (Please list inclusion criteria clearly).** Describe how the study selected their site, unit, or individuals for inclusion. This could be found in the setting description or in their outcome description. Especially studies that use "administrative" data as musculoskeletal outcomes their inclusion of employees or units could be found in the description of outcome measures. Please summarize the level for inclusion criteria using the following comment boxes "Site", "Unit", "Individuals" or "Not applicable". We use an example for administrative data because the inclusion criteria are found in unexpected places.

   E.g., Intervention units selected based on previous injury rate (UNIT); back injuries defined as upper or lower trunk injury resulting in either lost time or health-care expenses (INIDIVIDUALS)

7. **List the exclusion criteria described in the study. (Please list exclusion criteria clearly).** Describe how the study selected their site, unit, or individuals for exclusion. This could be found in the setting description or in their outcome description. Especially studies that use "administrative" data as musculoskeletal outcomes their exclusion of employees or units could be found in the description of outcome measures. Please summarize the level for inclusion criteria using the following comment boxes "Site", "Unit", "Individuals" or "Not applicable". List any exclusion for types of injuries or employee title excluded in abstraction from the injury record? **E.g. "neck or shoulder injuries (Individuals)".**

8. **What is the study design? (Choose only one)**. Please describe any unique characteristics verbatim about the study design in the comment boxes beside the choice you make. "*Trial*" indicates that the study had an intervention and control group.

Often in "administrative" data an explicit control group is not described in the design but may be described in the analysis section.
***Use notation (I_1 –Intervention #1, I_2 –Intervention #2, C_1 Control Group #1, C_2 Control Group #2, I_1C –crossover with intervention first, I_2C –crossover with intervention second)**.

a) Randomized Trial
b) Non-randomized Trial
c) Randomized Cross-Over Design
d) Non-randomized Cross-Over Design
e) Other (please specify)

Randomized Trial -a study where the intervention assignment is randomized.
R O X O
  O O

Non-randomized Trial –a study where the intervention assignment is not randomized.

O X O
O O

Randomized Cross-Over Design: –a study where two groups receive the intervention at different times and group assignment is randomized.

R O X O O
O O X O

Non-randomized Cross-Over Design –a study where two groups receive the intervention at different times and group assignment is not randomized.

O X O O
O O X O

9. **Was the study protocol reviewed and approved by a REB (Research Ethics Board)?**

    a) **Yes**
    b) **No**
    c) **Unsure (Not reported in the paper)**

Intervention characteristics:

10. **What type of prevention intervention did the study investigate? (check all that apply**) Indicate whether the study evaluated a primary, secondary or tertiary prevention/intervention. *Primary prevention* is aimed at reducing the incidence of disease and other departures from good health (28). The recipients of primary prevention are persons who are apparently free of clinical disorders. The goal is to prevent (i.e., reduce the risk of) these persons from experiencing any adverse outcomes (i.e., any known adverse consequence of exposure, from mild symptoms all the way to disability and, in conditions other than musculoskeletal disorders, mortality). *Secondary prevention* aims to reduce prevalence by early detection and prompt and effective intervention to correct departures from good health (28). The recipients of secondary prevention are those who have subtle evidence of disease (i.e., not overtly ill, but not fully healthy - this is usually found with some kind of testing or evaluation). They are no longer eligible for primary prevention because they have not been prevented from making the transition from no evidence of disease to some evidence of disease. The goal is to prevent these individuals from advancing to more severe forms of illness, including clinical illness, disability, or worse (any known adverse consequence of the subtle disease discovered with testing or some kind of evaluation). *Tertiary prevention* is aimed at reducing the number or the impact of complications (28). The recipients of tertiary prevention are those with clinically apparent disease. The goal of tertiary prevention is to minimize impairment, disability, lost time, etc. (any known adverse consequence of clinical illness).

To determine what the authors "aimed" to do, reviewers must only answer based on what was reported by the authors. Therefore any studies where clinical diagnoses or symptoms

(as part of a case definition) were used to identify and include participants with disorders will be classified as secondary or tertiary prevention. If a study excluded employees with clinical diagnoses or symptoms to create a cohort of individuals free from symptoms this would be considered a primary prevention. If no such exclusions were made, then the authors will be assumed to have intended to prevent both "asymptomatic" employees from developing symptom or disorder and "symptomatic" individuals from further morbidity and mortality, therefore will be classified as all three. If you choose other please provide details.

a) Primary prevention
b) Secondary prevention
c) Tertiary prevention
d) Other (please specify)

11. Describe all interventions in the study.

Please address the following questions:
What was the intervention in the study? If the control received any intervention or placebo please describe using the language of I (intervention) and C (control).
*Use notation (I_1 –Intervention #1, I_2 –Intervention #2, C_1 Control Group #1, C_2 Control Group #2, I_1C –crossover with intervention first, I_2C –crossover with intervention second).

How often was the intervention applied?

What was the duration of the intervention? (Note this is not the follow-up time but the actual duration of the intervention implementation). Indicate in months if possible, if not in weeks, days etc. or enter "not provided." Note: For "administrative" data it is best to establish what the intervention period is first (e.g. new workstations were installed between April 2002 to July 2002).

E.g.: I_1 – individualized training (in body mechanics, workstation adjustments, task modification and stretches) for 1 hour per week for 4 weeks; I_2 – group training (in body mechanics, workstation adjustments, task modification and stretches) for 1 hour per week for 4 weeks; C_1 – no intervention

12. Categorize the intervention using the following list of types of intervention.

Engineering Solution
An intervention with a goal of physically eliminating the hazard through redesign, automation or other means.

Administrative Technique
Administrative methods include job rotation, education and training, adjustment, exercise or stretching, pre-placement screening and examinations (i.e. nerve conduction testing, genetic testing) and return-to-work/disability management programs. These techniques do not eliminate the hazards; they function to reduce the time or exposure to the hazards.

Personal Protective Equipment
Interventions that provide employees with equipment such as mechanical lifts, wrist guards, foot stools, etc. These interventions rely on the correct use of the equipment by the employees as the hazards have not been reduced or mitigated.
Pre-placement Screening and Examinations
Exercise and/or Stretching
Other (specify any additional categories)

E.g.: I_1 – administrative technique; I_2 – administrative technique; C_1 – no intervention

13. Describe the process by which the intervention was selected/developed (if any)

14. Was participation in the intervention documented? (check all that apply)
This relates to the documentation of compliance and adherence with the intervention. Check all that apply and provide details in the comment box to support your response.
E.g.: "exercise" could be confirmed either by self-report of exercise logs, attendance in classes, or questionnaire report of exercises done.

a) Yes, direct measurement by equipment
b) Yes, observation
c) Yes, self-report
d) Yes, other (please specify)
e) No

15. Indicate the time period between the baseline measurement and all subsequent follow-up measurements. Use months to indicate the length of follow up, for example, questionnaires were administered at 6, 12, and 18 months. Indicate in months if possible, if not in weeks, days etc. or enter "not provided". Please make sure that you describe all intervention groups and all referent groups. Please use the same group names throughout the data extraction forms.

E.g., Baseline data collected on May 1st, 2000. Intervention implemented June 1st, 2000 continues until June 1st 2001. Follow-up data collected on May 1st 2002. Note this information may be presented in a number of ways (tables, figures, timelines etc). In this example the length of follow-up is ***I_1=24 months****.*

Often in administrative data there are not multiple time points of outcome data collection; instead there are time periods over which data is collected. For "administrative" data it is best to establish what the intervention period is first (e.g., lifts were installed between April 2002 to July 2002, should have been found in Q.15). Then establish the baseline data period for outcome measurements. This period may be a month, 6 months, or years before the intervention, state the full time-period for which baseline outcome data was collected (e.g., "data was collected 3 years prior to lifts installation" answer: April 1998 to April 2002). Finally establish the follow-up period

(e.g., "We compared to 3 years after the lifts were completed installation" answer: July 2002 to July 2005).

Study group:

16. **Describe the overall study group.** Provide answer in the comment box for each category. Type "not provided" in all comment boxes where information is not available in article.

Sample Size
Age (mean, SD, range)
% female
Loss to Follow up (N)

17. **Describe the Intervention Group(s).** (Provide answer for each category - enter "not provided" in all comment boxes where information is not available. If design is cross-over then answer for I_1C only.)

***Use notation (I_1, I_2, and I_1C)**

Sample Size	*Eg: I_1 =, I_2=, ... (or I_1C=, I_2C=, ...)*
Age (mean, SD, range)	*Eg: I_1 =, I_2=, ... (or I_1C=, I_2C=, ...)*
% female	*Eg: I_1 =, I_2=, ... (or I_1C=, I_2C=, ...)*
Loss to Follow up (N)	*Eg: I_1 =, I_2=, ...(or I_1C=, I_2C=, ...)*

18. **Describe the Referent Group.** (Provide answer for each category - Enter "not provided" in all comment boxes where information is not available in article. If design is cross-over then answer for I_2C only.)

***Use notation (C, I_1C, and I_2C)**.

Sample Size	*Eg: C_1 , C_2, ...(or I_1C=, I_2C=, ...)*
Age (mean, SD, range)	*Eg: C_1 , C_2, ...(or I_1C=, I_2C=, ...)*
% female	*Eg: C_1 , C_2, ...(or I_1C=, I_2C=, ...)*
Loss to Follow up (N)	*Eg: C_1 , C_2, ...(or I_1C=, I_2C=, ...)*

Not Applicable (No Control group)

Covariate/confounder:

19. **Were covariates/confounders evaluated for inclusion in the final analysis?**

Covariates include gender, age, non-work activities, education etc. Physical risk factors for musculoskeletal disorders include: force, repetition, static loading, time spent in awkward postures, etc. Psychosocial and organizational risk factors can include: social support, job satisfaction, control over one's job, etc. Temporal confounding factors can include: season of year (e.g., with agricultural workers). If many variables considered, may be entered in categories (e.g. demographic (5), medical (3), etc.)

a) **Yes (list in the comment box)**
b) **No**

c) **Not applicable (e.g. Crossover design in which each subject is his/her own control)**

20. **Did the investigators describe or characterize differences in covariates/confounders for those that participated in the study vs. those that were invited but did not participate if possible.** If non-participants cannot be identified from participants typically because it is an open population study or work unit based study then the answer is "Not applicable".

    a) **Yes, differences affect my confidence in the conclusions about the effectiveness of the intervention**
    b) **Yes, but differences do not affect my confidence in the conclusions about the effectiveness of the intervention**
    c) **No**
    d) **Not applicable**

21. **Did the investigators describe or characterize differences in covariates/confounders for those that participated in the study vs. those that were lost to follow-up.** If non-participants cannot be identified from participants typically because it is an open population study or work unit based study then the answer is "Not applicable".

    a) **Yes, differences affect my confidence in the conclusions about the effectiveness of the intervention**
    b) **Yes, but differences do not affect my confidence in the conclusions about the effectiveness of the intervention**
    c) **No**
    d) **Not applicable**

Outcome:

22. **Were outcomes "actively" assessed by the investigators or "passively" obtained through other sources? (check all that apply)**

"Active" refers to data collected by the researcher e.g. self reports, clinical examination. "Passive" refers to data that is readily available through administrative data sources, clinical records, standard self-reporting tools (e.g. health risk appraisals) or functional status tools (e.g. DASH) used in specialty clinics.

    a) **Active**
    b) **Passive**
    c) **Both**

(SRS will drop certain questions depending on the answers to the following 3 outcome questions.)

23. **Does the study use "administrative" records to collect measurements of upper extremity musculoskeletal health outcomes?** By administrative records we mean regulatory required employer record keeping data (e.g.,

OSHA logs), Form 7 WSIB, voluntary employer record keeping data (e.g. incident reports), or insurance record keeping systems (e.g., workman's comp). Voluntary record keeping systems are any record keeping systems that either regulatory agencies or insurance agencies do not require. Describe succinctly the type of administrative record.

a) **Yes (describe)**
b) **No**

24. **Does the study use <u>self-report questionnaire records</u> as completed by the employee to collect measurements of upper extremity musculoskeletal health outcomes?** Describe succinctly the nature of the upper extremity questionnaire used.

a) **Yes (describe)**
b) **No**

25. **Does the study use <u>clinical exams or clinical records or clinical diagnoses</u> as completed by the clinician to collect measurements of upper extremity musculoskeletal health outcomes?** Describe succinctly the protocol or clinical exam.

a) **Yes (describe)**
b) **No**

<u>"Administrative" Record:</u>

26. **Was the population studied "fixed" or "open"?** A "fixed" population is one where the population is fixed at some time and the same participants are followed over time. An open population is where individuals can come in and out of the study. It is a natural worksite population; the intervention happens at some point; and different individuals can contribute information before and after the intervention (new hires).

a) **Fixed population**
b) **Open population**

27. **What sources were used to "count" employee injuries? (check all that apply)**

a) **Regulatory required employer record keeping data (e.g. OSHA logs)**
b) **Voluntary employer record keeping data (e.g. incident reports)**
c) **Insurance record keeping systems (e.g. workers' compensation claims data)**

28. **How were employee hours collected? (check one only)** Many studies calculate injury rates for a unit or an organization. A critical piece to this calculation is the method of collecting employee hours. Estimations of employee hours by calculating from the number of employees are very different from getting actual employee billed hours from human resources. If unclear, please describe what the study has. Carol will be reviewing all unclears.

    a) **Estimation of employee hours worked from an estimated of number of employees**
    b) **Estimation of employee hours worked from an actual number of employees**
    c) **Actual employee hours from a specific number of employees**
    d) **Employee hours not collected**
    e) **Unclear (please describe)**
    f) **Not reported**
    g) **Not applicable**

29. **Indicate at what level employee hours were ascertained and/or estimated.**

    a) **Individual**
    b) **Unit**
    c) **Site**

30. **Did the study discuss how researchers handled any of the following special issues related to administrative record keeping: temporary or contract employees; employees who floated between units/departments; turnover rate; reinjury to the same employee? (Check all that apply and describe in comment box).**

    a) **Temporary employees**
    b) **Contract employees**
    c) **Employees who floated between units/departments**
    d) **Turnover rate**
    e) **Reinjury to the same employee**
    f) **Other (please specify)**

31. **Were injury rates calculated?**

    a) **Yes**
    b) **No**

32. **If outcome rates were calculated, list the equation(s).** Please define each unit using the author's language explicitly. If the equation is not described, type "not described".

Questionnaire:

33. **Check all upper extremity regions where symptoms were ascertained by questionnaire (check all that apply).** Provide details in the comment box to support your response. If unclear and do not feel information fits into one of these categories please call Carol (416) 927-2027 X2170.

    a) **Hand**
    b) **Wrist**
    c) **Elbow or forearm**
    d) **Shoulder or upper arm**
    e) **Neck**
    f) **Not attributed to a body part (NAB)**

Clinical Exam:

34. **Check all upper extremity regions where specific clinical disorders were ascertained by physical examination or laboratory test (check all that apply)**. Provide details in the comment box to support your response. If unclear and do not feel information fits into one of these categories please call Carol (416) 927-2027 X2170.

    a) **Hand**
    b) **Wrist**
    c) **Elbow or forearm**
    d) **Shoulder or upper arm**
    e) **Neck**
    f) **Not attributed to a body part (NAB)**

35. **Was blinding of physical assessment done?** Provide details in the comment box to support your response. This question is asking if the assessor was blinded to the intervention group.

    a) **Yes**
    b) **No**
    c) **Unclear**
    d) **Not applicable**

36. **Was a standard protocol used for the clinical exams?** Standardized protocols exist that we could compare across studies.

    a) **Yes (list standardized protocol name)**
    b) **No**
    c) **Unclear (describe)**

3Statistical analysis:

37. **Please check the types of final analyses done for testing the observed effects of the intervention from the list below and provide details about the analyses in the comment box.** You should select the one that represents the final test not the preliminary analyses. Provide details in the comment box to support your response. Give details if you select "other". If unclear and do not feel information fits into one of these categories please call Carol (416) 927-2027 X2170.

    a) **ANOVA (ANCOVA)**
    b) **MANOVA**
    c) **Linear/Logistic Regression**
    d) **Multilevel Regression (linear or logistic)**
    e) **Survival Regression**
    f) **Poisson Regression**
    g) **Percentage of change**
    h) **Nonparametric tests**
    i) **Nonparametric Matched Test**
    j) **Nonparametric Unmatched Test**
    k) **Other Parametric Matched Test**
    l) **Other Parametric Unmatched Test**
    m) **No Statistical Test**
    n) **Other (please specify)**

38. **Describe for each outcome of interest (upper extremity musculoskeletal) the observed intervention effects.** (Be brief and concise i.e., enter "effect size", "risk ratio", "rate differences, "mean differences" etc, the actual number and associated outcome). If there is more than one outcome of interest please number and identify them using the same names you used in Questions 21-23 above. For administrative data multiple types of information might be reported. For self-reported and clinical data please report by upper extremity regions. PLEASE use notation HWE, NS, UB, LB, LKF, NAB, or O)
    E.g.: I_1 – LWD Rate 13% change pre vs post, I_1 = left arm RR 1.3

39. **Were additional statistical analyses conducted to increase your confidence in the observed effects?** For example, if there was a significant loss to follow-up and/or movement between study arms then an intention-to-treat analysis may be appropriate.

    a) **Yes (please describe)**
    b) **No**

40. **Remark on the findings or enter information that is unique about the study that may not be adequately captured in the other data extraction questions.** Be clear and concise. Please note that this is your last opportunity to provide overall comments on the study.

Housekeeping:

41. **Check the names of both DE reviewers for this study.**
    BA, FG, JD, BE, RW, DR, CK, DVE, CS, AF, SC

42. **Is this the consensus – final - version of the DE form**? Please select "no" until consensus has been completed.

    a) **Yes**
    b) **No**

Appendix E

Table 12: Exclusion at Level 1a and 1b

Review phase	Exclusion criteria						Total
	Occupational health and safety intervention	Intervention occurred in a workplace setting	From peer-reviewed publication	Review, commentary, letter to editor, editorial or 2 pages or less in length	Outcome upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims or lost time	Single group or a post-only study	
Level 1a	13,818	13,685	886	3,213	11,220	N/A	14,564
Level 1b	266	199	37	197	312	22	610
Total excluded	14,084	13,884	923	3,410	11,532	22	15,174

N/A = Not applicable

Total exclusions: Level 1a + Level 1b (14,564 + 610 = 15,174)

15,279 – 15,174 = 105 articles (88 studies) moved forward to QA
(Note: n=6 articles NOT reviewed due to non-English; n=11 articles were grouped with other articles that described results from the same study)

Appendix F

Table 13: Research question and inclusion/exclusion criteria described by the studies reviewed

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
Lundblad, 1999 High	Ergonomics training & exercise (I_1), Exercise (I_2)	"To analyze whether two secondary intervention programs physiotherapy (I_1) and Feldenkrais (I_2) resulted in improvements in complaints from the neck and shoulder in female workers at a car and truck industrial workplace."	Inclusion: Working female employee with current neck-shoulder "complaints." Exclusion: Chronic sick leave, leave for studies, leave for parenting, difficulty with Swedish language, pregnancy, coronary disease, rheumatoid arthritis, rotator cuff tendonitis, plans to leave the job during the study period.
Sjogren, 2005 High	Exercise	"The purpose of this study was to examine the effects of a workplace physical exercise intervention, which consisted of light resistance training and guidance, on the perceived intensity of headache (i), the intensity of neck (ii) and shoulder symptoms (iii), as well as the muscular strength of the upper extremities (iv)."	Inclusion: Worker in one of four eligible departments in the City of Kuopio's Central Administration. Report of headache and/or pain in neck and/or shoulders that had restricted participation in daily activities during the 12-month period preceding the intervention. Exclusion: Not employed in one of the four chosen departments. No restriction in daily activities during the last 12 months due to headache, neck or shoulder symptoms.
Kamwendo, 1991 Medium	Exercise, Ergonomics training & exercise	"To conduct a controlled study of the effects of neck school as a preventive intervention on neck and shoulder disorders."	Inclusion: 1) Have experienced some pain in either the neck or shoulder region during the previous year, 2) Average time spent sitting during working hours minimum of five hours daily, 3) Worked at least 30 hours per week. Exclusion: Not provided
Faucett, 2002 High	Biofeedback training, Cognitive behavioural training	"We investigated, on behalf of a large electronics manufacturer, two types of worker training interventions for their efficacy in preventing unnecessary muscle tension and the symptoms of work-related musculoskeletal disorders. The first intervention, Muscle Learning Therapy (MLT), used electromyographic (sEMG) feedback and operant conditioning to decrease muscle tension during complex work tasks. The second intervention used adult learning and cognitive behavioral techniques in small group discussion to advance the worker's capabilities for symptom and stress management and problem-solving."	Inclusion: Employees from three company worksites who had never been diagnosed with Work Related Musculoskeletal Disorder (WRMSD). All participants' work stations initially complied with employer's workstation ergonomic guidelines (neutral posture). Exclusion: Never diagnosed with WRMSD (Work Related Musculoskeletal Disorder). Employees who reported symptoms (pain, numbness or stiffness of the upper extremity, neck or shoulders) worse than a moderate level of severity (defined as

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
			5 on a 0–10 scale) more frequently than eight times in the last month (to exclude previously unreported cases of muscle strain).
Thomas, 1993 Medium	Biofeedback training	"This study tested the null hypothesis that participation in a biofeedback programme for CTS (Carpal Tunnel Syndrome) intervention, using audible EMG signals from the forearm muscles to discourage awkward hand postures and exertion of excessive force with the fingers, has no effect on CTS symptoms."	Inclusion: Light weight hardware assembly workers that had held their jobs for at least 3 years. Exclusion: Not provided.
Voerman, 2007 High	Biofeedback training	Evaluate the effect of ambulant myofeedback training and ergonomic counselling on work-related neck-shoulder pain and disability.	Inclusion: Female computer workers, work for >= 20 h per week, with perpetuating work related neck and/or shoulder complaints for at least 30 days in past year. Exclusion: Reported pain in more than 3 body regions, severe arthrosis or joint disorders, using muscle relaxants, or upper extremity complaints not related to computer work.
Feuerstein, 2004 High	Job stress management training	Appears to say: In workers with upper extremity symptoms, this study evaluated the effect of ergonomic evaluation/modification and individual-focused job stress management intervention compared to ergonomic/modification alone on upper extremity pain, symptoms, functional limitations, job stress, and ergonomic risk exposures.	Inclusion: 1. Employed at the World Bank, Washington, DC, 2. worked on computers a minimum of 3–4 hours per day, 3. employed at least 32 hours per week, 4. had experienced symptoms (pain, aching, stiffness, burning, tingling, and/or numbness) in the fingers, hands, wrists, forearms, elbows, shoulders, and/or neck in the past 12 months, but were not diagnosed with a work-related upper extremity disorder, 5. these symptoms could not be related to accident and/or injury, and 6. absence of current pregnancy. Exclusion: 1. Diagnosed with WRUED, 2. symptoms related to accident or injury, 3. pregnant.

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
Horneij, 2001 High	Job stress management training, exercise	"To evaluate and compare the effects of two different intervention programmes in working home-care personnel on (1) reported neck, shoulder and back pain, (2) intermediate indicators such as perceived physical exertion at work and perceived work-related pyschosocial factors."	Inclusion: Swedish speaking, permanently employed, on duty and working at least 50% time, not pregnant, and not suffering from an intercurrent disease which could interfere with the results. Exclusion: Not provided.
Gerr, 2005 High	Workstation adjustment	"…examine the effect of two workstation and postural interventions on the incidence of musculoskeletal symptoms among computer users."	Inclusion: participation was one who 1. Anticipated using a single computer workstation for 15 hours or more per week, 2. Anticipated using a computer workstation for as many hours per week as in his/her previous job. Exclusion: 1. Those who had upper extremity musculoskeletal symptoms in a given anatomic location at the time of entry were excluded from follow-up to incident symptoms of that location. 2. Potential participants who reported discomfort in both the neck/shoulder and hand/arm of intensity 6 or greater on a 0-10 visual analogue scale or who reported musculoskeletal symptoms for which they took analgesic medication.
Ketola, 2002 High	Workstation adjustment (high & low intensity)	Evaluate the effects of physical ergonomics and participatory ergonomics education on musculoskeletal discomfort in VDU work.	Inclusion: Employees working with a VDU in the office for more than 4 hours a week who had MSK pain & strain were included. Individuals needed to have symptoms in neck, shoulders, or upper limb regions in at least one or most eight anatomical areas (out of 11 possible areas) during the preceeding month; mouse usage for more than 5% of the work time with a VDU, age < 61 yrs. Exclusion: No more than 8 of 11 anatomic areas of the body with symptoms.
Pillastrini, 2007 High	Workstation adjustment	"The purpose of our study was to evaluate the effectiveness of a personalized ergonomic intervention provided by physical therapists, combined with an educational activity, in influencing spinal and upper-extremity work-related posture and musculoskeletal disorders mainly in the wrist, hand, shoulders, neck and low back of workers who use video display terminals (VDTs)."	Inclusion: Using VDT > 20 hours per week. Exclusion: Not provided.

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
Cook, 2004 Medium	Workstation adjustment	"The aim of this study was to determine whether adjusting a conventional workstation to enable forearm support during computer use decreases reports of neck/ shoulder or wrist/hand musculoskeletal discomfort in intensive computer users in a field setting."	Inclusion: 1) employed at least 15 hours per week. Exclusion: 1) Receiving treatment for musculoskeletal discomfort, 2) planned > one week of leave during study.
Bohr, 2000 Medium	Ergonomics training (Traditional ergonomics training, Participatory ergonomics training)	"The present study was designed to investigate the efficacy of worker education programs in preventing musculoskeletal injuries in a population of reservation center employees who spend the majority of their workdays using a computer."	Inclusion: 1) volunteers, 2) 5 hours of computer work a day. Exclusion: Not provided.
Greene, 2005 Medium	Ergonomics training	Evaluate the effectiveness of an active ergonomics training program in computer users.	Inclusion: 1) work at a computer at least 10 hrs per week. Exclusion: 1) diagnosed by a physician as having an acute MSK injury or trauma to the trunk or upper extremities within the previous six months, 2) receiving treatment for cervical or upper extremity.
Peper, 2004 Medium	Ergonomics training	The purpose of this pilot study was to determine if Healthy Computing concepts taught in a group setting would reduce symptoms and improve work style.	Inclusion: 1) not receiving medical treatment for Repetitive Stress. Exclusion: Not provided.
Veiersted, 2007 Medium	Ergonomics training	"To analyse the effect of two different intensity levels of intervention, one with written information only and the other with additional follow-up, on the working technique and the complaints from the neck and shoulder."	Inclusion: 1) Right handed females between 20-45 years of age, 2) working more than 30 hours per week, 3) reporting less than 2 weeks sick leave due to neck or shoulder pain for the prior 12 months. Exclusion: Not provided.
Martin, 2003 (and Gatty, 2004) High	Ergonomics training & workstation adjustment	"1) To what extent did outcome measures differ significantly between clerical and office staff who received WIPP (work injury prevention program) and those who did not? 2) To what extent did outcome measures differ significantly from baseline measures for the clerical/office staff who received WIPP? 3) "The purpose of Phase II (Gatty 2004) was to describe group differences at weeks 16 and 22". In addition, "The control group (in Phase I) received intervention in Phase II during weeks 18-21; pre and post measures were compared for members within this group."	Inclusion: Employed as full time clerical/office worker. Exclusion: No newly diagnosed MSD (within last 3 months).

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
Nevala-Puranen, 2003 Medium	Ergonomics training & exercise	"The aim of our study was to compare the effects of 2 different intervention models (E=redesign measures for the environment only, ET=redesign measures for both the environment and work techniques) on the neck, shoulder and arm symptoms of newspaper employees."	Inclusion: 1) Musculoskeletal pain in the forearms on at least 30 days duration in past 12 months, 2) Work >= 4hours/day with VDU, 3) Selected by personnel management of the newspaper and occupational health professionals (this was, in fact, one of the inclusion criteria, although not explicitly stated in that manner). Exclusion: Not provided.
Rempel, 1999 High	Alternative keyboards	"To evaluate the health effects of the new keyboard in computer users with possible carpal tunnel syndrome in comparison to a keyboard containing typical switches."	Inclusion: 1) Full time employee, 2) hand or wrist symptoms reported to occupational medicine clinic within 6 months of the onset of the study, 3) used computer keyboard >= 2 h/day or 10 h/wk, 4) employed in current job for >= 3months, 5) met criteria for "possible carpal tunnel syndrome", 6) had no prior surgery of the hands or wrists. Exclusion: 1) Prior surgery on the hands or wrists.
Tittiranonda, 1999 Medium	Alternative keyboards	"The aim of the present study was to determine whether computer users with musculoskeletal disorders can gain health benefit from long-term use of alternative geometry keyboards."	Inclusion: 1) full time employees with possible carpal tunnel syndrome (CTS) and/or tendonitis as determined by review of workers' compensation injury and illness database, 2) employed on current jobs for > 3 months, 3) used computer keyboard for 4 h/day or 20 h/week or more, 4) not exposed to alternative geometry keyboards prior to the study. Exclusion: 1) previous hand/wrist surgeries, 2) diagnosed with CTS and/or tendonitis > 2 years prior to review date.
Conlon, 2008 High	Alternative pointing devices, Arm supports	"To determine whether a forearm support board and/or neutral forearm posture mouse, when used by engineers with heavy computer usage, would reduce the incidence of upper body musculoskeletal disorders and reduce discomfort severity."	Inclusion: 1) reported computer use >=20 hours per week, 2) member of engineering staff or a professional position supporting engineering, 3) completed the health questionnaire and at least four weekly discomfort surveys. Exclusion: 1) Non-professional occupations (administrative assistants, production technicians).

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
Rempel, 2006 High	Alternative pointing devices, Arm supports	"The aim of this study was to determine whether two simple workstation interventions—a forearm support board or a trackball—when used by computer based customer service workers, would reduce the incidence of upper body musculoskeletal disorders and pain severity. Secondary aims included estimating the effects of the intervention on productivity and costs."	Inclusion: 1) Performed computer based customer service work for more than 20 hours per week, 2) No active workers' compensation claim involving the neck, shoulders, or upper extremities. Exclusion: Not provided.
Lintula, 2001 Medium	Arm supports	"The aim of this worksite intervention study was to assess the effects of Ergorest arm supports on EMG activity of the upper trapezius muscles and extensor digitorum muscles on both sides of the body, wrist position and perceived musculoskeletal strain in the neck-shoulder-arm region during VDU work with the use of a mouse and keyboard."	Inclusion: 1) VDU workers without acute musculoskeletal symptoms, 2) working at least 20 hours/week. Exclusion: Not provided.
Rempel, 2007 High	New chair	"To compare the impact of a new task chair (has a curved, 2-part seat pan), a conventional task chair, and a placebo intervention on neck and shoulder pain in industrial sewing operators."	Inclusion: 1) Performed sewing machine work for more than 20 hrs per week, 2) were not in a probationary period, 3) had worked for at least 3 months. Exclusion: 1) Had active workers' compensation claim.
Galinsky, 2007 Medium	Rest breaks	"This follow-up study (1) assessed discomfort and eyestrain, and productivity levels by evaluating supplementary rest breaks in data entry operators at an IRS service center; (2) determined if the symptoms and performance would differ significantly for workers performing stretching exercises during breaks as compared to workers taking breaks without stretching exercises."	Inclusion: 1) seasonal employees hired on a temporary basis to process income tax forms, 2) participants needed to fill out daily questionnaires for eight weeks. Exclusion: 1) an individual's data set was deemed incomplete if more than four consecutive days of questionnaires were missing.
Galinsky, 2000 Medium	Rest breaks	"This study examined the effects of supplementary rest breaks on musculoskeletal discomfort, eyestrain, mood and performance in data-entry workers."	Inclusion: Not provided. Exclusion: Not provided.
McLean, 2001 Medium	Rest breaks	"... to investigate myoelectric signal (MES) activity and perceived discomfort in areas of common CTD complaints: the neck, the low back, the shoulder region, and the wrist. In particular, the first objective was to determine the effect of 'microbreak' protocols on muscle activation behavior. The second objective was to determine the effect of 'microbreaks' on perceived discomfort. The third objective was to determine the effect of 'microbreaks' on worker	Inclusion: 1) Participants were required to be free from acute episodes of pain at the time of participation. Exclusion: 1) Presence of known neuromuscular, musculoskeletal or other conditions.

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
		productivity."	
van den Heuvel, 2003 Medium	Rest breaks, Rest breaks & exercise	"The objective of this study was to evaluate the effects of a software program that stimulates extra breaks and exercises on the recovery from neck and upper-limb complaints among computer workers. In addition, effects on sick leave and productivity were studied."	Inclusion: 1) working >= 4 days a week, 2) involved in computer work at least 5 hours a day, 3) had their own personal computer at work, 4) current complaints in neck, shoulders, arms, wrists, hands, or fingers for at least 2 weeks, 5) considered complaints work-related, 6) not under medical treatment for these complaints. Exclusion: 1) employees needing treatment for complaints, according to physician, 2) employees with other health problems (including medication intake) that may affect behaviour at work, 3) age not between 18 and 50 years.
Laing, 2007 Medium	Participatory ergonomics	"The general objective of the study was to investigate the effectiveness of a participatory ergonomic program in decreasing WMSDs. The goal of the present analysis was to assess whether the same intervention influenced pain severity through aspects of the change process focused primarily on enhancing worker perceptions of empowerment and workplace self determination as a means of improving the workplace psychosocial environment."	Inclusion: Not provided. Exclusion: Not provided.
Leclerc, 1997 Medium	Broad-based MSK Injury Prevention Program (MIPP)	Prevention programs feasible for small companies could reduce back, neck and shoulder morbidity among active workers.	Inclusion: Not provided. Exclusion: 1) Sick leave longer than 3 months in previous 12 months, 2) pregnancy, 3) temporary work contract, 4) retirement in the following 12 months, 5) duration of employment less than one year.
Lemstra, 2003 Medium	Prevention strategies & physical therapy	"The purpose of the current study was to determine if an occupationally based program that focused on injury prevention, reassurance of a good prognosis, encouragement to resume normal activity, simple exercises,	Inclusion: Experimental company: the largest corporation in the only city without direct access to the EIP (Early Intervention Program). This corporation had access only to standard medical

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
	Early intervention program (EIP)	and early return to work would have a substantial effect on injury claim incidence, duration, and costs in comparison with standard care or the provision of rapid and expanded rehabilitation services (Early Intervention Program [EIP]).”	and physical therapy care, which included long waiting lists for physical therapy. Control company: was chosen within the same industry that was thought to be the most similar in the province with the exception that it had direct access to the EIP program (company B). The companies were thought to be comparable as they were listed within the same WCB industry code and WCB industry subcode (of six potential subcodes). Both companies were of a similar size, worked similar hours, performed similar measured work demands (constant standing, occasional lifting, and constant repetitive use of upper extremity), and had similar psychosocial factors (monotonous work, high self-perceived workloads, time pressure, and general worker dissatisfaction). As well, both companies were unionized and had a similar management structure. Exclusion: Not provided.
Lin, 2007 Medium	Miscellaneous work redesign (VDT workstation)	“To assess whether redesigning fixed workstations for optimal VDT use could effectively reduce MSK (musculoskeletal) risk factors and MSK (musculoskeletal) symptoms among female semiconductor fabrication room workers.”	Inclusion: 1) Fabrication room workers in a semiconductor company, 2) workers having complaints of MSK symptoms. Exclusion: Not provided.
Luijsterburg, 2005 Medium	Miscellaneous work redesign (raised bricklaying)	“Investigate whether the implementation of devices for raised bricklaying in the field results in long-term decreases in the physical workload on the lower back, shoulders and arms, decreases in the number of reported musculoskeletal complaints and sickness absence, or increases in job satisfaction among bricklayers.”	Inclusion: Not provided. Exclusion: Not provided.

Author, year and QA rating	Intervention category	Research question	Inclusion/exclusion criteria
Fredriksson, 2001 Medium	Miscellaneous work redesign (change from lineout to line production in car body sealing)	"The aim of the present investigation was to study the influence of changes in physical and psychosocial conditions on musculoskeletal symptoms and disorders among selected automobile assembly workers."	Inclusion: Intervention group: Employed in the sealing department both before and after the implementation of the intervention. Control group: Employed in the other car-body department that "had [the] most similar working conditions to those of the study group" either before or after the intervention was implemented in the intervention group. Subjects were included even if they answered questions on only one occasion (either baseline or follow-up), or on both occasions. Exclusion: Intervention group: Employed in the sealing department at the study plant. Note: It is not stated why n=116-90=26 workers from the sealing. department were not included. Subjects had to complete questionnaires both before AND after the intervention; subjects who only completed one questionnaire were excluded. Control group: Employed in the other car body department at the study plant. Note: it is not stated why n=52-45=7 workers from this department were not included.
van der Molen, 2004 Medium	Miscellaneous work redesign (Mechanical assist for materials transport)	Did local signs of musculoskeletal discomfort of shoulders in bricklayers' assistants decrease through the use of mechanical means of transport compared to conventional methods? (note: research question modified to include only the group (brick layer assistants) that assessed upper extremity musculoskeletal disorders).	Inclusion: 1) Had to be familiar with the working condition under study (mechanization- crane). Exclusion: Not provided.
Yassi, 2001 Medium	*Multi-component patient handling	A study was designed at the HSC to assess and compare the effectiveness of improved patient-handling techniques and availability of mechanical and other assistive devices in reducing the incidence and severity of reported injuries, as well as in decreasing physical discomfort and pain associated with patient lifts and transfers.	Inclusion: Three wards from each of these service areas (medical, surgical and rehabilitation) were selected based on similarity with respect to type of patient, size of ward, staffing, and previous injury rates, 2) Nurses and unit assistants employed on medical, surgical and rehabilitation wards. Excluded: Float pool staff.

*Multi-component patient handling - an intervention that included three components: policy change, equipment purchase and training on equipment usage and patient handling

Appendix G

Table 14: Intervention confirmation details described by the studies reviewed

Author, year and QA rating	Intervention category	Intervention confirmation?	Confirmation details
Lundblad, 1999 High	Ergonomics training & exercise (I_1), Exercise (I_2)	Yes	Observation Self-report
Sjogren, 2005 High	Exercise	Yes	Self-report
Kamwendo, 1991 Medium	Exercise, Ergonomics training & exercise	Yes	Observation
Faucett, 2002 High	Biofeedback training, Cognitive behavioural training	Yes	Self-report Observation Direct measurement by equipment
Thomas, 1993 Medium	Biofeedback training	No	
Voerman, 2007 High	Biofeedback training	Yes	Self-report Observation Direct measurement by equipment
Feuerstein, 2004 High	Job stress management training	No	
Horneij, 2001 High	Job stress management training, Exercise	Yes	Self-report
Gerr, 2005 High	Workstation adjustment	Yes	Self-report Direct measurement by equipment
Ketola, 2002 High	Workstation adjustment (high & low intensity)	Yes	Self-report Observation Direct measurement by equipment
Pillastrini, 2007 High	Workstation adjustment	Yes	Observation

Author, year and QA rating	Intervention category	Intervention confirmation?	Confirmation details
Cook, 2004 Medium	Workstation adjustment	Yes	Observation
Bohr, 2000 Medium	Ergonomics training (Traditional ergonomics training, Participatory ergonomics training)	Yes	Not explicitly stated, but seems to be trivial in this case, since going to the educational class was the definition of participation in the intervention.
Greene, 2005 Medium	Ergonomics training	Yes	Observation
Peper, 2004 Medium	Ergonomics training	Yes	Self-report
Veiersted, 2007 Medium	Ergonomics training	No	
Martin, 2003 (and Gatty, 2004) High	Ergonomics training & workstation adjustment	Yes	Self-report
Nevala-Puranen, 2003 Medium	Ergonomics training & exercise	Yes	Not stated explicitly. However, it would be nearly impossible for the participants to avoid the engineering changes. This applies to both I_1 & I_2 groups. Regarding the use of the mouse with the non-dominant hand and the implementation of exercise for I_2, no documentation is provided.
Rempel, 1999 High	Alternative keyboards	Yes	Observation
Tittiranonda 1999 Medium	Alternative keyboards	Yes	Observation
Conlon, 2008 High	Alternative pointing devices, Arm supports	Yes	Observation (Compliance with use of the interventions was assessed only once, at one month after the intervention, based on an unannounced visit to each subject's workstation)
Rempel, 2006 High	Alternative pointing devices, Arm supports	Yes	Observation
Lintula, 2001 Medium	Arm supports	Yes	Observation
Rempel, 2007 High	New chair	Yes	Self-report Observation

Author, year and QA rating	Intervention category	Intervention confirmation?	Confirmation details
Galinsky, 2007 Medium	Rest breaks	Yes	Self-report Direct measurement by equipment
Galinsky, 2000 Medium	Rest breaks	Yes	Self-report
McLean, 2001 Medium	Rest breaks	Yes	Direct measurement by equipment
van den Heuvel, 2003 Medium	Rest breaks, Rest breaks & exercise	Yes	Self-report Observation
Laing, 2007 Medium	Participatory ergonomics	Yes	Observation Direct measurement by equipment
Leclerc, 1997 Medium	Broad-based MSK Injury Prevention Program (MIPP)	No	
Lemstra, 2003 Medium	Prevention strategies & physical therapy	No	
Lin 2007 Medium	Miscellaneous work redesign (VDT workstation)	Yes	Self-report Observation
Luijsterburg, 2005 Medium	Miscellaneous work redesign (raised bricklaying)	Yes	Observation
Fredriksson, 2001 Medium	Miscellaneous work redesign (change from lineout to line production in car body sealing)	Yes	Self-report Observation Direct measurement by equipment
van der Molen, 2004 Medium	Miscellaneous work redesign (mechanical assist for materials transport)	Yes	Self-report Observation
Yassi, 2001 Medium	*Multi-component patient handling	Yes	Self-report

*Multi-component patient handling - an intervention that included three components: policy change, equipment purchase and training on equipment usage and patient handling

Appendix H

Table 1: Covariates/confounders examined and included in the final analysis in the studies reviewed

Author, year and QA rating	Intervention category	Covariates/confounders - examined for:	Covariates/confounders – included in final analysis:
Lundblad, 1999 High	Ergonomics training & exercise (I_1), Exercise (I_2)	Age, weight, height, prevalence of smokers, prevalence married, Swedish origin, children (0-6, 7-12 years), work tasks (repetitive, assembly or material-tasks), employment status (full-time, day-time), prevalences of complaints from neck and shoulders, pain intensity and disability indices during work and leisure.	None.
Sjogren, 2005 High	Exercise	Not applicable (e.g. Crossover design in which each subject is his/her own control)	Not applicable (e.g. Crossover design in which each subject is his/her own control).
Kamwendo, 1991 Medium	Exercise, Ergonomics training & exercise	Self-rated workload on muscular fatigue and pain, visual analogue scale rating.	Yes, controlled for workload.
Faucett, 2002 High	Biofeedback training, Cognitive behavioural training	Age, gender, education, handedness, smoking status, # of children under six years, hours spent in exercise/hobbies each week, VDU use outside of work, or average number of hours spent using VDUs or microscopes at work each day.	No, study reports "the three groups did not differ significantly in terms of their age, gender, education, handedness, smoking, status, number of children under 6 years of age, hours spent in exercise or hobbies each week, VDU use outside of work, or the average number of hours spent using VDUs or microscopes at work each day. Thus, the random assignment of participants to the intervention or control groups effectively controlled for influences these potentially confounding factors might have had on the final outcome measures."
Thomas 1993 Medium	Biofeedback training	None.	None.
Voerman 2007 High	Biofeedback training	Study group (Netherlands versus Sweden - comprises variances due to possible sociodemographic differences, different therapists, organizations, and job characteristics in the two countries), baseline pain intensity, baseline disability level.	Yes, Model 1: No adjustment Model 2: Adjusted for factor study group Model 3: Adjusted for factor study group and baseline pain intensity/disability level.
Feuerstein, 2004 High	Job stress management training	Sociodemographic (education, marital status, length of time employed at current job, average hours worked per week), baseline measures (symptoms, upper extremity function, general function, ergonomic risk, work stress).	No. Note: Baseline differences were observed for age between the 2 groups but NOT controlled for in analysis. No differences observed in baseline measures.

Author, year and QA rating	Intervention category	Covariates/confounders - examined for:	Covariates/confounders – included in final analysis:
Horneij, 2001 High	Job stress management training, Exercise	Age, degree of employment (full time/part time), years of employment, adults at home, smoking regularly, pain in preceding 12 months (neck, shoulders, upper back, lower back), incapacitating pain during preceding 12 months (neck, shoulders, upper back, lower back).	No, state "no significant differences between the groups at baseline for any demographic or outcome variable, but for supervisor climate the I_2 group was more satisfied than I_1 group (p=0.02) and the control group (p=0.03)."
Gerr, 2005 High	Workstation adjustment	Time invariant variables - age, gender, history of arm or hand symptoms, history of neck or shoulder symptoms, medication use, history of arthritis or rheumatism, slipped or ruptured intervertebral disc, self-reported typing speed, self-reported level of mouse use, job category, ability to step away from the workstation at any time, and chair comfort. Time varying variables - hours per week in office, hours per week keying, weekly report of job stress, hours per week of aerobic activity, and hours per week of hand.	Yes, controlled for gender, age and hours keying during the previous week.
Ketola, 2002 High	Workstation adjustment (high and low intensity)	Gender, age, prevalence of pain, dominant hand, height, body weight, VDU work time, mouse usage, work experience, baseline outcome (MSK discomfort).	Yes, controlled for baseline musculoskeletal discomfort and initial ergonomic rating (baseline ergonomic level of workstation ratings of video analysis) and baseline workload value (keyboard and mouse events).
Pillastrini 2007 High	Workstation adjustment	Age, sex, height, weight, BMI (Body Mass Index), Work experience, number of breaks per day, single break duration, VDT use per day, baseline pain symptoms (shoulder, wrist/hand, neck, low back).	Yes, controlled for age, sex, and BMI (Body Mass Index).
Cook, 2004 Medium	Workstation adjustment	MSK symptom reporting.	None.
Bohr, 2000 Medium	Ergonomics training (Traditional ergonomics training, Participatory ergonomics training)	None.	None.
Greene, 2005 Medium	Ergonomics training	Physical/biomechanical work conditions (force, repetition, static loading), workstation adjustment, musculoskeletal symptoms (head, neck, shoulder & upper arm, elbow/forearm, wrist, hands/fingers, upper back), demographics (age, gender, education level), tenure at present job, non-work activities, computer exposure (at work, at home, lifetime), ergonomics, efficacy, outcome expectation.	Yes, controlled for baseline pain.
Peper, 2004 Medium	Ergonomics training	Age, height, weight, years worked with computers, hours worked at home per day, percent mousing, percent devoted to data entry and percent devoted to telephone activities.	None.

Author, year and QA rating	Intervention category	Covariates/confounders - examined for:	Covariates/confounders – included in final analysis:
Veiersted, 2007 Medium	Ergonomics training	None.	None.
Martin, 2003 (and Gatty, 2004) High	Ergonomics training & workstation adjustment	Gender, age, education, employment status, number and duration of breaks taken during typical workday, number of days lunch taken at desk, duration of lunch break, diagnosis of MSD within last 3 months and/or prescribed medication taken, baseline measures of symptom frequency, symptom intensity, stress scale, energy scale.	None.
Nevala-Puranen, 2003 Medium	Egonomics training & exercise	None.	None.
Rempel, 1999 High	Alternative keyboards	Physical/biomechanical work conditions (force, repetition, static loading) Medical Conditions (diseases & disorders) Family environment Demographics Other: number of hours worked (17 covariates: Age, sex, typing speed, years of computer use, current smoker, current pregnancy, child at home, hand pain in last 7 days, pain doing usual job, duration of hand problem, frequency of hand problem, missed work days, wrist splints, anti-inflammatory drugs, right & left median mononeuropathy).	No, groups were considered equal on covariates of interest by matching.
Tittiranonda ,1999 Medium	Alternative keyboards	Psychosocial/cognitive work conditions (include social support here) Demographics (age, gender, weight, height, anthropometry) Subjective health Clinical measures Other: hours of computer use	None. By study design - they ascertained (using regression) that the randomization process was adequate to ensure there were no covariates/confounders to adjust for.
Conlon, 2008 High	Alternative pointing devices, Arm supports	Work history, demographics (age, gender, BMI, right-handed, single, educational level, ethnicity), previous surgery to upper extremity or neck, pregnant, oophorectomy, menopausal, medications, current smoker, activity outside work, pre-intervention discomfort scores, psychosocial factors.	Covariates in final model of incident musculoskeletal disorders: age, gender, effort/reward imbalance, birth control pill use, hours of aerobic activity, mean pre-intervention discomfort score and oophorectomy. Covariates in final model of change in discomfort score by body region: age gender, effort/reward imbalance, hours of aerobic activity, mean pre-intervention discomfort score and oophorectomy.

Author, year and QA rating	Intervention category	Covariates/confounders - examined for:	Covariates/confounders – included in final analysis:
Rempel 2006 High	Alternative pointing devices, Arm supports	Age, gender, pre-intervention pain score, three psychosocial variables (composite psychological strain, job strain ratio - psychological job demands/decision latitude, and sleep problems), work site, title, seniority, BMI, handedness, marital status, education level, ethnicity, pregnancy status, history of oopherectomy, menopausal, pain medication usage, antidepressant medication usage, systemic comorbidity score, regional disorders score, low back pain, lost work days in past year due to UE msk problems, previous surgery on UEs, smoking status, exercise at least once/week, hours per week of hand intensive activity outside of work, and hours per week of aerobic activity.	List of variables controlled for each analysis: 1) COX Neck/Shoulder Disorders: Trackball, Armboard, Pre-intervention mean neck-shoulders pain value, Age, Gender, Composite psychological strain; Iso-Strain, Ethnicity, Pain medication, Current smoker, Hand intensive activity outside of work. 2) COX Right Upper Extremity Disorders: Trackball, Armboard, Pre-intervention mean RUE pain value; Age; Composite psychological strain; Iso-strain; Seniority; Total break minutes per day; Educational level; Ethnicity; Current smoker; Hand intensive activity outside of work. 3) COX Left Upper Extremity Disorders: Trackball, Armboard, Pre-intervention mean LUE pain value, Age, Gender, Composite psychological strain, Iso-strain, Job title, Typing speed, BMI, Educational level, Ethnicity, Low back pain score, Previous surgery in neck, shoulders or upper extremities, Pain medication, Current smoker, Weekly exercise, Hand intensive activity outside of work. 4) REGRESSION Neck/Shoulder pain: Trackball, Armboard, Pre-intervention mean neck-shoulders pain value; Age, Gender, Composite psychological strain, Iso-strain, Current smoker. 5) REGRESSION Right Upper Extremity pain: Trackball, Armboard, Pre-intervention mean RUE pain value; Age; Gender; Composite psychological strain, Iso-strain, Educational level. 6) REGRESSION Left Upper Extremity pain: Trackball, Armboard, Pre-intervention mean LUE pain value, Age, Gender, Composite psychological strain, Iso-strain, BMI.
Lintula 2001 Medium	Arm supports	None.	None.
Rempel 2007 High	New chair	Demographic (gender, age, ethnicity, marital status, children at home, BMI (body mass index), physical activity, smoking, medical history of systemic illness, medical history of musculoskeletal disorders, health insurance, education, years in US, English ability), shop type (small/large) baseline pain score, total rest time per day, job control, job demands, social support, perceived physical exertion, perceived physical workload, pay method, job stress, job dissatisfaction, job	Yes, study reports that estimates did not change after adjustment for potential covariates (adjusted variables: age, gender, ethnicity, education level, years in US, BMI, shop type: small/large). Post hoc stratified analyses by: baseline pain score (>2), history of systemic illness, rest time/day (>35 min), job control (high, low), job demands (high, low),

Author, year and QA rating	Intervention category	Covariates/confounders - examined for:	Covariates/confounders – included in final analysis:
		security.	social support (high, low), perceived physical isometric workload (high, low).
Galinsky 2007 Medium	Rest breaks	None.	None.
Galinsky 2000 Medium	Rest breaks	None.	None.
McLean 2001 Medium	Rest breaks	Pre-intervention health (discomfort – VAS by body part), productivity.	None.
van den Heuvel 2003 Medium	Rest breaks, Rest breaks & exercise	Age, gender, level of education.	Age, gender.
Laing 2007 Medium	Participatory ergonomics	Pain severity (shoulder/upper arm, forearm/hand), perceived decision latitude and influence.	None.
Leclerc 1997 Medium	Broad-based MIPP (MSK Injury Prevention Program)	Age, sex, occupational group, baseline health.	None.
Lemstra 2003 Medium	Prevention strategies & physical therapy (I_1) Early intervention program (EIP) (I_2)	Yes, for I_1 vs I_2 the following: age (above or below the age of 40), gender, duration of employment, wage, previous WCB time-loss claim, injury location and severity, hospital visit, health care provider (MD, PT, chiropractor), relationship between employer & injured worker's MD, injured worker's WCB client service representative, and injured worker himself all measured by interview with employer. None for I_1 vs C. None for I_2 vs C.	None for I_1 vs C. None for I_2 vs C. Yes, for I_1 vs I_2 the following: age (above or below the age of 40), gender, duration of employment, wage, previous WCB time-loss claim, injury location and severity, hospital visit, health care provider (MD, PT, chiropractor), relationship between employer & injured worker's MD, injured worker's WCB client service representative, and injured worker himself all measured by interview with employer.
Lin 2007 Medium	Miscellaneous work redesign (VDT workstation)	Demographics (age, height, weight, employment duration in fabrication, employment duration in company) Working practices (VDT use, lifting, writing, other tasks).	None.
Luijsterburg 2005 Medium	Miscellaneous work redesign (raised bricklaying)	None.	None.
Fredriksson 2001 Medium	Miscellaneous work redesign (change from lineout to line production in car body sealing)	Gender.	Gender.

Author, year and QA rating	Intervention category	Covariates/confounders - examined for:	Covariates/confounders – included in final analysis:
van der Molen 2004 Medium	Miscellaneous work redesign (Mechanical assist for materials transport)	None.	None.
Yassi 2001 Medium	*Multi-component patient handling	None.	None.

*Multi-component patient handling - an intervention that included three components: policy change, equipment purchase and training on equipment usage and patient handling

Appendix I

Table 16: Upper extremity MSK outcomes and observed effects as described by the studies reviewed
This table is in the same order as Table 9 of report

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
Lundblad, 1999 High	Ergonomics training & exercise (I_1), Exercise (I_2)	Self-report, for prevalence (pre, post) of: neck pain in previous seven days shoulder pain in previous seven days Self-report, for complaint indices (pre, post) for: Neck-index Shoulders-index Neck-shoulders-index Self-report, for VAS ratings (pre, post) for: VAS usually VAS worst	The prevalence of neck pain in the previous seven days decreased across the intervention period for I_2 (Feldenkrais) whereas it increased among the I_1 (PT) and C (Control). Comparison across the three groups of the before-after differences was statistically significant. Comparisons across the three groups (I_1, I_2, C) of the before-after differences were not statistically significant for prevalence of shoulder pain in previous seven days, complaint indices (Neck-index, Shoulders-index, neck-shoulders-index), and VAS ratings.
Sjogren, 2005 High	Exercise	Self-report: symptom questionnaires (the Borg CR10 scale) for symptoms in the neck and shoulders.	Mean difference in intensity of neck symptoms from non-intervention (C) to intervention (I) periods was a decrease of 0.42 units on the Borg CR10 scale (95% CI: 0.11-0.72) or 49% (95% CI 13-85). Results not provided for shoulder symptoms, but it is stated that "the intervention had no effect on the intensity of shoulder symptoms".
Kamwendo, 1991 Medium	Exercise, Ergonomics training & exercise	Self-report: daily (VAS) for neck and shoulder pain.	No significant between-group differences (1_1, I_2, C) in mean neck and shoulder pain.
Faucett, 2002 High	Biofeedback training, Cognitive behavioural training	Self-report: Subjects recorded severity of symptoms (pain, stiffness, numbness) each work- day for 2 weeks. Composite symptom severity score (mean of pain, stiffness & numbness) over each 5 day work week. Clinical: Number of incident cases (diagnosed with upper extremity WRMSDs during the course of the study).	C steadily worsened over time. I_2 first improved (at 6 weeks) and then returned to baseline (at 32 weeks). I_1 stayed the same at 6 weeks, but worsened at 32 weeks. Repeated measures ANOVA testing indicated a significant difference among the three groups from baseline to post-treatment at 6 weeks ($F = 3.:3$; $p<0.04$), largely because of the increase in Control group symptoms and a modest decrease in symptoms for I_2. Repeated measures ANOVA testing of all three time periods, however, did not indicate a significant difference among the groups. Number of incident cases small (n=13) and no significant differences between groups (I_1 vs I_2 vs C).

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
Thomas, 1993 Medium	Biofeedback training	Self-report: Body part discomfort score (forearm & hands).	ANOVA of subjective discomfort scores (forearm & hands) found no significant differences in discomfort between groups I vs C, $F_{0.05}(1,8) = 0.45$, $p>0.5$ or sessions, $F_{0.05}(4,32) = 1.03$, $P>0.25$.
Voerman 2007 High	Biofeedback training	Self-report: Neck-shoulder pain intensity score (combined neck and shoulder VAS pain intensity score).	Significant reduction in shoulder/neck pain at 4 weeks, 3 and 6 months after the intervention compared to baseline for both groups I and C. These improvements were similar in both groups with adjusted OR (95% CI) (adjusted for factor study group and VAS at baseline) of improvement in I compared to C at six months of 1.04 (0.29 - 3.77). No differences were observed between I (Ambulant myofeedback training with ergonomics training) and C (Ergonomics training alone) for outcome and subjects in both groups showed comparable chances for improvement in pain intensity.
Feuerstein, 2004 High	Job stress management training	Self-report: VAS (0-10) pain in past week in neck and upper extremity. Self-report: Symptom severity subscale of DASH (Disabilities of the Arm, Shoulder & Hand) measure (scores ranging from 0-75).	A significant effect for time was found for VAS pain ratings ($F_{[2,136]} = 19.6$; p=0:01). There was no significant difference between the groups (I vs C) ($F_{[1,68]} = 0.01$; p=0.01) and no significant group by time interaction ($F_{[2,136]} = 0.51$; p= 0.60). Pairwise comparisons indicate that overall pain levels were lower at three months (mean=3.8; SD=2.2) than at baseline (mean=5.1; SD=2.2) and remained at that level at 12 months (mean=3.4; SD=2.7) in both groups (I & C). The same pattern was found for DASH symptom severity scores. A significant time effect was found ($F_{[2,134]} = 10.7$; p=0.01), but no significant differences.

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
Horneij, 2001 High	Job stress management training, Exercise	Self-report: Nordic Musculoskeletal Questionnaire (Yes/No questionnaire for the previous 6 months) for neck and shoulder pain.	While both groups improved over time there were no significant differences in neck and shoulder pain among the two intervention groups (I_1 & I_2) and the control group (C) at either 12 months or 18 months of follow-up. Neck pain (No significant differences between the groups) I_1 – at 12 months and 18 months: 6 improved, 6 decreased (not significant). I_2 – at 12 months: 17 improved and 9 decreased (improvement was significant $p<0.05$); at 18 months: 12 improved and 8 decreased (not significant). C – at 12 months: 16 improved and 6 decreased (improvement significant $p<0.05$), at 18 months: 15 improved and 3 decreased at 18 Months (improvement significant $p<0.05$). Shoulder pain (No significant differences between the groups) I_1, - at 12 months: 11 improved, 5 decreased (improvement significant $P<0.05$); at18 months: 10 improved and 6 decreased (not significant). I_2 – at 12months: 16 improved and 9 decreased (not significant); at 18 months: 15 improved and 6 decreased (not significant). C – 12 months: 21 improved and 10 decreased (not significant); at 18 months: 16 improved and 7 decreased (not significant).
Gerr, 2005 High	Workstation adjustment	Self-report: Weekly exposure and symptom diary (included VAS pain scale) for arm/hand and neck/shoulder	HR (95% CI) compared to C_1: Arm/hand: I_1 - 0.92 (0.49-1.71); I_2 - 1.05 (0.58-1.90) Neck/shoulder: I_1 - 1.07 (0.64-1.80); I_2 - 1.0 (0.60-1.68)
Ketola, 2002 High	Workstation adjustment (high and low intensity)	Self-report: Daily diary (3 entries per day over 2 weeks) for: Neck discomfort, discomfort in area between neck and right shoulder, discomfort in area between neck and left shoulder, right shoulder discomfort, left shoulder discomfort, right forearm discomfort, left forearm discomfort, right wrist discomfort, left wrist discomfort, right fingers discomfort, left fingers discomfort.	At two month follow-up, I_1 had significantly less discomfort than C in the neck, in the area between neck and shoulder on the right side, in the right and left shoulder, and in the fingers of the left hand. I_2 vs C had less discomfort in neck, in the area between the neck and shoulder on the right side, and in the right forearm. No significant differences were found between either I_1 or I_2 and C at 10-month follow-up.

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
Pillastrini, 2007 High	Workstation adjustment	Self-report: Physical discomfort using pain drawings to identify location and severity of symptoms for: shoulders, wrist/hand and neck.	At five month follow-up, there were decreases in discomfort measures for both groups (I and C). Though the decrease was greater in group I, this larger decrease was not significantly different than C. I: Prevalence of Shoulder, Hand/Wrist, and Neck decreased by 12, 5, and 13 %, respectively. C: Prevalence of Shoulder and Neck decreased by 2 and 4 %, respectively. Prevalence for wrist/hand increased by 2%. I vs C: Logistic regression models showing odds for improvement within the intervention group relative to the control group for each region were: Shoulder OR 2.9 (95% CI: 0.3 - 27.4), p=0.352 Wrist/hand OR 5.6 (95% CI: 0.7 - 45.9), p=0.109 Neck OR 2.2 (95% CI: 0.6 - 8.4), p=0.242.
Cook, 2004 Medium	Workstation adjustment	Self-report: Discomfort symptoms (dichotomized, present or absent) for neck, shoulder, forearm, and wrist.	Non-significant reductions seen in symptoms of neck, shoulder, forearm, and wrist among I vs C at 6 weeks.
Bohr, 2000 Medium	Ergonomics training (Traditional ergonomics training, Participatory ergonomics training)	Self-report: Upper body pain/discomfort (composite scores including neck, upper back, shoulder/upper arm, forearm, wrist/hand).	Analysis of the upper body composite data identified significant differences across the groups ($F_{[2,151]} = 4.86$, $p < 0.01$). Post hoc tests indicated that the control group (C) reported a much higher frequency of upper body pain/discomfort throughout the study period than did either of the intervention groups (I_1 and I_2). There was no significant difference in upper body pain/discomfort scores between the Traditional education intervention group (I_1) and the Participatory intervention group (I_2) although there was a noted time X group interaction for the intervention groups (I_1 & I_2) ($F_{[6,453]} = 2.78$, $p < 0.01$). Post hoc tests indicated that the control group (C) reported a significantly higher frequency of upper body pain/discomfort than did either of the intervention groups (I_1 & I_2). There was a time X group interaction ($F_{[6,453]} = 3.24$, $p < 0.01$) between the intervention groups; however, there was no significant difference in the composite scores for these groups at any of the data collection times.
Greene, 2005 Medium	Ergonomics training	Self-report: for a) intensity, b) frequency and c) duration of symptoms for upper extremity.	No statistically significant changes were observed for any upper extremity musculoskeletal symptoms (intensity, frequency, duration) at 1 week post intervention.
Peper, 2004 Medium	Ergonomics training	Self-report at unknown time of symptom changes compared to beginning of the program for: a) neck and shoulders, b) arms, c) wrists and hands.	I reported significant reductions (vs C) in: a) Neck and shoulders $t(19)=2.98$, $p<0.01$ b) Arms $t(22)=2.16$, $p<0.05$ c) wrists and hands $t(22)=3.02$, $p<0.01$.

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
Veiersted, 2007 Medium	Ergonomics training	Self-report: Symptoms experienced in the past 7 days using the Screening procedure from SNQ (Standardized Nordic Questionnaire for a) neck and b) shoulder complaints.	Wilcoxon signed rank test for paired samples I_1 & I_2: No effect on neck & shoulder complaints. The pre- vs. post-prevalence were similar in I_1 group; 28 vs 29% for the neck, and 28 vs 24% for the shoulder complaints. The prevalence of neck complaints in the I_2 group was reduced from 37% before intervention to 21% after, and the reported shoulder complaints was reduced from 21% before to 11% after the intervention (none statistically significant).
Martin, 2003 (and Gatty, 2004) High	Ergonomics training & workstation adjustment	Self-report of a) frequency (# of days with symptoms) and b) intensity (Likert scale) for: Neck/ache pain Shoulder ache/pain Elbow/forearm ache/pain Wrist/hand ache/pain	At five weeks, no statistically significant difference between I & C groups for a) symptom frequency & b) symptom intensity on all measures (including neck ache/pain, shoulder ache/pain, elbow-forearm ache/pain, and wrist-hand ache/pain). At 16 weeks: a) Frequency of elbow-forearm ache/pain [I mean(sd)=0.0 (0.0), C mean(sd) = 1.0 (1.83)] and b) Intensity of elbow-forearm ache/pain [I mean(sd)= 1.0 (0.0), C mean(sd) = 1.4 (0.53)] were statistically significantly lower for I vs C. No statistically significant difference between I & C groups for a) symptom frequency & b) symptom intensity on neck ache/pain, shoulder ache/pain and wrist-hand ache/pain.
Nevala-Puranen, 2003 Medium	Ergonomics training & exercise	Self-report: Pain rated on 100-mm VAS (range 0-100) for neck, shoulders, elbows, and wrists.	At seven months, the reduction of pain symptoms in the neck ($p < 0.0073$), shoulders ($p < 0.0071$) and elbows ($p < 0.0490$) was greater in I_2 vs I_1. No significant difference in wrist pain symptoms in I_1 vs I_2.
Rempel, 1999 High	Alternative keyboards	Self-report at 6 and 12 weeks for: hand pain. Physical examination/tests at 0, 6 and 12 weeks for: Phalen's test time and nerve conduction.	Hand pain: No significant differences between I and C at 6 weeks. At 12 weeks, I significantly greater reduction in hand pain (means 2.7 to 1.9) than C (means 2.6 to 4.3) ($p=0.05$). Note: In the absence of baseline symptoms information, symptoms reporting at 6 and 12 weeks is not possible to interpret and therefore these results are not included in the evidence synthesis. Phalen's test time: A statistically significant difference ($p=0.006$) in the change in right hand Phalen's test time was observed over the study period (from baseline to 12 weeks). Specifically, Phalen's test time for group I increased from 28 sec (no SD provided) to 52 sec (no SD provided) while right Phalen's test time for C changed from 35 sec to 37 sec (no SDs provided). Study reports "a nearly statistically significant difference" ($p=0.06$) in the change in left hand Phalen's times were observed over the study period (from baseline to 12 weeks). Specifically, left Phalen's test time for I increased from 29 sec (no SD provided) to 43 sec (no SD provided) while left Phalen's test time for C changed from 41 sec to 34 sec (no SDs provided). Nerve conduction: No statistically significant changes (I vs C) in right

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
			(p=0.81) or left (p=0.13) palm-wrist median sensory latency was observed from baseline to 12 weeks.
Tittiranonda, 1999 Medium	Alternative keyboards	Self-report at 0, 6, 12, 18 and 24 weeks for: Arm/hand symptoms Change in overall pain severity Clinical: Phalen's, Tinel's, and Finkelstein's tests at 0 and 6 months.	Arm/hand symptoms at 24 weeks: A significant trend of reduced arm/hand symptoms in I_1, I_2, I_3 groups, with significant reductions in arm/hand symptoms in I_3 at 24 weeks (1.21 +/- 3.1) compared to C (-0.29 +/- 1.5) (post-hoc Dunnett's test, one-sided, mean > control, $p < 0.05$). Change in overall pain severity: At six weeks, ANOVA comparing Change in overall pain severity between I_1, I_2, I_3, and C was of borderline significance (p=0.06). Each group demonstrated a reduction in pain at 6 weeks, after which the mean pain scores reversed back toward baseline for I_2 and C, but continued to decrease for I_1 and I_3 at 12 weeks. For the C group, post-hoc Tukey-Kramer procedure (p=0.05) indicated a significant pain decrease from baseline at 6 weeks for C, but no difference at later weeks. For I_3, change in overall pain severity was statistically significant at 18 and 24 weeks for I_3 (p=0.05). Within both of these time periods, change in overall pain severity for I_3 was significantly lower than the C (post-hoc Tukey-Kramer procedure, p=0.05). Clinical: Due to a high withdrawal rate (45%) for I_2, this group was excluded from the analyses of clinical outcomes. Overall, I_1 and I_3 groups showed no significant decrease in the prevalence of the Phalen's test, Tinel's sign, and Finkelstein's test, after 6 months of keyboard use.
Conlon, 2008 High	Alternative pointing devices, Arm supports	Self-report: Weekly discomfort surveys using 0 to 10-point scale for each of three body regions. Clinical: Incident musculoskeletal disorders (if symptoms were more than 5 on the 10-point scale, then the subject was examined for the presence of 40 upper extremity and neck musculoskeletal disorders).	Change in Discomfort Scores (beta coefficients adjusted models in Linear regression) I_1 (alternative mouse): Neck/Shoulder: -0.23 (95% CI -0.56 to 0.10), p=0.17 (protective for reducing neck/shoulder discomfort with borderline statistical significance); Right Upper Extremity: -0.11 (95% CI -0.43 to 0.21), p=0.50 (weakly protective effect that was not statistically significant); Left Upper Extremity: -0.07 (95% CI -0.26 to 0.12), p=0.47 (neutral effect).

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
			I_2 (forearm support board): Neck/Shoulder: -0.02 (95% CI -0.36 to 0.32), p=0.89 (neutral effect); Right Upper Extremity: -0.35 (95% CI -0.67 to -0.03), p=0.035 (protective effect); Left Upper Extremity: 0.09 (95% CI -0.10 to 0.28), p=0.36 (neutral effect). Incident Musculoskeletal disorders (adjusted hazard ratios using Cox-proportional hazard model) for: I_1 (alternative mouse): Neck/Shoulder: 0.62 (95% CI 0.23 to 1.67), p=0.34; Right Upper Extremity: 0.57 (95% CI 0.24 to 1.34), p=0.20 (strong protective effect, although this effect was of borderline statistical significance); Left Upper Extremity: 2.06 (95% CI 0.42 to 10.1), p=0.38. I_2 (forearm support board): Neck/Shoulder: 1.69 (95% CI 0.62 to 4.64), p=0.31; Right Upper Extremity: 0.74 (95% CI 0.31 to1.74), p=0.49; Left Upper Extremity: 0.68 (95% CI 0.15 to 3.08), p=0.62.
Rempel, 2006 High	Alternative pointing devices, Arm supports	Self-report: Weekly discomfort survey using 0 to 10 point scale (0=no pain to 10=unbearable pain) for three boy regions 9 (neck/shoulder, right & left elbow/forearm/wrist/hand) for worst pain during preceding 7 days. Clinical: Incident musculoskeletal disorders (if pain intensity symptoms were more than 5 on the 10-point scale, or if they used medications for 2 days or more for upper extremity or neck pain that was not associated with acute traumatic event) then subject examined for the presence of 40 upper extremity and neck musculoskeletal disorders.	Change in Discomfort Scores (beta coefficients adjusted models in Linear regression) Armboard: Neck/shoulder: -0.48 (95% CI -0.85 to -0.10), p=0.01; Right Upper Extremity: -0.66 (95% CI -1.06 to -0.25), p=0.002; Left Upper Extremity: -0.07 (95% CI -0.26 to 0.12), p=0.08. Trackball: Neck/Shoulder: -0.27 (95% CI -0.66 to 0.11), p=0.16; Right Upper Extremity: -0.29 (95% CI 0.69 to -0.12), p=0.17; Left Upper Extremity: -0.35 (95% CI -0.69 to -0.02), p=0.04. Incident Musculoskeletal disorders (adjusted hazard ratios using Cox-proportional hazard model) for: Armboard: Neck/Shoulder: 0.49 (95% CI 0.24 to 0.97), p=0.04; Right Upper Extremity: 0.64 (95% CI 0.28 to 1.45), p=0.29; Left Upper Extremity: 0.29 (95% CI 0.08 to 1.05), p=0.06. Trackball: Neck/Shoulder: 0.62 (95% CI 0.30 to 1.28), p=0.19; Right Upper Extremity: 1.26 (95% CI 0.56 to 2.86), p=0.58; Left Upper Extremity: 0.19 (95% CI 0.04 to 0.90), p=0.04.
Lintula, 2001 Medium	Arm supports	Self -report: (VAS) at unknown time for MSK strain of neck/shoulder/arm region [mean value of VAS 0 (no strain) to 100 (extreme strain) from six body regions (neck, shoulder, upper arm, forearm, wrist, hand and fingers) for right and left side].	No statistically significant changes were observed in the change in upper extremity MSK strain between groups (I_1, I_2, C) or within groups.

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
Rempel, 2007 High	New chair	Self-report: Monthly pain intensity rating on 5-point scale (1=a little painful to 5=very painful) for neck and shoulder.	Pain score changes based on estimates from repeated-measures linear regression: I_2(flat seat) vs C experienced a decline in pain (difference in the slope of pain score change) of 0.14 (95% CI 0.07–0.22) points (on a 0–5 scale) per month. I_1(curved seat) vs C experienced a decline in pain (difference in the slope of pain score change) of 0.34 (95% CI 0.28–0.41) per month.
Galinsky, 2007 Medium	Rest breaks	Self-report: Musculoskeletal discomfort ratings, daily (3 times/day) for: Neck discomfort Right shoulder/upper arm discomfort Right forearm/wrist/hand discomfort Left shoulder/upper arm discomfort Left forearm/wrist/hand discomfort	I (supplemental break schedule) significantly lower symptoms (mean ratings) than C (conventional break schedule) for: Neck discomfort (F=5.04, p=0.03) Right shoulder/upper arm discomfort (F=10.0, p=0.003) Right forearm/wrist/hand discomfort (F=7.01, p=0.02) Left shoulder/upper arm discomfort (F=5.31, p=0.03) No significant difference (I vs C) in symptoms for left forearm/wrist/hand discomfort. Note: For stretching exercises the study reports "no significant effects of exercise conditioning on feeling state questionnaire occurred". However, no results are presented on the stretching group and therefore our evidence synthesis only reports on the rest break intervention.
Galinsky 2000 Medium	Rest breaks	Self -report, daily (3 times/day) for: Neck discomfort Shoulder/upper arm discomfort Right elbow discomfort Right forearm/wrist/hand discomfort Left shoulder/upper arm discomfort Left elbow discomfort Left forearm/wrist/hand discomfort	I (supplemental break schedule) significantly lower symptoms (mean ratings) than C (conventional break schedule) for: Neck (F=20.65, p=0.0002) Right shoulder/upper arm (F=6.60, p=0.01) Right elbow (F=7.90, p=0.009) Right forearm/wrist/hand (F=6.04, p=0.02) Left shoulder/upper arm (F=7.70, p=0.009) Left elbow (F=6.64, p=0.02) No significant difference (I vs C) in symptoms for left forearm/wrist/hand.
McLean, 2001 Medium	Rest breaks	Self-report: VAS [(vertical 100cm ranging from worst possible (top) to no discomfort (bottom)] for 2 days at end of each week for: Neck discomfort Shoulder discomfort Forearm/wrist discomfort	No significant differences found between I_1 and C for neck, shoulder and forearm/wrist discomfort. No significant differences found between I_2 and C for neck and shoulder discomfort. Significant (interaction for protocol versus time) differences found between I_2 and C for forearm/wrist discomfort.

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
van den Heuvel, 2003 Medium	Rest breaks, Rest breaks & exercise	Self-report: Frequency of complaints (discomfort or pain in neck, shoulders, upper arms, elbows, forearms, wrists/hands or fingers during previous week). Self-report: Severity of complaints (rate on scale from 1 to 10). Self-report: Sick leave (as result of their complaints in neck or upper extremity during last 3 months).	Frequency and severity of complaints: In all groups (I_1, I_2, C) the frequency and severity of most of the complaints decreased during the intervention period. The severity of complaints concerning the neck, shoulder, upper arm, forearm, wrist/hands and fingers and the frequency of neck and shoulder complaints decreased; only the frequency of complaints concerning the elbow, wrists/hands and fingers increased. The changes in the frequency and severity of complaints in I_1 and I_2 did not significantly differ from C. Sick leave: No statistically significant differences in change (before & after intervention) between I_1 vs I_2 vs C.
Laing, 2007 Medium	Participatory ergonomics	Self-report: Pain severity scores (shoulder, forearm/hand) at 0 and 10 months. Calculated as average of body-part specific responses to 2 questions [1. How bad was worst pain/discomfort in past 3 months? and 2) On average, how intense was pain/discomfort in past 3 months?] and rated on 5-point scale (0=none and 5=unbearable) .	Pain severity remained unchanged for shoulder/upper arm and increased for forearm/hand for I. However, no significant interaction effects observed between plant (I & C) and time in pain severity change for shoulder/upper arm ($p = 0.356$) and forearm/hand ($p = 0.286$).
Leclerc, 1997 Medium	Broad-based MSK Injury Prevention Program (MIPP)	Self-report: French version of the Nordic questionnaire for the analysis of musculoskeletal symptoms at 0 and 12 months.	Change in Musculoskeletal symptoms (mean differences) Neck: No significant difference between I vs C. No significant differences for subgroups: hospital, warehouse and office groups. Shoulder: Significant mean differences (I = 0.17, positive=improvement; C = -0.35, negative=worsening) for I vs C ($p=0.03$). Significant for subgroups: warehouse and office groups. Not significant for hospital subgroup.
Lemstra, 2003 Medium	Prevention strategies & physical therapy Early intervention program (EIP)	Administrative: WCB work related UE musculoskeletal disorder time loss injury claims, wage replacement, medical/rehab compensation and total compensation.	I_1 (Prevention strategies & Physical Therapy - company A, 2000) vs C (standard care company A, 1999) crossover design: In response to I_1, the incidence of upper extremity time-loss claims reduced to 0.6 per 100,000 hours worked. By calculating the RR, they found that the rate of injury occurrence reduced by 72% for upper extremity time-loss claims (RR = 0.28; 95% CI 0.07–1.09). As well, company A had 12.3 upper extremity time-loss days per 100,000 hours worked. By calculating the RR, they found that the rate of days lost had been reduced by 91% for upper extremity time-loss days (RR = 0.09; 95% CI 0.07–0.12). Upper extremity time-loss costs reduced from $15,777 to $597 per 100,000 hours worked. C (Standard care company A, 1999) vs I_2 (EIP company B, 1999) retrospective comparison between 2 companies - no direct between group statistical comparison. Note: Descriptive comparison only, therefore will not report this comparison in the evidence synthesis.

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
			I_1 (Prevention strategies & Physical Therapy - company A) versus I_2 (EIP company B) prospective non-randomized design: Reviewing the RR's, the rate of injury occurrence for company B (EIP) in the year 2000 (in comparison with 1999) for upper extremity time-loss claims increased by 22% (RR = 1.22; 95% CI 0.74–2.00). Reviewing the RR's for days lost in company B (EIP) in 2000, upper extremity time-loss days reduced by 9% (RR = 0.91; 95% CI 0.86–0.95). Corresponding upper extremity time-loss costs reduced from $80,816 to $73,136 per 100,000 hours worked. (NOTE: no control group in this comparison, only compare 2 interventions, therefore will not report this comparison in the evidence synthesis)
Lin 2007 Medium	Miscellaneous work redesign (VDT workstation)	Self-report: Percentage of musculoskeletal symptoms (using Modified Nordic Musculoskeletal Questionnaire) in shoulders at 1 and 3 months after intervention.	There was no baseline difference (Fisher's exact test, p=0.52) in shoulder symptoms (I = approx 52%, C = approx 63%). There was a significant difference at 1 month after intervention (Fisher's exact test, p=0.01) between groups I versus C (I = approx 28%, C = approx 75%). No group difference in shoulder symptoms was found at 3 months after intervention (Fisher's exact test, p= 0.33, I = approx 48%, C = approx 67%). Note: only the longest follow-up (3 months after intervention) included in the evidence synthesis.
Luijsterburg, 2005 Medium	Miscellaneous work redesign (raised bricklaying)	Self-report: 10-month prevalence of musculoskeletal complaints (using Dutch adaptation of Nordic questionnaire) of: Shoulder, Hand-wrist, Shoulder due to work, Hand-wrist due to work. Self-report: Change (0 and 10 month follow-up) in average duration of sickness absence due to shoulder problems	No statistically significant differences between the number of complaints reported in I vs C (Shoulder complaints p=0.46; Hand-wrist complaints p=0.95; Shoulder complaints due to work p=0.68; Hand-wrist complaints due to work p=0.40). Most complaints were reported at a similar level during baseline and follow-up. Although I group reported more shoulder complaints in the follow-up than reported at baseline, the difference between I vs C was not statistically significant. No statistically significant difference between I vs C in average duration of sickness absence due to shoulder problems (p=0.26). I and C reported minimal sick leave due to shoulder complaints (change: I=0 and C=+1.3).

Author, year & and QA rating	Intervention category	Upper extremity MSK outcomes (administrative, self-report, clinical)	Observed effects
Fredriksson, 2001 Medium	Miscellaneous work redesign (change from lineout to line production in car body sealing)	Self-report: Prevalence of musculoskeletal symptoms (aches, pain or discomfort) in last 7 days for: Neck Shoulders Hand/wrist	Prevalence of musculoskeletal symptoms (neck, shoulders, hand/wrist) increased for I vs C but results were not statistically significant. Odds ratio, controlled for gender, and 95% CI for symptoms, comparing workers exposed to changed working organization conditions (I) and workers not exposed to any change (C) for: Neck: 1997 (before change) OR 3.0, 95% CI 0.3-35.4 and 1998 (after change): OR 3.0, 95% CI 0.8-12.1. Shoulders 1997 OR 1.1, 95% CI 0.2-6.2 and 1998 OR 3.9, 95% CI 0.8-18.6. Hand/wrist 1997: OR 0.2, 95% CI 0.02-3.0 and 1998 OR 2.6, 95% CI 0.6-12.0.
van der Molen, 2004 Medium	Miscellaneous work redesign (Mechanical assist for materials transport)	Self-report: Perceived discomfort of shoulders on VAS from 0 (no discomfort at all) to 10 (extreme perceived discomfort) on four repeated observations in one day.	Local discomfort of the shoulder(s) showed no significant mean effect between I vs C.
Yassi, 2001 Medium	*Multi-component patient handling	Self-report: Shoulder pain in past week on VAS, 0 (never) to 100 (constant).	Shoulder pain in past week: VAS- 0 (never) to 100 (constant) - repeated measures ANOVA "Safe Lifting" I_1: Positive effect on shoulder pain (decrease in I_1 vs C at 12 months). "Safe Lifting" I_1: No effect on shoulder pain (decrease in I_1 vs C at 6 months). "No Strenuous Lifting" I_2: No effect on shoulder pain (decrease in I_2 vs C at 12 months) "No Strenuous Lifting": Positive effect on shoulder pain (decrease in I_2 vs C at 6 months)

*Multi-component patient handling - an intervention that included three components: policy change, equipment purchase and training on equipment usage and patient handling
I = Intervention
C = Control
RR = Relative Risk
OR = Odds Ratio
HR = Hazard Ratio
CI = confidence interval