OEM Online First, published on November 12, 2015 as 10.1136/oemed-2015-102992

Effectiveness of workplace interventions in the prevention of upper extremity musculoskeletal disorders and symptoms: an update of the evidence

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▶ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/oemed-2015-102992)

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Received 31 March 2015
Revised 18 September 2015
Accepted 27 September 2015

ABSTRACT

The burden of disabling musculoskeletal pain and injuries (musculoskeletal disorders, MSDs) arising from work-related causes in many workplaces remains substantial. There is little consensus on the most appropriate interventions for MSDs. Our objective was to update a systematic review of workplace-based interventions for preventing and managing upper extremity MSD (UEMSD). We followed a systematic review process developed by the Institute for Work & Health and an adapted best evidence synthesis. 6 electronic databases were searched (January 2008 until April 2013 inclusive) yielding 9909 non-duplicate references. 26 high-quality and medium-quality studies relevant to our research question were combined with 35 from the original review to synthesise the evidence on 30 different intervention categories. There was strong evidence for one intervention category, resistance training, leading to the recommendation: *Implementing a workplace-based resistance training exercise programme can help prevent and manage UEMSD and symptoms*. The synthesis also revealed moderate evidence for stretching programmes, mouse use feedback and forearm supports in preventing UEMSD or symptoms. There was also moderate evidence for no benefit for EMG biofeedback, job stress management training, and office workstation adjustment for UEMSD and symptoms. Messages are proposed for both these and other intervention categories.

INTRODUCTION

Work-related musculoskeletal disorders (MSDs) are a constellation of painful disorders of muscles, tendons, joints and nerves which can affect all body parts, although the neck, upper limb and back are the most common areas.[1 2] Overall work-related MSDs account for 29% of all US workplace injuries.[2] In Canada, MSDs account for between 40% and 60% of lost-time claims since 2000.[3–6] In Canada and the USA, upper extremity MSDs (UEMSDs) and low back pain are the leading causes of disabling work-related injuries.[2–6] In Europe, UEMSDs and low back pain are considered to be an increasing and significant health problem, making up approximately 39% of occupational diseases.[1] Recent attention and studies suggest that MSDs are considered a growing problem in the developing world as well.[7–12]

It has been estimated that work-related UEMSDs and low back pain costs are between 0.5% and 2% of the EU's gross national product.[1] UEMSDs are significant causes of disability claims cost, and lost productivity in many economic sectors worldwide.[7 13–16] In summary, UEMSDs are prevalent and costly demanding focused prevention campaigns.

The peer-reviewed literature about workplace prevention describes a variety of interventions that have been implemented and evaluated.[17–25] However, few studies show sustainable positive effects on symptom, claim and disability outcomes. Overall, the studies and reviews to date reveal that there is no 'magic bullet' to deal with the significant burden of UEMSD.[18–23] Consequently, systematic reviews, to date, have not been able to provide strong guidance for practice.

Despite the lack of guidance from literature, Occupational Health and Safety (OHS) practitioners have created workplace-based interventions to reduce UEMSD burden based on their training, knowledge and experiences. The challenges of conducting well-designed, rigorous evaluations have been a barrier to building the strong scientific evidence base necessary to guide practice.[26–29] Poorly implemented interventions that could not be expected to lead to sustainable change in outcomes studied are another barrier. Kristensen[26] has referred to this as programme failure versus theory failure. The implementation aspects of workplace-based interventions have been explored[30–33] revealing the importance of intervention intensity, implementation, as well as scientific rigour.

A previous review Kennedy *et al*[23] found moderate evidence for arm supports and limited evidence for ergonomics training plus workstation adjustments, new chair and rest breaks. Levels of evidence for interventions associated with 'no effect' were: there was also strong evidence for no effect of workstation adjustment alone; moderate evidence of no effect for biofeedback training and job stress management training; and limited evidence of no effect for cognitive behavioural training. The overall conclusion of the review was that it was not possible to make recommendations to practitioners about how to prevent or manage UEMSDs.

Therefore, the study objective was to systematically review the literature to synthesise the evidence on the effectiveness of workplace-based interventions focused on UEMSDs. This is the first update of the earlier review.[23] Stakeholders from Ontario, Canada, were engaged iteratively throughout, particularly in refining evidence synthesis categories and developing practical messages based on the synthesis to support evidence-based practice.

To cite: Van Eerd D, Munhall C, Irvin E, *et al*. *Occup Environ Med* Published Online First: [*please include* Day Month Year] doi:10.1136/oemed-2015-102992

METHODS

The systematic review followed the six review steps developed by the Institute for Work & Health (IWH) for OHS prevention reviews:[34] (1) question development, (2) literature search, (3) relevance/inclusion screen, (4) quality appraisal, (5) data extraction and (6) synthesis. The review team participated in all review steps. Eleven researchers from Canada, Europe and the USA with expertise/experience in conducting MSD studies or systematic reviews comprised the team.

The IWH Systematic Review programme follows an integrated stakeholder engagement model during reviews.[35] This results in stakeholders providing feedback throughout the review process. For this review, the stakeholders were all from Ontario and included ergonomists, policymakers, labour, employers, business and disability management consultants.

Question development

The review team and stakeholders participated in a meeting to discuss the review update research question, and proposed search terms. The review team and stakeholders retained the original review question and search terms for this update.

Literature search

Six electronic databases were searched: MEDLINE, EMBASE, Cumulative Index to Nursing & Allied Health Literature (CINAHL), Canadian Centre for OHS's CCINFO web, Cochrane Library, and Ergonomic Abstracts from 2008 to April 2013. The databases were chosen based on those that yielded references in the original review and were still available. Additional databases were added to the search based on feedback from stakeholders. The search strategy was guided by the original review search and designed to be inclusive, using terms from three broad areas: work setting terms, intervention terms and health/claim outcome terms. The terms within the work setting and intervention categories were combined using a Boolean OR operator and the three main categories were then combined using a Boolean AND operator.

The search terms and database languages differ significantly; therefore, the search terms were customised. For the most part, the titles, abstracts or subject headings were searched for keywords.

In addition to the database searches, the reference lists of all papers selected for review were manually searched. The team also contacted experts in the field and sought out references that were prepublication to ensure a comprehensive search.

References were loaded into commercially available review software (DistillerSR),[36] which was also used for all remaining review steps. DistillerSR is an online application designed specifically for the screening, quality appraisal and data extraction phases of a systematic review.

Relevance screen

The review team devised five screening criteria to exclude articles not relevant to our review question: (1) non-English or commentary/editorial; (2) study was not in a work setting; (3) no OHS intervention was evaluated; (4) no comparison group was used; and (5) study outcomes did not include upper extremity musculoskeletal symptoms, signs, disorders, injuries, claims or lost time. The review team decided to exclude non-English references based on low yields in the previous review and other preventions reviews. We note that the non-English articles were excluded due to other criteria in this review.

First, titles and abstracts of references were screened by a single reviewer. To limit the possibility of bias, a quality control (QC) step was implemented. A QC reviewer independently assessed a randomly chosen set of 446 titles and abstracts (approximately 5% of references from the search). Comparing the QC reviewer responses directly to review team responses, 92 conflicts (20%) were found. However, only 6 (1.3%) were conflicts where the review team excluded references and the QC reviewer included them. Consequently, the review team is confident that the titles and abstracts were screened reflecting inclusion and exclusion requirements. The small (1.3%) number of discrepancies suggests that reviewers had a similar understanding and application of the screening criteria.

Second, the remaining full-text articles were screened using the same criteria, with two reviewers independently reviewing and coming to consensus. When consensus could not be reached, a third reviewer was consulted. Third, relevance criteria were revisited in each subsequent review step and articles were excluded if the two reviewers were in consensus.

Quality appraisal

Relevant articles were appraised for methodological quality. Since this is a review update,[23] the same criteria and scoring algorithm were used. Quality was assessed using 16 methodological criteria within the following broad headings: Design and Objectives, Level of Recruitment, Intervention Characteristics, Intervention Intensity, Outcomes, and Analysis.

Methodological quality scores for each article were based on a weighted sum score of 16 quality criteria (with a maximum score of 41). The weighting values assigned to the 16 criteria ranged from 'somewhat important' (1) to 'very important' (3). Each article received a quality ranking score by dividing the weighted score by 41 and then multiplying by 100. The quality ranking was used to group articles into three categories: high (>85%), medium (50–85%) and low (<50%) quality.[23]

Each article was independently assessed by two reviewers, who were required to reach consensus on all criteria. Where consensus could not be achieved, a third reviewer was consulted. Team members did not review articles they had consulted on, authored or co-authored.

The quality appraisal represents an assessment on: internal validity, external validity and statistical validity.[37] A higher quality score increases the team's confidence that an effect was an intervention consequence versus the effect(s) of other workplace or external environment factors. Therefore, data extraction and evidence synthesis were only completed on high-quality and medium-quality studies.

Data extraction

Standardised forms based on the previous review were used. Extracted data were used to create summary tables sorted by intervention category and used for evidence synthesis. Data were extracted independently by pairs of reviewers. Again, reviewer pairs were rotated to reduce bias. Team members did not review articles they consulted on, authored or co-authored. Any conflicts between reviewers were resolved by discussion. Stakeholders were consulted to determine relevant intervention categories.

Evidence synthesis

The evidence synthesis approach[34 38] considers the quality, quantity and consistency in the body of evidence (see table 1).

First, the intervention categories created in the data summary tables were examined by the entire team. Once consensus was

Table 1 Best evidence synthesis algorithm/algorithm for messages

Level of evidence	Minimum quality* and quantity	Consistency	Strength of message
Strong	3 High (H)	3H agree; if 3+studies, 3/4 of the M and H agree	Recommendations
Moderate	2H or 2H and 1Medium (M)	2H agree or 2M and 1H agree; if 3+, >2/3 of the M and H agree	Practice considerations
Limited	1H or 2M or 1M and 1H	2 (M and/or H) agree; if 2+, >1/2 of the M and H agree	Not enough evidence to make recommendations or practice considerations
Mixed	2	Findings are contradictory	
Insufficient	Medium-quality studies that do not meet the above criteria		

*High is >85% in quality assessment; medium is 50–85% in quality assessment.

reached on the categories, the team moved to summarising the evidence per category. Owing to the heterogeneity across outcome measures, study designs and reported data, we chose not to calculate a pooled effect estimate. To determine individual study intervention effects, the following rules were applied: an intervention with a positive and no negative results was classified as positive effect, an intervention with both positive and no effect was also classified as positive effect, an intervention with only no effects was classified as no effect, an intervention with any negative effect was classified as negative effect. The direction of the intervention effect was considered along with study quality rating and number of studies to determine the level of evidence for each intervention category (see table 1).

To reach a strong level of evidence, there had to be at least three high-quality studies that had that same direction of effect or at least 75% of all studies within the intervention category had to have the same direction of effect.

To generate practical messages, an algorithm developed by IWH along with OHS stakeholders was followed.[39] A strong level of evidence leads to 'recommendations'. A moderate level of evidence leads to 'practice considerations'. For all evidence levels below moderate, the consistent message is: 'Not enough evidence from the scientific literature to guide current policies/practices'. This does not mean that the interventions with limited, mixed or insufficient evidence may not be effective; only that there is not enough scientific evidence to draw conclusions.

RESULTS

Literature search

The search (covering 2008–April 2013) identified 9908 references once results from EMBASE, MEDLINE, Ergonomic Abstracts, CINAHL, Cochrane Library, CCInfoWeb were combined and duplicates removed. One additional paper was identified by the research team that was not captured by the search, resulting in a total of 9909 references (figure 1).

Relevance screen

Overall, 9655 references and 216 full articles were excluded for not meeting relevance criteria (reference list is available from corresponding author on request). The remaining 38 relevant articles described 30 unique studies (figure 1).

Quality appraisal

Four studies were classified as low quality (<50% of criteria met), 14 studies were medium quality (50–85% of criteria met), and 12 studies were high quality (>85% of criteria met; see online supplementary table S2). Low-quality studies had high loss to follow-up, found differences in baseline characteristics between intervention and control groups, participants' outcomes were not analysed by the groups they were originally allocated to, and the statistical analyses were not optimised for best results (eg, not accounting for baseline differences). The quality criteria that differentiated medium-quality and high-quality studies were also loss to follow-up and whether statistical methods were optimised for best results.

Four low-quality studies[40–43] did not move on to data extraction leaving 26 studies (34 articles) for data extraction.

Data extraction

Study characteristics

The study designs included randomised controlled trials (n=9), cluster-randomised controlled trials (n=12) and non-randomised trials with a control group (n=5).

The studies came from the Netherlands (n=7), Denmark (n=6), Finland (n=3), Italy (n=2), the USA (n=2), India (n=1), Canada (n=1), Brazil (n=1), Malaysia (n=1), Sweden (n=1) and Israel (n=1).

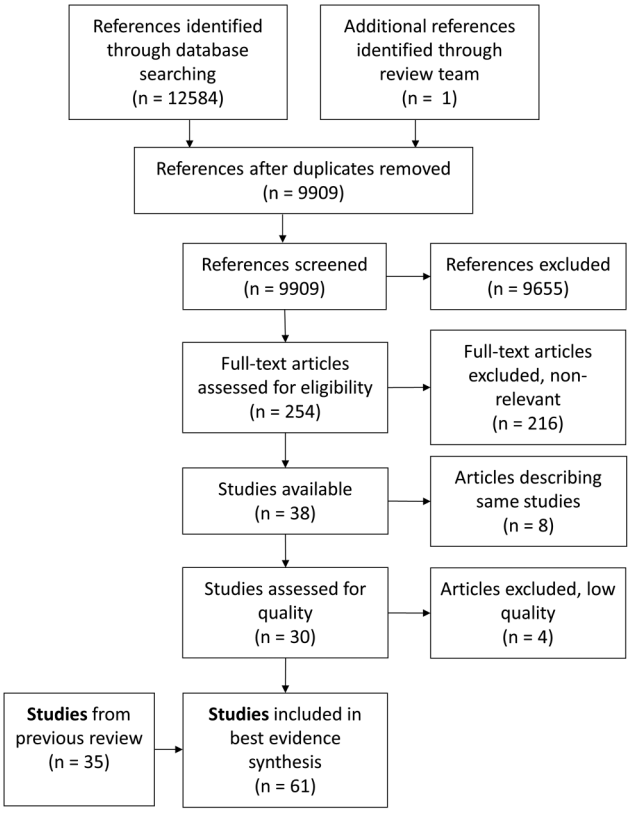

Figure 1 Flow chart of study identification, selection and synthesis.

The sectors included public administration (n=5), professional, scientific or technical services (n=5), manufacturing (n=3), retail (n=1), healthcare and social assistance (n=5), educational services (n=4), hospitality (n=1), armed services (n=1), municipality (n=1), other (n=9), and unknown (n=1). Some studies included populations from multiple sectors. Out of the 26 studies, 16 were considered office based. Overall, positive effects were reported for at least one outcome in 19 of the 26 studies.

Combining studies from original and update

To present an up-to-date synthesis of the evidence, we combined 35 studies[46 79–112] from the original review[23] with the 26 studies from the update for a total of 61 studies.

Intervention effects

There were no negative effects reported in the 61 studies (see online supplementary table S3). The most common UEMSD outcome reported was symptoms. Additional outcomes included sickness absence, disability, disorders (diagnosed) and physical function.

Evidence synthesis

The interventions across the 61 studies were grouped into 30 different intervention categories (see online supplementary table S3) and evidence synthesis for each category was determined (table 2). The intervention category evidence was paired with practical messages (table 2).

The message content was determined through iterative stakeholder consultations to improve practicality. The messages were worded to help clarify the strength of the evidence, limit misinterpretation and increase user uptake.

Seven studies were identified and grouped within the resistance exercise category. Four high-quality[44–47] and three medium-quality studies[48–50] presented a positive effect of resistance exercise, such as dumbbell or kettlebell exercises, on UEMSD outcomes (see online supplementary table S3 for a more complete description of the resistance training programmes; see table 3 for a description of the work environments and sector). The strong level of evidence resulted in the message: implementing a workplace-based resistance training exercise programme can help prevent and manage UEMSD and symptoms.

Three intervention categories had a moderate level of evidence showing a positive effect on UEMSD outcomes (see tables 2, 3 and see online supplementary table S3 for details). The forearm supports category had evidence from two high-quality studies[79 91] and one medium-quality study.[80] The vibration feedback about static mouse use category includes evidence from two high quality studies[62 67] and one medium quality study.[53] The stretching exercise programmes category includes evidence from one high-quality study[68–70] and five medium-

Table 2 Level of evidence for UEMSD interventions and accompanying messages

Level of evidence (direction of effect)*	Intervention (number of studies)†	Message
Strong (positive)	▶ Resistance training (7)	Implementing a workplace-based resistance training exercise programme, policy or practice can help manage and prevent UEMSD symptoms and disabilities
Moderate (positive)	▶ Stretching exercise programmes (includes UE component) (6) ▶ Vibration feedback on static mouse use (3) ▶ Forearm supports (workstation) (3)	Consider implementing in practices if applicable to the work context
Moderate (no effect)	▶ Job stress management training (UE outcomes) (2) ▶ Biofeedback (EMG) training (5) ▶ Workstation adjustment alone (minimal worker engagement) (5)	Seek alternative interventions based on OHS experience/knowledge
Limited (positive)	▶ Aerobic exercise programmes (3) ▶ Alternative keyboard (force profile) (1) ▶ Trackball pointing device (+/− arm supports) (1) ▶ Rest breaks (5) ▶ Postural exercise programme (1) ▶ Specialised exercise program (Feldenkrais) (1) ▶ Curved seat pan chair (non-office) (1) ▶ Lighter/wider dental tools (1) ▶ Neuromuscular exercise (non-office) (1)	Not enough evidence from the scientific literature to guide current policies/practices
Limited (no effect)	▶ Work redesign to minimise shoulder load (non-office) (4) ▶ Joystick pointing device (+/− arm supports) (1) ▶ Neck school programme (1) individualised exercise programme (+/− stress management) (1)	Not enough evidence from the scientific literature to guide current policies/practices
Mixed	▶ Ergonomics training+workstation adjustment (8) ▶ Low-intensity participatory ergonomics (PE) programmes (4) ▶ Cognitive behavioural training programme (2) ▶ Ergonomics training (2)	Not enough evidence from the scientific literature to guide current policies/practices
Insufficient	▶ Rest breaks plus exercise (1) ▶ Reduced hours (1) ▶ Alternative keyboard (split) (1) ▶ Individual interventions (office) (1) ▶ Patient handling programme (1) ▶ OHS training (2–3 h) and/or ergonomic advice/change and/pr exercise and/or medical examination (1)	Not enough evidence from the scientific literature to guide current policies/practices

*No studies reported a negative effect.
†Studies may appear in multiple intervention categories if they have different intervention arms.
OHS, Occupational Health and Safety; UEMSD, upper extremity musculoskeletal disorders.

Table 3 Characteristics of studies

Author, year	Country	Study design	Industry/sector job titles	Sample size
Andersen, 2012[45]	Denmark	Cluster-RCT	Public administration	I1=116, I2=126, I3=106, C1=101
Andersen, 2008, 2010[51 47]; Blangsted, 2008[52]	Denmark	Cluster-RCT	Public administration	I1=180, I2=187
De Kraker, 2008[53]	The Netherlands	RCT	Other: call centre	I1=46
Driessen, 2011, 2008, 2011, 2012[54–57]	The Netherlands	Cluster-RCT	Professional, scientific or technical services; healthcare and social assistance; manufacturing; other: rail and airline companies	I1=1472 (19 departments)
Haukka, 2008[58]	Finland	Cluster-RCT	Retail; hospitality	59 kitchens, 263 workers
Heinrich, 2009[59]	The Netherlands	RCT	Other: predominantly agricultural workers but also other occupations	I1=53; I2=76
Jay, 2011[44]	Denmark	RCT	Professional, scientific or technical services	I1=20
Jepsen, 2008[60]	Denmark	Non-randomised field trial	Professional, scientific or technical services	125
Joshi, 2011[61]	India	RCT	Educational services	I1=30
King, 2013[62]	Canada	RCT	Professional, scientific or technical services	I=11
Lacaze, 2010[63]	Brazil	Non-randomised field trial	Other: transportation and warehousing—flight-booking operators from the call centre of one airline	32
Levanon, 2012, 2012[64 65]	Not specified	Before and after design	Other: hi tech firms	I1=23, I2=22
Mahmud, 2011[66]	Malaysia	Cluster-RCT	Educational services	I1=69
Meijer, 2009[67]	The Netherlands	Cluster-RCT	Other: governmental institute	I=178
Mongini, 2008, 2009, 2010[68–70]	Italy	Non-randomised field trial	Municipality	I=192
Parkkari, 2011[71]	Finland	Cluster-RCT	Armed services	I=536
Pedersen, 2009[50]	Denmark	Cluster-RCT	Public administration	I1=180; I2=187
Pillastrini, 2009[48]	Italy	Cluster-RCT	Educational services	I1=35
Rempel, 2012[72]	USA	Cluster-RCT	Healthcare and social assistance	I1=56
Robertson, 2008[73]	USA	Non-randomised field trial	Professional, scientific or technical services	I1=61, I2 N=not provided
Shiri, 2011[74]	Finland	RCT	Public Administration; Manufacturing; Healthcare & social assistance; Other: 'Warehouse workers'?	I=91
Spekle, 2010[75]	The Netherlands	RCT	Healthcare and social assistance; educational services; municipality; other: nature conservation, regulatory affairs	I1=605
van Eijsden-Besseling, 2008[76]	The Netherlands	RCT	Unknown	I1=44, I2=44
Vermeulen, 2011[77]	The Netherlands	RCT	Public administration; other services	79
Von Thiele Schwarz, 2008[78]	Sweden	Cluster-RCT	Healthcare and social assistance	162
Zebis, 2011[49]	Denmark	Cluster-RCT	Manufacturing	I=282

C, control; I, intervention; RCT, randomised controlled trial.

quality studies.[60 61 63 81 82] The moderate level of evidence of a positive effect resulted in the message: consider implementing these interventions if applicable to the work context.

Three additional studies showed a moderate level of evidence for no effect on UEMSD outcomes. These intervention categories include: EMG biofeedback with two high-quality studies[83 84] and three medium-quality studies;[64 65 85 86] job stress management training category with two high-quality studies;[87 88] and office workstation adjustment category with one high-quality study[89] and three medium-quality studies.[73 74 90] Since there was a moderate level of evidence that these three intervention categories have no effect on UEMSD outcomes, the resulting message is: seek alternatives if possible based on your OHS experience/knowledge.

The remaining 23 intervention categories had too few high-quality studies or had conflicting evidence across studies, resulting in the message: there is not enough evidence from the scientific literature to guide current policies or practices. For a message to be provided for these interventions, more high-quality evidence is needed (table 2).

DISCUSSION

Preventing UEMSD injury and disability is challenging. OHS practitioners are charged with designing and implementing solutions. Evidence-based approaches should help identify and implement more effective solutions. Optimal evidence-based practice employs the knowledge and experience of practitioners along with the most up-to-date evidence from the scientific literature in the context of the client (patient, worker, etc) to determine prevention solutions.[113]

It can be challenging for busy OHS practitioners to find and read the latest research on any given topic. This challenge is compounded by the increase in the number of OHS publications year to year. Using the same literature search strategy as the earlier review,[23] we found over 9900 references in a 5-year period (2008–2013) as compared with approximately 15 400 in a much longer period (mid-1960s–2008). We did find a higher proportion of relevant high-quality studies (50% vs 39%) in the past 5 years as compared with the original review.[23]

The current review and evidence update gathers and synthesises the scientific literature and presents practical messages for

OHS practitioners. The review team consulted with OHS stakeholders to help ensure the messages were useful and applicable in practice.

Combining newer studies with those from the original review resulted in the potential for stronger levels of evidence according to our synthesis approach. However, the new studies also resulted in a greater number of intervention categories as compared with the original review. While we found a strong level of evidence for the positive effect of resistance training, the remaining findings were quite consistent with the original review. Our finding of moderate levels of evidence for positive effects of arm supports is consistent with the original review as is the moderate evidence for no effect of EMG biofeedback and of job stress management training. Kennedy *et al*[23] found a strong level of evidence for no effect of workstation adjustments alone, while in the current update, a moderate level of evidence was found. In this case, one of the newer medium-quality studies had a positive outcome; we note that worker engagement was higher in the recent studies than it was in the original studies, which also contributed to the change in level of evidence.

The diversity of workplace-based interventions for UEMSD likely reflects the variety of potential relevant hazards, the number and types of UEMSD, the distinctness of workplaces, and the practical challenges of trying to design, implement and evaluate policies, programmes and practices. We note that there are many studies (approximately 60%) conducted in office-based workplaces. There are a number of potential reasons for this: the prevalence of UEMSD in office-workers,[1] the nature of the work and workplace with similar equipment designs and work patterns, or possibly because it is easier to conduct an evaluation in an office setting. Office settings may have more consistent work schedules (less shift work), typically there are individual (non-shared) workstations, and the workstation can be relatively easily modified (through adjustment or alternative products). While it may be more challenging to implement and study interventions in non-office settings, our findings suggest it is possible.

Our findings are consistent with other recent reviews that included workplace-based interventions.[17 18 114 115] Reviews that focused on RCTs only and attempted a meta-analysis also did not find strong levels of evidence for workplace interventions.[19–22] While the findings are consistent, our synthesis of workplace-based interventions to prevent and manage UEMSD includes practical messages for, and developed with, practitioners.

A unique aspect of this review (update) was the integration of messages related to the levels of evidence developed with OHS stakeholders.[39] We shared our review findings with multiple groups of OHS stakeholders and received feedback about how to create useful messages. The iterative approach[35] led to concise messages that focused on practice as well as context that a varied group of OHS stakeholders agreed on. The messages are in keeping with an evidence-based practice approach. They provide recommendations or practice considerations to be weighed by the practitioner based on their own knowledge and experience along with the context and end-user needs.

Despite the useful messages provided here, more high-quality workplace-based intervention research is required. Current studies show high-quality evaluations that incorporate concurrent comparison groups (in some cases using randomisation) can be designed and performed. Importantly, the interventions must be properly implemented.

Strengths and limitations

A meta-analysis was not conducted due to the substantial intervention heterogeneity, different workplace contexts and study designs. Instead, a best evidence synthesis (BES) approach consistent with the original review[23] was used. While this approach has been criticised,[27] it provides practitioners with useful information. In addition, the BES is a transparent approach with clearly defined criteria to determine the level of evidence. Beyond the messages that arise from the consistent algorithm employed, practitioners can also consider the evidence from the individual studies. This is especially useful when there are few studies available for a given intervention type. Practitioners must come up with solutions even when there is a lack of scientific evidence available.

The likelihood of publication bias was not addressed; however, we included many relevant peer-reviewed studies that reported no effects for important outcomes. A key aspect of publication bias is that studies reporting positive effects are more likely to be published. While publication bias cannot be ruled out, the number of studies reporting no effects suggests publication bias is not a significant issue in this synthesis.

To determine intervention effects from individual studies, we decided to classify an intervention effect as positive when the study reported any positive result. This followed the method used in the original review.[23] Hence, if a single study outcome regarding UEMSD showed positive results while several other UEMSD study outcomes showed no effect, then this study was still classified as positive intervention effect. Since classification of effect is often based on the primary outcome results, it should be noted that we were not conservative in this part of our evidence synthesis approach. However, we feel that any positive effect might benefit workers and should be taken into account in evidence-based practice.

A particular strength of the synthesis is the OHS stakeholder engagement throughout the review process. Stakeholders helped ensure we were asking a relevant question. Stakeholders were also asked for advice regarding possible literature search terms to ensure our search was up-to-date. Stakeholders were consulted about our findings and how to word the messages for OHS practitioners (consultants or in the workplace) to support evidence-based practice approaches.

CONCLUSIONS

Our synthesis update of the scientific literature identified 30 different intervention types from 61 evaluation studies. There were many intervention types that did not meet the criteria for high or moderate levels of evidence. However, we note that this does not mean that the interventions are not effective, only that there is insufficient evidence to support recommending these interventions based on the scientific evidence.

No intervention evaluations produced negative effects (eg, increased symptoms or lost time claims). However, job stress management training, EMG biofeedback training and workstation adjustment alone interventions had a moderate level of evidence of no effect for UEMSD outcomes. Practitioners should consider *seeking alternative interventions based on OHS experience/knowledge*.

Stretching exercise programmes, vibration feedback on mouse use and workstation forearm supports had a moderate level of evidence for a positive effect in preventing UEMSD. Practitioners should consider *implementing stretching exercise programmes, vibration feedback on mouse use or workstation forearm supports in practices if applicable to the work context*.

Resistance training programmes had a strong level of evidence. We recommend *implementing a workplace-based resistance training exercise programme to help prevent and manage UEMSD symptoms and disorders*.

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Acknowledgements Quenby Mahood, Joanna Liu and the IWH library for valuable help with search strategy design/execution and article acquisition. Trevor King for knowledge transfer and exchange activities and stakeholder engagement. Our stakeholders for their suggestions about practical messages. The Institute for Work & Health operates with the support of the Province of Ontario. The views expressed in this publication are those of the authors and do not necessarily reflect those of the Province of Ontario.

Contributors DVE and EI conceived the study with input from BA. EI developed the search strategy with library support (acknowledged), all authors reviewed the search terms. All authors contributed to article screening, quality appraisal, data extraction and synthesis. DVE, CM and EI wrote the draft paper. All authors contributed to writing, reviewing or revising the paper and have read and approved the final manuscript.

Funding Ontario Ministry of Labour. KS is funded by the UK Medical Research Council (MCUU12017/8 and MCPC13027).

Competing interests None declared.

Provenance and peer review Not commissioned; externally peer reviewed.

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Table 2. Quality appraisal*

Author, Year	Question	Is the research question clearly stated	Were comparison groups(s) used?	Was intervention allocation described adequately?	Was recruitment rate reported?	Were pre-intervention characteristics described?	Was the loss to follow up (attrition)	Were important difference between remaining and dropouts examined?	Was intervention process adequately described?	Were intervention effects on exposure parameters documented?	Was the participation in the intervention documented?	Were the UEMSD symptoms, signs, disorders, injuries, claims and/or lost time outcomes described at baseline and follow-up?	Was the length of follow-up 3 months or greater?	Was there adjustment for pre-intervention differences	Were the statistical analyses optimized for the best results?	Were all participants' outcomes analysed by the groups to which they were originally allocated?	Was there a direct between group comparison?	Total	%	Quality Rating
	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**		
Rempel, 2012[65]		1	1	2	1	1	1	1	1	0	1	1	1	1	1	1	1	40	97.6	H
Haukka, 2008 [48]		1	1	2	1	1	1	0	1	1	1	1	1	1	1	1	1	39	95.1	H
Jay, 2011[50]		1	1	2	1	1	1	1	1	1	1	1	0	1	1	1	1	39	95.1	H
Parkkari, 2011[62]		1	1	2	1	1	0	1	1	1	1	1	1	1	1	1	1	39	95.1	H
Andersen, 2012[42]		1	1	2	1	1	0	1	1	0	1	1	1	1	1	1	1	38	92.7	H
van Eijsden-Besseling, 2008[69]		1	1	2	1	1	1	0	1	0	1	1	1	1	1	1	1	38	92.7	H
Vermeulen, 2011[70]		1	1	2	1	1	1	0	1	0	1	1	1	1	1	1	1	38	92.7	H

Heinrich, 2009[49]		1	1	2	1	1	1	1	0	0	1	1	1	1	1	1	1	37	90.2	H
King, 2013[53]		1	1	2	1	0	1	1	1	1	1	1	1	0	1	1	1	36	87.8	H
Meijer, 2009[58]		1	1	2	1	1	1	1	1	1	1	1	1	0	1	0	1	36	87.8	H
Andersen, 2008, 2010[39, 40]; Blangsted 2008 [41]		1	1	2	1	1	1	0	1	0	1	1	1	0	1	1	1	35	85.4	H
Mongini, 2008, 2009, 2010[59-61]		1	1	1	1	1	1	0	1	0	1	1	1	1	1	1	1	35	85.4	H
Levanon, 2012, 2012[55, 56]		1	1	1	0	1	1	1	1	1	1	1	0	1	1	1	1	34	82.9	M
Spekle, 2010[68]		1	1	2	1	1	0	0	1	1	1	1	1	0	1	1	1	34	82.9	M
Von Thiele Schwarz, 2008[71]		1	1	2	1	1	1	1	1	1	0	1	1	1	0	0	1	34	82.9	M
Pillastrini, 2009[64]		1	1	2	1	1	1	1	1	0	1	1	0	0	0	1	1	32	78.0	M
Shiri, 2011[67]		1	1	2	1	1	0	0	0	1	1	1	1	1	1	0	1	32	78.0	M
Zebis, 2011[72]		1	1	2	1	1	0	0	1	1	1	1	1	1	0	0	1	32	78.0	M
Driessen, 2011, 2008, 2011,		1	1	2	1	1	0	1	1	1	0	0	1	1	0	1	1	31	75.6	M

2012[44-47]																				
Mahmud, 2011[57]		1	1	2	0	1	1	0	1	1	0	1	1	0	0	1	1	29	70.7	M
Pedersen, 2009[63]		1	1	2	1	1	0	0	1	0	1	1	1	0	0	0	1	28	68.3	M
De Kraker, 2008[43]		1	1	2	0	1	0	0	1	1	1	0	0	1	0	0	1	25	61.0	M
Robertson, 2008[66]		1	1	1	1	0	0	0	0	1	1	1	1	0	1	0	1	24	58.5	M
Lacaze, 2010[54]		1	1	1	0	1	1	1	1	0	0	0	0	1	0	0	1	23	56.1	M
Joshi, 2011[52]		1	1	1	0	1	1	1	0	0	0	1	0	0	0	1	1	22	53.7	M
Jepsen, 2008[51]		1	1	1	0	0	0	0	1	0	1	1	1	0	0	0	1	21	51.2	M
Pereira, 2013**[38]		1	1	2	1	0	0	0	0	0	0	1	0	0	0	0	1	19	46.3	L
Bernaards, 2010**[35]		1	1	1	1	1	0	0	0	0	1	0	1	0	0	0	1	19	46.3	L
Laestadius, 2009**[36]		1	1	1	0	1	0	0	0	1	0	1	1	0	0	0	1	19	46.3	L
Choobineh, 2011**[37]		1	1	1	0	1	0	0	0	0	0	1	1	0	0	0	0	15	36.6	L

*Note the quality appraisal of studies published before 2009 can be found in Kennedy et al. 2010[18]

**Excluded from analysis due to lower quality scores

H=high quality, M=medium quality, L=low quality

Table 3. Study intervention descriptions and outcome summaries organized by Intervention Category. Note when there are multiple interventions the non-relevant intervention is in light grey text.

Author, Year	Quality	Intervention description	Outcome
Intervention Category: Resistance exercise			
Jay, 2011[44]	High (39)	I: Kettlebell training: 5-10 min warm up with 10-15 min progressive weight interval training. C: No intervention.	+ (I vs C) neck/shoulder pain intensity
Andersen, 2012[45]	High (38)	I1, I2, I3: Dumbbell strength training exercises: front raises, lateral raises, reverse flies, shrugs and wrist extensions. I1: I hour per week, I2: 20 min three times per week, I3: 7 min nine times per week. C: No intervention.	+ (I1, I2, I3 vs C) right shoulder; Ø (I1, I2, I3 vs C) neck; Ø (I1, I2, I3 vs C) left shoulder
Sjogren, 2005[46]	High (37)	I: ''Progressive light resistance training'' exercise, on-site with physiotherapist guidance in 20 min group sessions over 15 weeks. 6 min training sessions in 3 five-week intervals—1st: 19/day, 2nd and 3rd: 1–2 per day, (7–89/week). C: No intervention. I1C: Cross-over with intervention first (15-week I then 15-week C). I2C: Cross-over with intervention second (15-week C then 15-week I).	+ (I vs C) intensity of neck symptoms Ø (I vs C) intensity of shoulder symptoms
Andersen, 2008, 2010[47, 48]; Blangsted 2008 [49]	High (35)	I1: Specific resistance training 20 min 3 times per week. I2: All round physical exercise 1 hour weekly. C: Encouraged to form groups to improve health and working conditions.	+ (I1 vs C) neck, elbow, hand, pain intensity; + (I1 vs C) maximal muscle strength; Ø (I1 vs C) neck pain duration; Ø (I1 vs C) shoulder pain, intensity and duration
Pillastrini, 2009[50]	Medium (32)	I: Physical therapist led extension-oriented exercise program. Exercises reinforced lumbar extension and strengthened the spine primary stabilizers (transversus abdominis,oblique abdominal, multifidus, quadratus lumborum and erector spinae muscles).	+ (I vs C) neck pain 0-10 VAS

Zebis, 2011[51]	Medium (32)	I: High-intensity strength training with four dumbbell exercises for neck and shoulder muscles and 1 exercise for the wrist extensor muscles. C: Advised to stay physically active and received weekly supervisor consulting for 20 weeks.	+ (I vs C) neck pain intensity; neck pain case status change from baseline; shoulder pain case status change from baseline Ø shoulder pain intensity
Pedersen, 2009[52]	Medium (28)	I1: Strength resistance training with dynamic exercises with dumbbells for shoulder girdle muscles and isometric exercises for cervical spine muscles. I2: All round physical exercise encouraging participants to engage in various physical activities at the worksite and during leisure time with instruction from experts 1 to 4 times a month. C: Encouraged workers to organize and meet surrounding work place health conditions. Workers could get help but researchers did not implement changes.	+ (I1 vs C) pain duration right shoulder; pain duration low back; Ø (I1 vs C) pain duration neck
Intervention Category: Forearm supports (added to workstation)			
Rempel, 2006[53]	High (40)	I1: Trackball and ergonomics training. I2: Forearm support board and ergonomics training. I3: Forearm support board, trackball and ergonomics training. C: Only the ergonomics training.	+ (neck/sh, RUE pain) Ø (LUE pain) + (neck/sh disorders) Ø (R&LUE disorders) (I2&I3 vs I1&C) * the forearm effect is w or w/o trackball.
Conlon, 2008[54]	High (36)	I3: Alternative mouse with forearm support board. I2: Conventional mouse with forearm support board. I1: Alternative mouse without forearm support. C: Conventional mouse without forearm support board.	+ (I2&I3 vs I1&C) (RUE) Ø (I2&I3 vs I1&C) (neck/sh, LUE)
Lintula, 2001[55](I1 one hand, I2 both hands)	Medium (30)	I1: One Ergorest® arm support with a mouse pad for the mousing hand. I2: Ergorest® arm supports for both hands with a mouse pad for the mousing hand. C: No arm supports and instructed not to change workstations during study period.	Ø (I1 vs. I2 vs. C) (neck/sh/arm)
Intervention category: Vibration feedback about static mouse use			

King, 2013[56]	High (36)	I: Hoverstop mouse with a feedback signal that caused mouse to vibrate when the hand was on or above the mouse and mouse did not move for 10 seconds. A short information session about how to interpret feedback was provided. C: Alternative mouse with vibration mechanism turned off.	+/Ø (I vs C) shoulder Ø (I vs C) UE
Meijer, 2009[57]	High (36)	I: Hoverstop mouse with a feedback signal that caused mouse to vibrate when the hand was on or above the mouse and the mouse did not move for 10 seconds. A short information session about how to interpret the feedback was provided. C: Mouse without feedback feature.	+ (I vs C) physical disability Ø (I vs C) UE
de Kraker, 2008[58]	Medium (25)	I: Hoverstop mouse with a feedback signal that caused mouse to vibrate when the hand was on or above the mouse and mouse did not move for 10 seconds. A short information session about how to interpret the feedback was provided. C: Control group kept working with the regular mouse: same features as experimental mouse but without the tactile, vibrating feedback signal.	Ø (I vs C) arm/ shoulder
Intervention category: Stretching exercise programs (including Yoga) with an UE component			
Mongini, 2008; 2009; 2010[59-61]	High (35)	I: Brief shoulder and neck exercises performed several times a day, a relaxation exercise, and instructions on how to reduce craniofacial and neck muscle parafunction and hyperfunction. C: No intervention.	+ (I vs C) frequency of neck pain; neck shoulder pain;
Galinsky, 2007[62]	Medium (31)	I1: Neck, shoulders, back, and upper extremities stretching for 2 minutes at every break. C: No stretching. Note: Mixed design with stretching as between-subject factor and breaks as within-subject factor. Within both groups, over the 8 weeks, workers spent 4 weeks with conventional breaks every two hours (15-minute breaks in morning and afternoon and 30-minute break for lunch) and 4 weeks with a break every hour (conventional schedule plus four five-minute breaks).	Ø (I1 vs C) (Musculoskeletal discomfort ratings were made for neck, shoulders, upper arms, elbows, forearms, wrists, hands)

Lacaze, 2010[63]	Medium (23)	I: Daily 10-min exercise program with10 different sets of exercises, including stretching (hamstrings, spinal column, forearms, and shoulders), joint mobilization (hands, wrists, shoulders, column, hips, knees and ankles) and relaxation. C: Daily 10-min rest break with no physical activity or work tasks.	Ø (I vs C) neck and shoulder discomfort; neck and should improvement
Joshi, 2011[64]	Medium (22)	I1: 3 x 1h/day counseling by physiotherapists and 3 x 1h/day yoga training. I2: 3 x 1h/day counseling by physiotherapists.	+ (I1 vs I2) Symptom severity score; + (I1 vs I2) Cervico-thoracic myalgia; Ø (I1 vs I2) Functional status score; Ø (I1 vs I2) Tingling; Ø (I1 vs I2) on Weakness; Ø (I1 vs I2) on Numbness; Ø (I1 vs I2) on Nocturnal exacerbation.
Jepsen, 2008[65]	Medium (21)	I: Stretches (4) for wrist, forearm, and shoulder repeated 3X per day for 6 months. C: Questionnaire and physical examinations.	+ (I vs C) shoulder symptoms; Ø (I vs C) elbow or wrist/hand symptoms; pain level
Nevala Puranen, 2003[66]	Medium (21)	I1: Redesign of workstations (included workstation placement in room, new worktables allowing forearm/hand support, new adjustable chair, more table space, monitors placed below eye level, paper holders provided, heights of tables and chairs adjusted for each subject, training on possibilities for adjustment, new mice and standard flat keyboards were acquired if needed). I2: Redesign of workstations (same as I1) 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 workstation) for upper extremity).	+ (I2 vs. I1) on neck, shoulder, and elbow symptoms Ø (I2 vs. I1) on wrist symptoms
Intervention category: EMG Biofeedback (+/- ergo training)			

Faucett, 2002[67]	High (39)	I1: Muscle learning therapy (MLT) that used sEMG (Electromyographic) feedback and operant conditioning to decrease muscle tension. I2: 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 solving. C: No intervention.	Ø (I1 vs C) (UE/neck/sh)
Voerman, 2007[68]	High (36)	I: Ergonomic counseling on workstation adjustments via weekly visits by therapist (physiotherapist, health scientists) for four weeks. First visit comprised an ergonomic risk inventory and discussions with the worker about possible improvements. Workstation adjustments focused on modifying existing workstation (no new equipment). Remaining visits used to further discuss the ergonomic aspects and ergonomic adjustment consequences. In addition, workers received ambulant myofeedback training (consisted of shoulder/neck relaxation methods to reduce EMG inactivity recorded and training in a muscle reset procedure). C: Received same information as Intervention group with the exception of ambulant myofeedback.	Ø (I vs C) (sh/neck)
Levanon,2012; 2012[69, 70]	Medium (34)	I1: Ergonomics intervention with biofeedback. I2: Ergonomics Intervention without Biofeedback -- muscle activity was assessed through palpation. Oral feedback was provided. C: Received short oral presentation on how to sit, the preferred height of chair, table, keyboard and screen, and the NIOSH recommended position of the back, shoulders elbows and wrists.	+ (I1 vs I2) hand pain severity score
Peper, 2004 [71]	Medium (25)	I: Training of six weekly two hour group sessions in ergonomic principles, psychophysiological awareness and control, sEMG feedback while practicing at the workstation. C: No intervention.	+ (I vs. C) (neck/sh, arms, wr/hand)

Thomas, 1993[72]	Medium (22)	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 excessive force exertion with fingers. Used device for one hour per day. C: No intervention.	Ø (I vs C) (forearm/hands)
Intervention category: Job stress management training (UE outcomes)			
Horneij, 2001[73](I2)	High (39)	I1: individually designed physical training program based on baseline physical exam results. 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. I2: 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." Groups (five to 12 subjects) met seven times over seven weeks, each time for 1.5 hours. Follow-up meetings covering both “theory and practice” occurred at three and six months. C: No intervention.	Ø (I2 vs C) (neck, sh)
Feuerstein, 2004[74]	High (36)	I: Worksite checklist evaluation by a health professional, workstation adjustments (no new equipment), stretching exercises and access to an ergonomics information website (ErgoClinic). Workeers also received 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.	Ø (I vs C) (neck/UE)
Intervention category: Workstation adjustment with minimal worker engagement			

Pillastrini, 2007[75]	High (41)	I: Individual workstation adjustments by trained/expert physical therapist, approx 30 minutes per individual at baseline and five to 10 minutes twice a month for five months. Brochure about VDT and MSDs was provided. C: informative brochure about VDT and MSDs.	Ø (I vs C) (sh, hand/wr, neck)
Shiri, 2011[76]	Medium (32)	I: Work accommodations, physiotherapist visiting the workplace and making recommendations regarding ergonomic improvements to improve UE disorder recovery. C: No intervention.	Ø (I vs C) pain intensity; pain interference with work; sickness absence due to UE MSD
Lin, 2007[77]	Medium (31)	I: Redesigned workstations (mainly to reduce shoulder loadings), according to workstation specification design by Occupational Safety and Health Administrations of Oregon State (OR-OSHA, 2004). C: Original workstations (matched by their similarity of age, height, weight, employment duration, working practice, and musculoskeletal (MSK) risk factors and symptoms).	Ø (I vs C) (sh) at 3 months
Robertson, 2008[78]	Medium (24)	I1: Workstation changes only: a new flexible office work space with adjustable workstations and a highly adjustable chair. I2: Workstation changes and training: a two-hour office ergonomics training with a follow-up ergo-buddy workstation assessment supported by the training facilitation. C: Control: no intervention.	+ (I1 v C) wrist/hand, finger at T1 v T3 Ø (I1 v C) Neck, Shoulder, Elbow at T1 vs T3
Intervention category: Aerobic exercise program			
Andersen 2008,2010[47, 48], Blangsted 2008 [49]	High (35)	I1: Specific resistance training (SRT) 20 min 3x a week. I2: All round physical exercise (APE) 1 hour a week. C: Participants were encouraged to form groups to improve health and working conditions.	+ (I2 vs C) neck, shoulder, elbow, hand pain intensity; maximal muscle strength; Ø (I2 vs C) neck pain duration; shoulder pain, intensity and duration
Von Thiele Schwarz, 2008[79]	Medium (34)	I1: Physical-exercise group. I2: Reduced-work hours group (RWH). C: No intervention.	Ø (I1 vs C) UE disorder

Pedersen, 2009[52]	Medium (28)	I1: SRT dynamic strengthening exercises with dumbbells for the shoulder girdle muscles and isometric exercises for the cervical spine muscles. I2: Participants encouraged to engage in various types of physical activities at work and during leisure time with instruction from experts 1 to 4 X a month. C: Encouraged workers to organize and meet surrounding work place health conditions. Workers could get help but researchers did not implement change with this group.	+ (I2 vs C) pain duration right shoulder; pain duration low back;(I2 vs C) pain duration neck ;
Intervention category: Alternative keyboards– key force profile			
Rempel, 1999 [80]	High (38)	I: Keyboard with alternative switch design: the key force-displacement profiles have a greater travel distance until the key is "made" and greater "dampening" when the key reaches the bottom of its travel. C: Conventional keyboard.	+/ Ø (I vs C) on reducing Phalen's test time and nerve conduction
Intervention category: Lighter/wider handle dental tools			
Rempel, 2012[81]	High (40)	I: Introduction of light dental scaling instrument with larger diameter. C: Heavier, smaller diameter dental instrument.	+ (I vs C) right shoulder pain; number of nights that participants were awakened with numbness in the right thumb or index or middle finger; Ø right wrist/hand, elbow/forearm pain
Intervention category: Postural exercise program			
van Eijsden-Besseling, 2008[82]	High (38)	I1: The Mensendieck/Cesar exercises use of feedback from muscle, joint, tendon, and ligaments, therapist instructions, mirrors and videotaping. Training includes patient-specific everyday activities such as computer work. Postural exercises at home in front of a mirror and at their work place. Intevention is 10 weeks with 12 sessions lasting a total of 1.5 hours longer than I2. I2: PT strength and physical fitness training with 18 sessions in 10 weeks.	+ (I1 vs I2) on Pain VAS (0-10) at 3 months; Ø (I1 vs I2) number of participants with complaints; Ø (I1 vs I2) Pain VAS (0-10) at 6, 12 months; Ø (I1 vs I2) DASH (0-100) at 3, 6 12 months
Intervention category: Neuromuscular exercise intervention (military)			

Parkkari, 2011[83]	High (39)	I: Military recruits participated in neuromuscular training (9 exercises) to improve balance, posture, coordination and agility and received injury prevention training. During first 8 weeks recruits worked in groups for 30-45 minutes 3 X per week at moderate intensity. In weeks 9-26 they were instructed to continue exercises at least once weekly and exercise logs were reviewed weekly. They performed group exercises 2-4 X per month on top of usual training regimen (below). Injury prevention training was an informational booklet a one hour lecture/video. C: Usual training regimen of the Finnish army (17 hours weekly including marching cycling, skiing, swimming, orienteering, drill training and 7 hours of additional physical activity including jogging, team sports and circuit training).	+ (I vs C) risk for acute upper extremity injury among men with moderate to high baseline fitness; Ø (I vs C) risk for acute upper extremity injury among all men in study group
Intervention category: Specialized exercise program (+/- Feldenkrais)			
Lundblad, 1999[84]	High (36)	I1: 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. I2: 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.	+ (I2 vs. I1 and C) on prevalence of neck pain in the previous seven days Ø (I1 and I2 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)
Intervention category: New adjustable chair with different seat pans (non-office)			
Rempel, 2007[85] I1 (curved) and I2 (flat)	High (38)	I1: New adjustable height curved seat pan chair and miscellaneous items. I2: New adjustable height 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).	+ (I1 vs I2 vs C) (neck/sh)
Intervention category: Rest breaks (office based)			

Galinsky, 2007[62]	Medium (31)	Mixed design with stretching exercise (Neck, shoulders, back, and upper extremities stretching for 2 minutes at every break) as a between-subject factor and rest-break schedule as a within-subject repeated measures with randomized order. Over the 8 weeks, all workers spent (C) 4 weeks with conventional breaks every two hours (15-minute breaks in morning and afternoon and 30- minute break for lunch) and (I2) 4 weeks with a break every hour (conventional schedule plus four five-minute breaks).	+ (C vs I2) (neck, Rsh/upper arm, Rforearm/wr/hand, Lsh/upper arm, Lforearm/wrist/hand)
Galinsky, 2000[86]	Medium (29)	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.	+ (I vs C) (neck, Rsh/upper arm, Relbow, Rforearm/wr/hand, Lsh/upper arm, Lelbow) Ø (I vs C) (Lforearm/wrist/hand)
McLean, 2001[87] (I1 q40 min, I2 q20 min)	Medium (28)	I1: Workstation assessment and adjustments. Ergobreak™ software prompted users to take 30-second breaks every 40 minutes. I2: 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.	+ (I2 vs C) forearm/wr Ø (I2 vs C) neck, sh Ø (I1vs C) neck/sh/forearm/wr
van den Heuvel, 2003[88]	Medium (26)	I1: 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. I2: Break reminder software plus exercise. Same as I1 plus software prompted user to do exercises during the breaks. C: Only workstation adjustment and training.	Ø (I1 vs C) (neck/sh, arms/elbows/ forearms/wr/hands/ fingers)
Intervention category: Trackball pointing device (+/- forearm support)			

Rempel, 2006[53] (Trackball)	High (40)	I1: Trackball and ergonomics training. I2: Forearm support board and ergonomics training. I3: Forearm support board, trackball and ergonomics training. C: Only the ergonomics training.	+ (LUE) pain & disorders Ø (neck/sh, RUE) pain & disorders (I1&I3 vs C&I2)
Intervention category: Neck school program (+/- reinforcement)			
Kamwendo, 1991[89]	Medium (30)	I1: Traditional neck school (four hours): four trainings by a physiotherapist on active and stretching exercises and muscle relaxation. I2: 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.	Ø (I1 or I2 vs. C) on neck and shoulder pain
Intervention category: Work redesign to allow for reduced shoulder loads (non-office)			
Luijsterburg, 2005[90]	Medium (33)	I: Bricklayers that implemented raised bricklaying. C: Bricklayers that did not implement raised bricklaying.	Ø (I vs. C) (sh, hand/wr)
Veiersted, 2007[91]	Medium (27)	I1: 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. I2: Written information (same as I1) plus personal follow-up with a demonstration and discussion of each recommendation (10 minutes).	Ø (I1 vs. I2) (neck, sh)
van der Molen, 2004[92]	Medium (26)	I: Mechanical lifting with a crane (adjusted method), transporting materials with a crane (bricks and mortar). C: Manual (conventional method). Note: I1C: Cross-over with intervention first. I2C: Cross-over with intervention second. Order of I and C was varied across participants (each participant took part in both conditions (I and C), condition order and time of observation am/pm was randomly assigned).	Ø (I vs C) (sh)

Fredriksson, 2001[93]	Medium (21)	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 and 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. Four times a day the workers changed stations. C: No change in work process (another car-body department with most similar working conditions to intervention group).	Ø (I vs. C) (neck, sh, hand/wr)
Intervention category: Joystick pointing device (+/- arm supports)			
Conlon, 2008 [54]	High (36)	I1C2: Alternative mouse (vertical mouse) without forearm support board. C1I2: Conventional mouse with forearm support board. C1C2: Conventional mouse without forearm support board. I1I2: Alternative mouse with forearm support board.	Ø (I1 vs C1) neck/sh, R&LUE; neck/sh, R&LUE
Intervention category: Individualized exercise program (+/- stress management)			
Horneij 2001[73]	High (39)	I1: Individually designed physical training program based on baseline physical exam results. 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. I2: 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." Groups (five to 12 subjects) met seven times over seven weeks, each time for 1.5 hours. Follow-up meetings covering both “theory and practice” occurred at three and six months. C: No intervention.	Ø (I1 and I2 vs. C) on neck and shoulder pain (Nordic Musculoskeletal Questionnaire)
Intervention category: Low intensity participatory ergonomics program			

Haukka, 2008[94]	High (39)	I: The workers identified problems in their work and generated and evaluated solutions for them. The changes were implemented together with the workers, middle management and technical staff. C: Three monthly visits to distribute questionnaires and document spontaneously occurred ergonomic changes.	+ (I vs C) MSK pain in neck at three months; MSK pain in forearms or hands at 3 and 9 months; Ø (I vs C) MSK pain in neck at 6, 9, 12 months; MSK pain in forearms or hands at 6 and 12 months; MSK pain in shoulder at 3,6, 9, 12 months;
Vermeulen, 2011[95]	High (38)	I: Intervention group participants received usual care and then were referred to participate in a RTW program to discuss obstacles for returning to work. C: Usual care.	Ø (I vs C)Neck Pain intensity (1-10 score)
Driessen, 2011; 2008; 2011; 2012[96-99]	Medium (31)	I: Followed steps of the Stay@Work participatory ergonomics programme which involves identifying risks, ergonomic measures and creating an implementation plan. C: Watched 3 educational films.	Ø (I vs C) neck pain at 3, 6, 9, 12 months; Ø (I vs C) the probablity of preventing neck pain
Laing, 2007[100]	Medium (24)	I: 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.	Ø (I vs. C) on pain severity of shoulder/upper arm and forearm/hand
Intervention category: Ergonomics training and workstation adjustment (+/- new chair)(office-based)			
Ketola, 2002[101] (high I2 & low I1 intensity)	High (39)	I1: Ergonomic checklist, evaluation and adjusted workstations with physical therapist. New forearm and wrist rests provided if needed I2: 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.	Ø (I1 vs C) (neck, R&Lneck/sh, R&L sh, R&L forearm, R&L wr, R&L fingers) at 10 months Ø (I2 vs C) (neck, R&Lneck/sh, R&L sh, R&L forearm, R&L wr, R&L fingers) at 10 months

Gerr, 2005[102]	High (37)	I1: Training and workstation adjustments based on protective factors identified from prior studies. I2: Training and workstation adjustments based on OSHA, NIOSH and private industry standards. C: No instruction, but received the same visits from the study staff.	Ø (I1 vs I2 vs C) (arm/hand, neck/sh)
Martin, 2003 [103](and Gatty, 2004)[104]	High (36)	I: Individual training for one hour per week for four weeks in body mechanics, workstation adjustments and task modification. C: No intervention.	Ø (I v C) (elbow/forearm) Ø (I vs C) (neck, sh, wr/hand)
Levanon, 2012; 2012[69, 70]	Medium (34)	I1 vs C, I2 vs C I1: Ergonomics intervention with biofeedback (This intervention was accompanied by traditional biofeedback which is appropriate for pain prevention as well as chronic pain.) I2: Ergonomics Intervention without Biofeedback -- muscle activity was assessed by the researcher through palpation and oral feedback was provided. C: Received short oral presentation on how to sit, the preferred heights of the chair, table, keyboard and screen, and the best position of the back, shoulders elbows and wrists, based on NIOSH recommendations.	+ (I1 vs C, I2 vs C) shoulder, neck Ø (I1 vs C, I2 vs C) wrist, elbow
Cook, 2004[105]	Medium (33)	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.	Ø (I vs C) (neck, sh, forearm, wr)
Mahmud, 2011[106]	Medium (29)	I1: Training over 1 day. The first session consisted of lectures on office ergonomics, understanding the relationship between office ergonomics and the development of MSDs, ergonomic improvements and adjustments of workstations, and stretching exercises. The second session focused on the practical aspects of the training; trainers visited the participants' workstations and provided assistance to them on how to adjust workstations effectively. C: No ergonomic training or visit to adjust workstation	+ (I vs C) Prevalence of Neck Pain; + (I vs C) Prevalence of Right Shoulder Pain; + (I vs C)Right upper limb; + (I vs C) Left Upper Limb Ø (I vs C) Prevalence of Left Shoulder Pain;

Robertson, 2008[78]	Medium (24)	I1: Workstation adjustment only: a new flexible office work space with adjustable workstations and a highly adjustable chair. I2: Workstation adjustment and training: a two-hour office ergonomics training with a follow-up ergo-buddy workstation assessment supported by the training facilitation. C: Control: no intervention.	+ (I2 vs C) Neck, Shoulder, wrist/hand, finger at T1 vs T3 Ø (I2 v C) Elbow, at T1 vs T3
Nevala Puranen 2003[66]	Medium (21)	I1: Redesign of workstations (included workstation placement in room, new worktables allowing forearm/hand support, new adjustable chair, more table space, monitors placed below eye level, paper holders provided, heights of tables and chairs adjusted for each subject, training on possibilities for adjustment, new mice and standard flat keyboards were acquired if needed). I2: Redesign of workstations (same as I1) 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 workstation) for upper extremity).	+ (I2 vs. I1) on neck, shoulder, and elbow symptoms Ø (I1 vs. I2) on wrist symptoms
Intervention category: Cognitive behavioural training (UE outcomes)			
Faucett, 2002 (I2)[67]	High (39)	I1: Muscle learning therapy (MLT) that used sEMG (Electromyographic) feedback and operant conditioning to decrease muscle tension. I2: 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 solving. C: No intervention.	Ø (I2 vs C) UE/neck/sh

Heinrich, 2009[107]	High (37)	I1: Physical training including cardiovascular training, strengthening, relaxation exercises and posture exercises. I2: Cognitive behavioural training to focus the participant on the functional level they could achieve at work for 30 minutes/session over 2-3 sessions of 6-8 workers per week. Each session was 1-1.5 hours for 3 months. The remainder of each session was usual physical training (comparison group) including cardiovascular training, strengthening, relaxation exercises and posture exercises. Workplace specific exercises were developed after a video was taken of participants' workplace (all self-employed) to develop exercise tailored to workplace. C: Usual care.	+ (I1vs C)Pain, claim duration at 6 months; Ø (I2vs C) Pain, claim duration at 6 months; Ø (I1, I2 vs C) Functional status NPDI, QBPDS at 6 months; Ø (I1, I2 vs C)) Pain, Functional status NPDI, claim duration, QBPDS at 12 months;
Intervention category: Ergonomic training (office based)			
Greene, 2005[108]	Medium (31)	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.	Ø (I vs. IC) (sh/upperarm/elbow/ forearm/wr/hand)
Bohr, 2000[109]	Medium (26)	I1: One-hour traditional ergonomics training session consisting of lecture and handouts about office ergonomics. I2: Two-hour participatory ergonomics training session with problem solving. C: No intervention.	+ (I1 or I2 vs C) (neck/upper back/shoulder/upper arm/forearm/wrist/hand)

Robertson, 2008[78]	Medium (24)	I1: Workstation adjustment only: a new flexible office work space with adjustable workstations and a highly adjustable chair. I2: Workstation adjustment and training: a two-hour office ergonomics training with a follow-up ergo-buddy workstation assessment supported by the training facilitation. C: Control: no intervention.	+ (I1 vs I2) Neck, Shoulder, wrist/hand, finger at T1 v T3 Ø (I1 vs I2) Elbow, at T1 v T3
Intervention category: Alternative keyboard (split keyboard)			
Tittiranonda, 1999[110]	Medium (29)	I1: Apple Adjustable Keyboard™ (adjustable split) plus one-hour ergonomics training. I2: Comfort Keyboard System™ (adjustable split) plus one-hour ergonomics training. I3: Microsoft Natural Keyboard™ (fixed split)plus one-hour ergonomics training. C: Conventional keyboard plus one-hour ergonomics training.	+ (I3 vs C) (arm/hand) Ø (I1 or I2 vs C) (arm/hand) Ø (I1 or I3 vs C)
Intervention category: OHS training (2-3 hours) and/or ergonomic advice and/or exercise and/or medical examination			
Leclerc, 1997[111]	Medium (32)	I: Multiple interventions across multiple worksites tested. Interventions included OHS training and/or ergonomics advice and/or exercise and/or medical examination. C: Usual injury prevention policies.	+ (I vs C) (sh) Ø (I vs C) (neck; upper back
Intervention category: Individualized interventions (office-based)			
Spekle, 2010[112]	Medium (34)	I: The RSI QuickScan, A short office ergonomic hazard identification tool, was completed and each participant received a scorecard. !6 different types of interventions were offered that were paid for by the employer. The following interventions were completed: visiting an occupational physician, obtaining an eye exam, education on RSI prevention, a single office visit with personalized workstation adjustments, a task analysis and a stress prevention training. C: Usual care.	Ø (I vs C) Arm shoulder and neck symptoms, proximal symptoms, Distal symptoms;
Patient handling program			

Yassi, 2001[113]	Medium (22)	I1: "Safe-lift" policy; lifting and transfer equipment; three hours of education on back care, patient assessment and handling techniques. I2: "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 change; 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.	+ (I1 vs C) (sh) Ø (I2 vs C) (sh)
Intervention category: Rest breaks and exercise			
van den Heuvel, 2003[88]	Medium (26)	I1: 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. I2: Break reminder software plus exercise. Same as I1 plus software prompted user to do exercises during the breaks. C: Only workstation adjustment and training.	Ø (I2 vs C) (neck/sh, arms/elbows/ forearms/wr/hands/ fingers)
Intervention category: Reduced hours			
Von Thiele Schwarz, 2008[79]	Medium (34)	I1: Physical-exercise group. I2: Reduced-work hours group (RWH). C: No intervention.	Ø (I2 vs C) UE disorder

Ø= no effect, += positive effect, I= Intervention, C=Control