# Ergonomic design and training for preventing work-related musculoskeletal disorders of the upper limb and neck in adults (Review)

**Hoe VCW, Urquhart DM, Kelsall HL, Sim MR**


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[Intervention Review]

# Ergonomic design and training for preventing work-related musculoskeletal disorders of the upper limb and neck in adults

Victor CW Hoe[1], Donna M Urquhart[2], Helen L Kelsall[2], Malcolm R Sim[2]

[1]Centre for Occupational and Environmental Health, University of Malaya, Kuala Lumpur, Malaysia. [2]Department of Epidemiology & Preventive Medicine, Monash University, Melbourne, Australia

Contact address: Victor CW Hoe, Centre for Occupational and Environmental Health, University of Malaya, Pantai Valley, Kuala Lumpur, 50603, Malaysia. drvictorhoe@gmail.com. victor@ummc.edu.my.

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## ABSTRACT

### Background

Work-related upper limb and neck musculoskeletal disorders (MSDs) are one of the most common occupational disorders around the world. Although ergonomic design and training are likely to reduce the risk of workers developing work-related upper limb and neck MSDs, the evidence is unclear.

### Objectives

To assess the effects of workplace ergonomic design or training interventions, or both, for the prevention of work-related upper limb and neck MSDs in adults.

### Search methods

We searched MEDLINE, EMBASE, the Cochrane Central Register of Controlled Trials (CENTRAL), CINAHL, AMED, Web of Science (Science Citation Index), SPORTDiscus, Cochrane Occupational Safety and Health Review Group Database and Cochrane Bone, Joint and Muscle Trauma Group Specialised Register to July 2010, and Physiotherapy Evidence Database, US Centers for Disease Control and Prevention, the National Institute for Occupational Safety and Health database, and International Occupational Safety and Health Information Centre database to November 2010.

### Selection criteria

We included randomised controlled trials (RCTs) of ergonomic workplace interventions for preventing work-related upper limb and neck MSDs. We included only studies with a baseline prevalence of MSDs of the upper limb or neck, or both, of less than 25%.

### Data collection and analysis

Two review authors independently extracted data and assessed risk of bias. We included studies with relevant data that we judged to be sufficiently homogeneous regarding the intervention and outcome in the meta-analysis. We assessed the overall quality of the evidence for each comparison using the GRADE approach.

**Main results**

We included 13 RCTs (2397 workers). Eleven studies were conducted in an office environment and two in a healthcare setting. We judged one study to have a low risk of bias. The 13 studies evaluated effectiveness of ergonomic equipment, supplementary breaks or reduced work hours, ergonomic training, a combination of ergonomic training and equipment, and patient lifting interventions for preventing work-related MSDs of the upper limb and neck in adults.

Overall, there was moderate-quality evidence that arm support with alternative mouse reduced the incidence of neck/shoulder disorders (risk ratio (RR) 0.52; 95% confidence interval (CI) 0.27 to 0.99) but not the incidence of right upper limb MSDs (RR 0.73; 95% CI 0.32 to 1.66); and low-quality evidence that this intervention reduced neck/shoulder discomfort (standardised mean difference (SMD) -0.41; 95% CI -0.69 to -0.12) and right upper limb discomfort (SMD -0.34; 95% CI -0.63 to -0.06).

There was also moderate-quality evidence that the incidence of neck/shoulder and right upper limb disorders were not reduced when comparing alternative mouse and conventional mouse (neck/shoulder RR 0.62; 95% CI 0.19 to 2.00; right upper limb RR 0.91; 95% CI 0.48 to 1.72), arm support and no arm support with conventional mouse (neck/shoulder RR 0.67; 95% CI 0.36 to 1.24; right upper limb RR 1.09; 95% CI 0.51 to 2.29), and alternative mouse with arm support and conventional mouse with arm support (neck/shoulder RR 0.58; 95% CI 0.30 to 1.12; right upper limb RR 0.92; 95% CI 0.36 to 2.36).

There was low-quality evidence that using an alternative mouse with arm support compared to conventional mouse with arm support reduced neck/shoulder discomfort (SMD -0.39; 95% CI -0.67 to -0.10). There was low- to very low-quality evidence that other interventions were not effective in reducing work-related upper limb and neck MSDs in adults.

**Authors' conclusions**

We found moderate-quality evidence to suggest that the use of arm support with alternative mouse may reduce the incidence of neck/shoulder MSDs, but not right upper limb MSDs. Moreover, we found moderate-quality evidence to suggest that the incidence of neck/shoulder and right upper limb MSDs is not reduced when comparing alternative and conventional mouse with and without arm support. However, given there were multiple comparisons made involving a number of interventions and outcomes, high-quality evidence is needed to determine the effectiveness of these interventions clearly. While we found very-low- to low-quality evidence to suggest that other ergonomic interventions do not prevent work-related MSDs of the upper limb and neck, this was limited by the paucity and heterogeneity of available studies. This review highlights the need for high-quality RCTs examining the prevention of MSDs of the upper limb and neck.

## PLAIN LANGUAGE SUMMARY

**Ergonomic intervention for preventing work-related musculoskeletal disorders of the upper limb and neck.**

Work-related musculoskeletal disorders of the upper limb and neck are one of the most common occupational disorders around the world. It is likely that addressing ergonomic factors, such as the design of workplace equipment or the environment, or both, as well as training workers in ergonomic principles may reduce the risk of workers developing these musculoskeletal disorders. This Cochrane review presents what we know from research about the effect of workplace ergonomic interventions for preventing work-related musculoskeletal disorders of the upper limb and neck.

We included 13 studies involving 2397 workers in this systematic review. We judged one study to have a low risk of bias. Four studies evaluated the effectiveness of ergonomically designed equipment, and four studies evaluated the effectiveness of breaks or reduced work hours in preventing work-related musculoskeletal disorders of the upper limb and neck. A further three studies evaluated the effectiveness of training in ergonomic principles and techniques, while one study evaluated this training in combination with ergonomically designed equipment and one study evaluated the effectiveness of a safe lifting intervention.

The results of this review suggest that the use of arm support together with an alternative mouse may prevent work-related musculoskeletal disorders of the neck and shoulder but not those of the right upper limb. The use of arm support alone or alternative mouse alone is not effective. However, given there were multiple comparisons made involving a number of interventions and outcomes, more high-quality research is needed to determine the effectiveness of these interventions clearly. This review was not able to determine the effectiveness of other ergonomic interventions for preventing musculoskeletal disorder of the upper limb and neck.

## SUMMARY OF FINDINGS FOR THE MAIN COMPARISON [Explanation]

**Patient or population:** patients with work-related musculoskeletal disorders of the upper limb and neck in adults
**Settings:** VDU users (> 20 hours per week)
**Intervention:** arm support with alternative mouse
**Comparison:** conventional mouse alone (no arm support)

| Outcomes | Illustrative comparative risks* (95% CI) | | Relative effect (95% CI) | No of participants (studies) | Quality of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Assumed risk | Corresponding risk | | | | |
| | Conventional mouse alone | Arm support with alternative mouse | | | | |
| **Incidence of upper body disorders (neck, shoulder, and upper extremity)**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.66**<br>(0.42 to 1.04) | 191<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **333 per 1000** | **220 per 1000**<br>(140 to 347) | | | | |
| | **Moderate** | | | | | |
| | **344 per 1000** | **227 per 1000**<br>(144 to 358) | | | | |
| **Incidence of neck/shoulder disorder**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.52**<br>(0.27 to 0.99) | 186<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **232 per 1000** | **120 per 1000**<br>(63 to 229) | | | | |
| | **Moderate** | | | | | |
| | **250 per 1000** | **130 per 1000**<br>(68 to 248) | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Incidence of right upper extremity disorder**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.73**<br>(0.32 to 1.66) | 181<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **174 per 1000** | **127 per 1000**<br>(56 to 289) | | | | |
| | **Moderate** | | | | | |
| | **174 per 1000** | **127 per 1000**<br>(56 to 289) | | | | |
| **Neck/shoulder discomfort score**<br>Questionnaire<br>Follow-up: 12 months | | The mean neck/shoulder discomfort score in the intervention groups was **0.41 standard deviations lower**<br>(0.69 to 0.12 lower) | | 194<br>(2 studies) | ⊕⊕○○<br>**low**[1,2] | SMD -0.41 (-0.69 to -0.12) |
| **Right upper extremity disorder**<br>Questionnaire<br>Follow-up: 12 months | | The mean right upper extremity disorder in the intervention groups was **0.34 standard deviations lower**<br>(0.63 to 0.06 lower) | | 194<br>(2 studies) | ⊕⊕○○<br>**low**[1,2] | SMD -0.34 (-0.63 to -0.06) |

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% CI) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
**CI:** confidence interval; **RR:** risk ratio; **VDU:** visual display unit.

GRADE Working Group grades of evidence
**High quality:** Further research is very unlikely to change our confidence in the estimate of effect.
**Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
**Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
**Very low quality:** We are very uncertain about the estimate.

[1] Total number of participants <300 (small sample size for categorical variable)
[2] Measure of outcome was based on subjective symptoms (detection bias)

# BACKGROUND

## Description of the condition

Work-related musculoskeletal disorders (MSDs) are the most common occupational disorders around the world, and have been recognised as a problem since the 17th century (Ramazzini 1964). Other general terms for these disorders include repetitive strain injury, occupational overuse syndrome and cumulative trauma disorders (Yassi 1997). Work-related upper limb musculoskeletal disorders (WRULDs) are MSDs of the neck and upper limbs, which include the shoulders, upper arms, elbows, forearms, wrists, and hands (Buckle 1999). These are also known as complaints of the arm, neck and/or shoulder (CANS) (Huisstede 2006). WRULDs can be divided into specific conditions with clear diagnostic criteria and pathological findings, which include tendon-related disorders (e.g. tendonitis), peripheral-nerve entrapment (e.g. carpal tunnel syndrome), neurovascular/vascular disorders (e.g. hand-arm vibration syndrome), and joint/joint-capsule disorders (e.g. osteoarthritis) or non-specific conditions where the main complaint is pain or tenderness, or both, with limited or no pathological findings (Buckle 1997; Yassi 1997).

The prevalence of WRULDs varies considerably across occupations and working populations. According to a review of epidemiological studies from 1966 to June 2004 the point prevalence of upper-extremity MSDs in workers ranged from 30% to 47%, and the 12-month prevalence ranged from 12% to 41% worldwide (Huisstede 2006). The annual prevalence of neck pain in the working population ranged from 19% to 48% (Buckle 1999; Cote 2008). Other studies found the prevalence of upper limb pain in the working population to range from 12% to 30% (Bernard 1997; Buckle 1999; Engels 1996; Smith 2004). The reasons for the wide variance in the reported prevalence of WRULDs include: the absence of a universally accepted definition, the use of different diagnostic criteria (e.g. self-reported or medical examination), and different populations (Buckle 1999; Huisstede 2006).

The cost of WRULDs in the EU has been estimated to be between 0.5% and 2% of gross national product (Buckle 1999). In Australia, disorders of the muscles, tendons, and soft tissue (excluding back pain) were estimated to cost AUD519 million or 17% of the total health system costs in 1993 and 1994 (Mathers 1999). In the UK, MSDs were recorded as the second highest reason for sickness certification in 2005, with an average of 22.84 sickness certificates being issued per 1000 person-years (Wynne-Jones 2009). In the US, 52% of the total lost work days were due to MSDs (USBJD 2008), and in Sweden WRULDs constituted 15% of all sick-leave days and 18% of all sickness pensions in 1994 (Buckle 1999).

The risk factors for developing WRULDs include individual factors (e.g. inadequate strength, poor posture), physical requirements at the workplace (e.g. work requiring prolonged static posture, highly repetitive work, use of vibrating tools), and organisational and psychosocial factors (e.g. poor work-rest cycle, shift work, low job security, little social support) (Bernard 1997; Buckle 1997; Marras 2009; NIOSH 2001; Shanahan 2006; Yassi 1997).

## Description of the intervention

Ergonomics as defined by the International Ergonomics Association is the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system. Ergonomics in the workplace refers to interactions among workers and other elements in the working environment. It is essentially about fitting the job to the worker.

Ergonomic design refers to the design of workplace equipment and the work environment; for example by equipment design (e.g. keyboard, mouse, hand tools), workplace design (e.g. workstations, visual display units (VDUs), lighting), and job design (e.g. work pace, work-rest cycle).

Ergonomic training includes training in the identification of risk factors for WRULDs, proper work practice, selection of appropriate equipment, correct use of equipment and workstation adjustment. Ergonomic design and training interventions have been heavily promoted for the prevention of WRULDs (NIOSH 1997; NIOSH 2001).

## How the intervention might work

Many studies have found that ergonomic factors correlate with musculoskeletal symptoms (Bernard 1994; Bonfiglioli 2006; Ortiz-Hernandez 2003; Szeto 2009; Werner 2005). Adjusting ergonomic factors (such as the design of workplace equipment or the work environment, or both) to reduce the physical and mental load on workers is likely to reduce the risk of workers developing WRULDs. For example, the use of a split keyboard has been found to reduce the severity of pain in computer users with MSDs (Tittiranonda 1999). Ergonomic training is also focused on modifying risk factors through education and empowerment of workers.

## Why it is important to do this review

In a systematic review of interventions for the prevention and treatment of WRULDs, Boocock 2007 reviewed papers published between 1999 and 2004. The authors concluded that there was some evidence to support the use of mechanical and modifier interventions for preventing and managing neck/upper extremity musculoskeletal conditions. A further review by Kennedy 2010, which focused on the role of occupational health and safety interventions, found that the use of arm supports reduced upper extremity musculoskeletal diseases (MSDs). However, in addition to randomised controlled trials (RCTs), Boocock 2007 and Kennedy 2010 included other study designs that are at greater risk of bias. Our review extends and updates the search period covered by

these two reviews and considers all published and unpublished randomised and quasi-randomised trials investigating the use of ergonomic design and training programmes for the prevention of WRULDs.

## OBJECTIVES

To assess the effects of workplace ergonomic design or training interventions, or both for the prevention of WRULDs in adults.

This review aims to make the following main comparisons:

1. ergonomically designed equipment or environmental interventions versus no or placebo intervention;

2. ergonomically designed equipment or environmental intervention versus another intervention;

3. ergonomic training versus no training or placebo training; and

4. a combination of ergonomically designed equipment and environmental interventions or ergonomic training versus a single intervention or a different combination of interventions.

## METHODS

### Criteria for considering studies for this review

#### Types of studies

We included RCTs, quasi-randomised trials (methods of allocating participants to a treatment that are not strictly at random; e.g. by date of birth, hospital record number or alternative), cluster RCTs (i.e. where the unit of randomisation is a group of people such as people working in the same office or shift rather than individual workers) and cross-over trials (i.e. where participants are randomly allocated to a sequence of interventions).

#### Types of participants

We included studies where participants were adults working at the time of the intervention, and who were exposed to risk factors for WRULDs at their workplace. Because the review is focused on prevention of WRULDs, the majority of participants (75% or more) should have been free of WRULDs at the time of the intervention. We only included studies conducted at the workplace or at work-related venues.

We excluded studies evaluating treatment interventions for people with established WRULDs (this will be covered in the replacement review to Verhagen 2009), as well as those that focus on rehabilitation of people with acute or chronic conditions (e.g. trauma, neoplasm, and inflammatory or neurological diseases).

#### Types of interventions

We included studies examining at least one ergonomic design or training intervention, or both, at the workplace aimed at the prevention of WRULDs. We excluded studies testing ergonomic design and training for the treatment of individuals diagnosed with WRULDs or for prevention of WRULDs outside the workplace.

##### Interventions and specific comparisons

We categorised interventions as:

- ergonomically designed equipment such as specially designed computer mouse or arm support;
- ergonomically designed work environment (including workplace and job design);
- ergonomic training;
- ergonomic training combined with ergonomic equipment.

#### Types of outcome measures

##### Primary outcomes

1. Number of people with newly diagnosed or verified WRULDs (incident cases).
2. Complaints or symptoms of pain or discomfort in the upper limb or neck, or both, using a dichotomy scale (e.g. yes/no), Likert scale, visual analogue scale (VAS), or any similar scale measuring pain or discomfort.
3. Work-related function as measured by number of work days lost, loss of or change in job, work disability, and level of functioning. For the lattermost, preference was given to validated outcome measures (e.g. Disability of the Arm, Shoulder, and Hand (DASH) questionnaire (Kitis 2009)). However, all studies that fulfilled the inclusion and exclusion criteria were included in the review regardless of whether the outcome measures used had been validated.

##### Secondary outcomes

Secondary outcomes included change in productivity, costs (including costs of implementation of the intervention and treatment/rehabilitation costs for workers with pain/disability), and compliance (attitude and practice).

### Search methods for identification of studies

#### Electronic searches

We systematically searched the following databases:

- Cochrane Bone, Joint and Muscle Trauma Group Specialised Register (19 Jul 2010);
- the Cochrane Occupational Safety and Health review group database (19 Jul 2010);
- the Cochrane Central Register of Controlled Trials (*The Cochrane Library*, 2010 issue 3) (Appendix 1);
- MEDLINE (1950 to Jul Week 1 2010) (Appendix 2);
- EMBASE (1980 to 2010 Week 28) (Appendix 3);
- Science Citation Index (ISI) (Web of Science expanded to 19 Jul 2010) (Appendix 4);
- CINAHL (1982 to 16 Jul 2010) (Appendix 5);
- AMED (1985 to 19 Jul 2010) (Appendix 6);
- SPORTDiscus (1949 to 16 Jul 2010) (Appendix 7);
- Physiotherapy Evidence Database (PEDro) (accessed 15 Nov 2010);
- US Centers for Disease Control and Prevention, the National Institute for Occupational Safety and Health ( NIOSHTIC-2) database (accessed 15 Nov 2010);
- International Occupational Safety and Health Information Centre (CIS) database (15 Nov 2010).

We searched the following websites for unpublished and ongoing studies:

- World Health Organization International Clinical Trials Registry Platform (15 Nov 2010);
- Centre Watch (15 Nov 2010);
- Trials Central (15 Nov 2010);
- UK National Research Register (NRR) Archive (15 Nov 2010);
- US Centers for Disease Control and Prevention's National Institute for Occupational Safety and Health (NIOSH) website (15 Nov 2010).

We considered reports of all languages. The searches were based on the MEDLINE search strategy combined with the sensitivity- and precision-maximising version of the Cochrane Highly Sensitive Search Strategy for identifying RCTs (Lefebvre 2009) (see Appendix 2). We modified the search strategy to use in the other databases.

### Searching other resources

We contacted experts in the field to identify theses and unpublished studies. We looked for additional studies by checking the bibliographies of relevant articles.

## Data collection and analysis

### Selection of studies

Two review authors (VCWH and MRS) obtained and screened abstracts and citations identified by the searches. The review authors retrieved the full-text articles independently to identify any that may describe eligible studies and performed independent study selection. We resolved all disagreements by discussion. Where there was uncertainty, we contacted the corresponding author to ascertain whether a potentially relevant study met the review inclusion criteria.

### Data extraction and management

Data extraction was performed independently by two review authors (VCWH and DMU), with checks for discrepancies and processing as described in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011). We resolved all discrepancies by consensus. We used a standard data extraction form based on the form recommended by the Cochrane Bone, Joint and Muscle Trauma Group. We performed all statistical analyses using Review Manager 5.1 (RevMan 2011) software.

### Assessment of risk of bias in included studies

The risk of bias of included studies was independently assessed by two review authors (VCWH and DMU), using The Cochrane Collaboration's 'Risk of bias' tool (Appendix 8) (Higgins 2011). We graded each study for risk of bias in each of the following domains: sequence generation, allocation concealment, blinding of participants and personnel (performance bias), blinding of outcome assessment (detection bias), incomplete outcome data, selective outcome reporting, and 'other' such as contamination bias and reliability of instruments. We assessed the risk of bias associated with (a) blinding and (b) completeness of outcomes for self-reported outcomes and objective outcomes separately. We resolved disagreements between authors regarding the risk of bias for domains by consensus.

### Measures of treatment effect

We plotted the results of each trial as point estimates, meaning risk ratios (RR) for dichotomous outcomes, and means and standard deviations (SD) for continuous outcomes with 95% confidence intervals (CI) for both types of data. When studies reported different outcome measures but measured the same concept, we calculated the standardised mean differences (SMD) with 95% CI. For studies that had outcomes for both right and left upper limb, we only used the outcome for the right upper limb.

### Unit of analysis issues

We intended to calculate the design effect for studies that employed a cluster-randomised design but that did not make an allowance for the design effect. According to our assessment the three included cluster-randomised trials were not comparable and thus we did not include them in the meta-analyses. We report their results separately in the text.

### Dealing with missing data

We dealt with missing data according to the recommendations in the *Cochrane Handbook for Systematic Reviews of Interventions* (Higgins 2011); we contacted study authors to request missing data. We contacted four authors for clarification and additional data relating to five studies (Bohr 2000; Brisson 1999; Galinsky 2000; Galinsky 2007; McLean 2001) and we were able to use the additional data for three studies (Brisson 1999; Galinsky 2000; Galinsky 2007).

### Assessment of heterogeneity

First we assessed whether studies were sufficiently homogeneous to be included in one comparison, based on the similarity of the timing of the outcome measurement (short term: three to eight weeks, intermediate: eight weeks to six months or long-term: six months or longer) and the type of intervention, what the control condition was, and when the outcome was measured.

Second, we tested for statistical heterogeneity by means of the $I^2$ statistic as presented in the meta-analysis graphs generated by the RevMan software (RevMan 2011). If this test statistic was greater than 50% we considered there to be substantial heterogeneity between studies.

### Assessment of reporting biases

We did not assess publication bias as there were no comparisons for which we could include more than five studies.

### Data synthesis

Results of studies were pooled if they had a similar type of intervention, control conditions, and outcome. When studies were statistically heterogeneous a random-effects model was used, otherwise a fixed-effect model was used. We pooled study results data with Review Manager 5.1 software (RevMan 2011).

We considered the types of intervention evaluating the effectiveness of ergonomic equipment, supplementary breaks or reduced work hours, and ergonomic training to be sufficiently similar to be pooled for comparison. We did not pool data from the studies assessing ergonomic training together with equipment and safe lifting intervention as the interventions were deemed to be too different.

Whether we had sufficient data to combine the results statistically or not, we assessed the overall quality of the evidence for our primary outcomes by an adapted GRADE approach (Furlan 2009) using the GRADEprofiler software (GRADE 2008).

The quality of the evidence for a specific outcome was based on performance against five domains: limitations of the study design, inconsistency, indirectness (inability to generalise) and imprecision (insufficient or imprecise data) of results and publication bias across all studies that measured that particular outcome. The overall quality of the evidence for each outcome is the result of a combination of the assessments in all domains.

There are four grades of evidence:

- high-quality evidence: there were consistent findings among at least 75% of RCTs with no limitations of the study design, consistent, direct and precise data and no known or suspected publication biases. Further research is unlikely to change either the estimate or our confidence in the results;
- moderate-quality evidence: one of the domains was not met. Further research is likely to have an important impact on our confidence in the estimate of effect and might change the estimate;
- low-quality evidence: two of the domains were not met. Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate;
- very-low-quality evidence: three of the domains were not met. We are very uncertain about the estimate.

### Subgroup analysis and investigation of heterogeneity

We intended to perform subgroup analysis based on: type of participant occupation, study setting, participant gender, and rigour of outcome measurement but sufficient data were not available.

The $I^2$ values calculated by RevMan to quantify statistical heterogeneity between studies ranged from 0% to 86%. However, as the same two studies (Conlon 2008; Rempel 2006) were included in all meta-analyses, we could not explain why they could have statistically very similar results with some outcomes and then also statistically very different results with others.

### Sensitivity analysis

We intended to analyse what the influence of studies with a high risk of bias was by re-analysing the data only for studies with a low risk of bias. However this was not possible as only one study was deemed to have a low risk of bias.

## RESULTS

### Description of studies

#### Results of the search

Our search strategy identified 934 potentially relevant references. Two review authors (VCWH and MRS) assessed the titles, keywords, and abstracts of these references, and selected 27 potentially eligible references. We obtained the publication for all these 27 references.

We identified one additional reference (Meijer 2009) by searching the following additional databases: the US Centers for Disease

Control and Prevention, the National Institute for Occupational Safety and Health (NIOSHTIC-2) database, and the International Occupational Safety and Health Information Centre (CIS) database. Our search for unpublished and ongoing studies through the following websites: World Health Organization International Clinical Trials Registry Platform, Centre Watch, Trials Central and UK National Research Register (NRR) Archive identified one ongoing study that we had identified previously (Driessen 2008). The search of the US Centers for Disease Control and Prevention's National Institute for Occupational Safety and Health (NIOSH) website did not reveal any additional studies.

We checked the reference lists of all articles that we retrieved as full papers in order to identify potentially eligible studies. We identified two additional studies (Faucett 2002; Galinsky 2000) this way. Of the 30 full-text reports identified, we included 15 reports concerning 13 studies. We excluded 14 and one was an ongoing study (Driessen 2008).

## Included studies

We included 15 reports on 13 studies. These studies recruited a total of 2397 participants. For further details regarding the study populations and settings see 'Characteristics of included studies'. All of the studies were RCTs, with three of a cluster-randomised (Brisson 1999; von Thiele 2008; Yassi 2001) and two of a cross-over design (Galinsky 2000; Galinsky 2007).

### Location and settings

Eight studies were conducted in the US (Bohr 2000; Conlon 2008; Galinsky 2000; Galinsky 2007; Gatty 2004; Gerr 2005; Greene 2005; Rempel 2006), three studies in Canada (Brisson 1999; McLean 2001; Yassi 2001), and the remaining two studies in Finland (Lintula 2001) and Sweden (von Thiele 2008).

Three studies were conducted in data processing or call centres (Galinsky 2000; Galinsky 2007; Rempel 2006), three studies in universities or colleges (Brisson 1999; Gatty 2004; Greene 2005), two studies in the healthcare sector (von Thiele 2008, Yassi 2001), one study in a transportation company (Bohr 2000), one study in an aerospace firm (Conlon 2008), one study among office employees and researchers (Lintula 2001), and two studies involved several sectors (insurance and financial companies, food product producers, government offices, and universities) (Gerr 2005; McLean 2001).

### Type of work

Eleven studies were conducted on participants using computers or conducting data processing (Bohr 2000; Brisson 1999; Conlon 2008; Galinsky 2000; Galinsky 2007; Gatty 2004; Gerr 2005; Greene 2005; Lintula 2001; McLean 2001; Rempel 2006), and two on participants engaged in healthcare tasks (von Thiele 2008; Yassi 2001).

### Type of intervention

Three studies evaluated training interventions alone (Bohr 2000; Brisson 1999; Greene 2005), one study evaluated a combination of training and equipment interventions (Gatty 2004), one study evaluated a safe lifting intervention (Yassi 2001), four studies evaluated equipment interventions alone (Conlon 2008; Gerr 2005; Lintula 2001; Rempel 2006), and four studies evaluated supplementary breaks or reduced work hours (Galinsky 2000; Galinsky 2007; McLean 2001; von Thiele 2008).

### Follow-up period

Five studies had a short follow-up period of between three and eight weeks (Galinsky 2000; Galinsky 2007; Greene 2005; Lintula 2001; McLean 2001). One study had an intermediate-term follow-up period of 16 weeks (Gatty 2004), and seven studies had a long-term follow-up period of between six and 12 months (Bohr 2000; Brisson 1999; Conlon 2008; Gerr 2005; Rempel 2006; von Thiele 2008; Yassi 2001).

### Outcomes

The incidence of MSDs was measured in three studies (Conlon 2008; Gerr 2005; Rempel 2006) and the prevalence in a further three studies (Brisson 1999; Gatty 2004; Greene 2005). The severity, intensity, discomfort, and strain associated with musculoskeletal conditions were measured in 11 studies (Bohr 2000; Conlon 2008; Galinsky 2000; Galinsky 2007; Gatty 2004; Greene 2005; Lintula 2001; McLean 2001; Rempel 2006; von Thiele 2008; Yassi 2001). One study (von Thiele 2008) reported work ability and a further study (Yassi 2001) had measured DASH.

Eight studies assessed compliance (Bohr 2000; Brisson 1999; Galinsky 2000; Gatty 2004; Gerr 2005; McLean 2001; Rempel 2006; Yassi 2001) and one study examined the cost of musculoskeletal injuries (Yassi 2001).

## Excluded studies

We excluded altogether 14 studies. We excluded nine studies because more than 25% of the participants at baseline reported musculoskeletal symptoms of the upper limb or neck, or both (Cook 2004; Faucett 2002; Fostervold 2006; Haukka 2008; Ketola 2002; Meijer 2009; Mekhora 2000; Rempel 2007; Veiersted 2008). We excluded two studies because they were not RCTs (Aaras 1998; Pillastrini 2007) and a further two studies had no separate outcome data for upper limb or neck, or both, disorders (Earl-Richardson 2006; Faucett 2007). We excluded one study because it only reported on change in risk level for upper extremity cumulative trauma disorders (Melhorn 1996). For further details regarding the study populations and settings see 'Characteristics of excluded studies'.

## Risk of bias in included studies

Overall we found the risk of bias in the included studies to be high. Of the 13 studies, we judged only one study (Rempel 2006) to have a low risk of bias. The results are summarised in the 'Risk of bias' graph, which is an overview of the review authors' judgements about each 'Risk of bias' item presented as percentages across all included studies (Figure 1). Figure 2 shows the 'Risk of bias' summary of each 'Risk of bias' item for each included study.

**Figure 1. 'Risk of bias' graph: review authors' judgements about each 'Risk of bias' item presented as percentages across all included studies.**

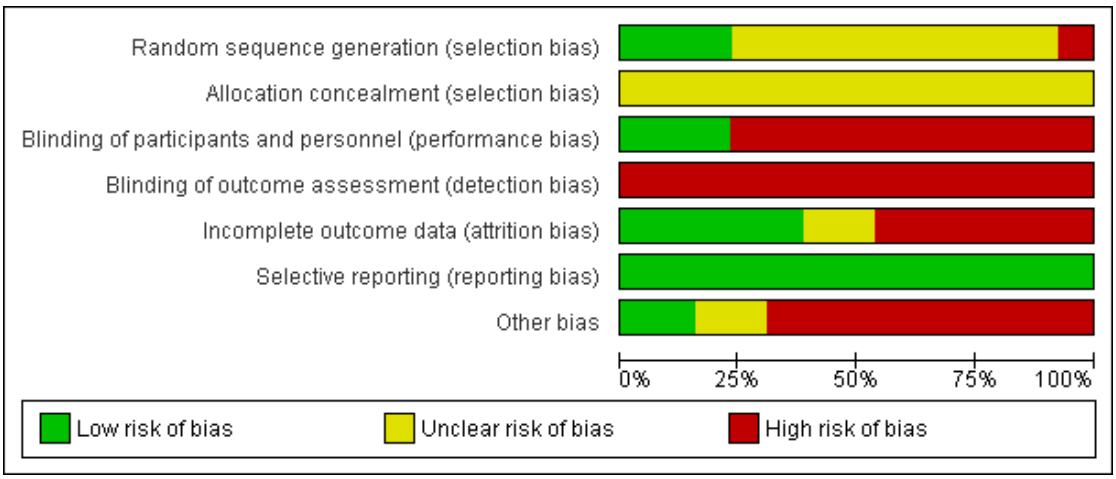
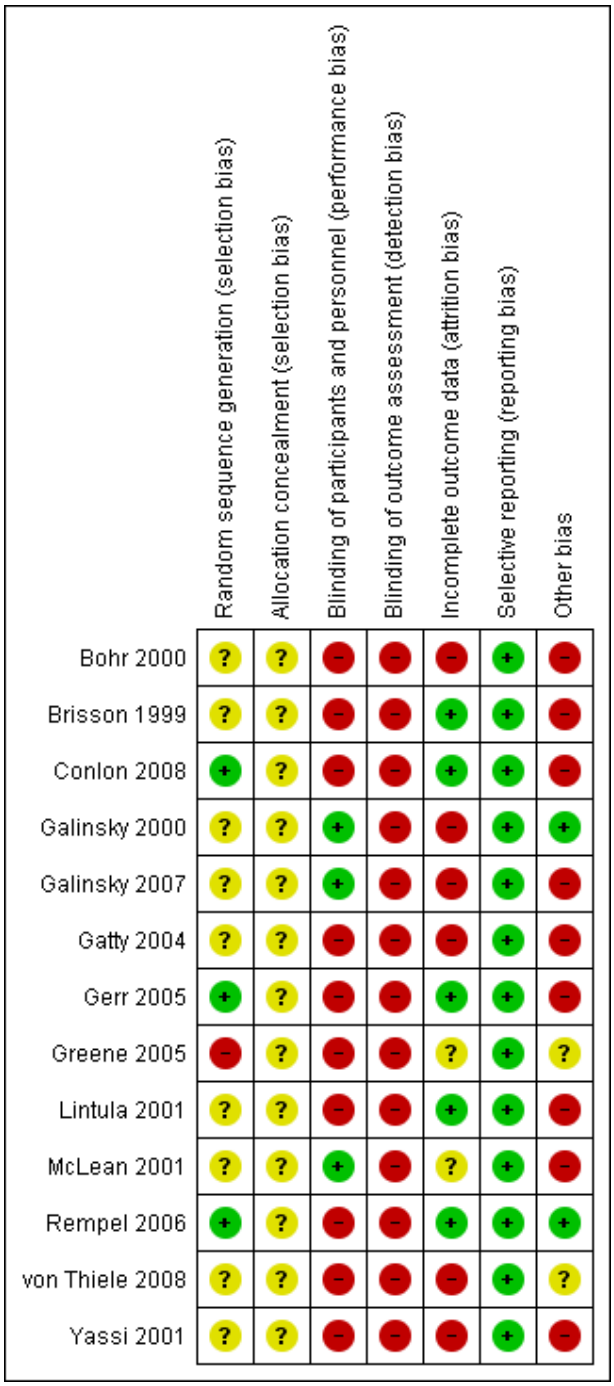


**Figure 2. 'Risk of bias' summary: review authors' judgements about each 'Risk of bias item for each included study.**



### Allocation

Three studies (Conlon 2008; Gerr 2005; Rempel 2006) reported using a random number table or equivalent for generating a random sequence and were thus judged to have a low risk of bias. None of studies reported using adequate measures for concealing allocation such using sealed opaque envelopes and so we judged all to have an unclear risk of bias.

### Blinding

Blinding of the intervention was not performed in most of the interventions as blinding of the use of different equipment, breaks and training are difficult to achieve. Therefore we judged ten studies to have a high risk for performance bias. The remaining three studies assessed work breaks and work hours interventions (Galinsky 2000; Galinsky 2007; McLean 2001). Although complete blinding for breaks was not possible in these studies, the use of a strict protocol for taking breaks by the use of either custom-made electrical timers or the 'Ergobreak' computer program minimised the risk for bias. Thereby we judged these three studies to have a low risk for performance bias.

In three studies (Brisson 1999; Conlon 2008; Rempel 2006) the physical examination for the detection of MSD was blinded although the examination was only performed on participants that reported symptoms (which were self-reported) meeting the case definition. Thus, we rated the risk for detection bias for all 13 studies as high.

### Incomplete outcome data

Three studies conducted an intention-to-treat (ITT) analysis ( Conlon 2008; Gerr 2005; Rempel 2006), one study had no loss to follow-up (Lintula 2001) and one study had a low drop-out rate (Brisson 1999). We rated these five studies as having a low risk for attrition bias. We rated six studies (Bohr 2000; Galinsky 2000; Galinsky 2007; Gatty 2004; von Thiele 2008; Yassi 2001) as having a high risk as they did not conduct ITT analyses. In addition, two of these six studies had an uneven drop-out rate across the groups (Bohr 2000; Yassi 2001), two studies had an uneven distribution of participants in experimental groups (von Thiele 2008; Yassi 2001), and three studies had a high drop-out rate (Galinsky 2000; Galinsky 2007; Gatty 2004). We rated two studies as having an unclear risk for attrition bias as they did not conduct ITT analyses and information on their drop-outs was limited (Greene 2005; McLean 2001).

### Selective reporting

We judged all studies to be free of selective reporting because they reported all outcomes described in the methods.

### Other potential sources of bias

We judged nine studies to have a high risk of bias from other potential sources (Bohr 2000; Brisson 1999; Conlon 2008; Galinsky 2007; Gatty 2004; Gerr 2005; Lintula 2001; McLean 2001; Yassi 2001). According to our assessment, two studies were judged to have a low risk of bias (Galinsky 2000; Rempel 2006) and another two studies to have an unclear risk of bias (Greene 2005; von Thiele 2008).

In five studies, baseline data on the outcome measures were not available (Bohr 2000; Brisson 1999; Lintula 2001; McLean 2001; Yassi 2001) for comparison. In the Gatty 2004 study, the intervention group had lower average wrist-hand and upper back ache or pain intensity compared to the control group. In the Conlon 2008 study the participants who volunteered for the study had higher levels of discomfort than non-participants. In the Bohr 2000 study, the close proximity of the workstations may have led to cross contamination of the intervention effect. In the Gerr 2005 study, there was large number of drop-outs in the intervention and control groups, although the authors have conducted ITT analysis, the large number of drop-outs may affect the results.

Six studies (Galinsky 2000; Galinsky 2007; Gatty 2004; Greene 2005; McLean 2001; Rempel 2006) did not compare the differences between the participants and non-participants, which has the potential to jeopardise the external validity of the results. In one cluster-RCT, differences between the workplaces may have influenced the intervention (von Thiele 2008).

Of the two cross-over RCTs (Galinsky 2000; Galinsky 2007), Galinsky 2007 had the potential for carry-over effect (Hawthorne effects). The authors did not report on the wash-out period between the two data collection periods.

## Effects of interventions

See: **Summary of findings for the main comparison** Comparing arm support with alternative mouse versus conventional mouse alone for preventing work-related musculoskeletal disorders of the upper limb and neck in adults; **Summary of findings 2** Comparing alternative mouse alone versus conventional mouse alone for preventing work-related musculoskeletal disorders of the upper limb and neck in adults; **Summary of findings 3** Comparing arm support with conventional mouse versus conventional mouse alone for preventing work-related musculoskeletal disorders of the upper limb and neck in adults; **Summary of findings 4** Comparing alternative mouse with arm support versus conventional mouse with arm support for preventing work-related musculoskeletal disorders of the upper limb and neck in adults; **Summary of findings 5** Comparing supplementary breaks versus conventional breaks for preventing work-related musculoskeletal disorders of the upper limb and neck

in adults

The 13 included studies evaluated several ergonomic interventions for preventing WRULDs. They included ergonomic training alone, ergonomic training and equipment, ergonomic equipment alone, and supplementary breaks or reduced work hours.

## 1. Studies evaluating the effectiveness of ergonomic equipment

### Primary outcome

Four studies (Conlon 2008; Gerr 2005; Lintula 2001; Rempel 2006) evaluated the effectiveness of interventions involving ergonomic equipment. All the studies were conducted among computer users.

Two studies (Conlon 2008; Rempel 2006) evaluated four different interventions. These studies compared conventional mouse alone (without arm support), alternative mouse alone (without arm support), conventional mouse with arm support, and alternative mouse with arm support. One study (Gerr 2005) evaluated three different interventions; that is two different monitor, mouse and keyboard placements with arm rest and high-quality chair intervention, and no intervention. Another study (Lintula 2001) evaluated arm support for the hand that operated the mouse, arm support for both hands, and no arm support.

According to our judgement, only the studies by Conlon 2008 and Rempel 2006 were comparable and also their data were available for meta-analysis. Although the study by Lintula 2001 also evaluated an arm support, the duration of the study was only for six weeks, whereas the duration of the studies by Conlon 2008 and Rempel 2006 were 12 months. Lintula 2001 only assessed perceived musculoskeletal strain and did not assess MSDs or symptoms.

Gerr 2005 evaluated the difference of two different placements of the monitor, keyboard, mouse, arm rest and chair (intervention groups A and B) compared with no intervention (control group C). There were no differences in time to symptoms between intervention group A or group B when compared to control group C for either hand or arm symptoms (group A vs C: hazard ratio (HR) 0.92; 95% CI 0.49 to 1.71; group B vs C: HR 1.05; 95% CI 0.58 to 1.90), or neck or shoulder symptoms (group A vs C: HR 1.07; 95% CI 0.64 to 1.80; group B vs C: HR 1.00; 95% CI 0.60 to 1.68).

Data from the Conlon 2008 and Rempel 2006 studies were included in meta-analysis.

#### a. An arm support together with an alternative mouse versus a conventional mouse alone

Using an arm support together with an alternative mouse compared to using a conventional mouse alone decreased the incidence of neck/shoulder disorders (RR 0.52; 95% CI 0.27 to 0.99; Analysis 1.1). However, there was no difference in the incidence of right upper limb (RR 0.73; 95% CI 0.32 to 1.66; Analysis 1.2) or upper body disorders (RR 0.66; 95% CI 0.42 to 1.04; Analysis 1.3) when these interventions were compared. The use of an arm support together with an alternative mouse also decreased neck/shoulder discomfort scores (SMD -0.41; 95% CI -0.69 to -0.12; Analysis 1.4) and right upper limb discomfort scores (SMD -0.34; 95% CI -0.63 to -0.06; Analysis 1.5) when compared to using a conventional mouse alone.

#### b. An alternative mouse alone versus a conventional mouse alone

The results comparing alternative mouse alone and conventional mouse alone showed that there was no difference in the incidence of disorders of the neck/shoulder (RR 0.62; 95% CI 0.19 to 2.00; Analysis 2.1), right upper limb (RR 0.91; 95% CI 0.48 to 1.72; Analysis 2.2), or upper body (RR 0.79; 95% CI 0.52 to 1.21; Analysis 2.3), and no difference in discomfort scores for neck/shoulder (SMD 0.04; 95% CI -0.26 to 0.33; Analysis 2.4) or right upper limb (SMD 0.00; 95% CI -0.28 to 0.28; Analysis 2.5).

#### c. An arm support together with a conventional mouse versus a conventional mouse alone

The results comparing arm support with conventional mouse and conventional mouse alone showed that there was no difference in the incidence of disorders of the neck/shoulder (RR 0.67; 95% CI 0.36 to 1.24; Analysis 3.1), right upper limb (RR 1.09; 95% CI 0.51 to 2.29; Analysis 3.2), or upper body (RR 0.87; 95% CI 0.42 to 1.80; Analysis 3.3), and no difference in discomfort scores for neck/shoulder (SMD 0.02; 95% CI -0.26 to 0.30; Analysis 3.4) or right upper limb (SMD -0.07; 95% CI -0.35 to 0.22; Analysis 3.5).

#### d. An alternative mouse with an arm support versus a conventional mouse with an arm support

The results comparing alternative mouse with arm support and conventional mouse with arm support showed no difference in the incidence of disorders of the neck/shoulder (RR 0.76; 95% CI 0.22 to 2.63; Analysis 4.1), right upper limb (RR 0.76; 95% CI 0.37 to 1.59; Analysis 4.2), or upper body (RR 0.77; 95% CI 0.36 to 1.63; Analysis 4.3). The results did show a decrease in the discomfort scores for the neck/shoulder (SMD -0.39; 95% CI -0.67 to -0.10; Analysis 4.4) and also a non-significant decrease in the right upper extremity (SMD -0.27; 95% CI -0.55 to 0.02; Analysis 4.5).

### Secondary outcome

In the Gerr 2005 study, compliance with all components of the intervention was attained for only 25% to 38% of participants

mainly because of the inflexibility of the workstation configurations. Rempel 2006 found that there were no significant differences between intervention groups for company-tracked productivity or self-perceived measures.

#### Quality of evidence

There was moderate-quality evidence from two studies to support using an arm support together with an alternative mouse to prevent neck/shoulder disorders over a 12-month follow-up but not disorders of the upper body or right upper extremity (Conlon 2008; Rempel 2006). There was also low-quality evidence from the same two studies that the intervention reduced the discomfort score for neck/shoulder and right upper extremity over a 12-month follow-up. There was moderate-quality evidence from one study that different VDU placement produced no difference in neck, shoulder, or arm and hand symptoms over a six-month follow-up (Gerr 2005).

### 2. Studies evaluating the effectiveness of supplementary breaks or reduced work hours

#### Primary outcome

Four studies (Galinsky 2000; Galinsky 2007; McLean 2001; von Thiele 2008) evaluated the effectiveness of supplementary breaks or reduced work hours. Three studies (Galinsky 2000; Galinsky 2007; McLean 2001) evaluated supplementary breaks among computer users or data entry operators over a period ranging between four and eight weeks and one study (von Thiele 2008) evaluated reduced work hours in a large public healthcare organisation over 12 months. The von Thiele 2008 study compared physical exercise and reduced work hours to a reference group (normal work hours). We used only the results comparing reduced work hours and normal work hours for this review.

We included data from the Galinsky 2000 and Galinsky 2007 studies in a meta-analysis. We could not enter the data from the McLean 2001 study into a meta-analysis as the authors reported no measure of variance and this data could not be imputed from the information provided.

#### a. Supplementary breaks versus conventional breaks

The results comparing supplementary versus conventional breaks showed that there were no differences in the end of the shift discomfort scores for the neck (MD -0.25; 95% CI -0.53 to 0.02; Analysis 5.1), right shoulder/upper arm (MD -0.24; 95% CI -0.51 to 0.03; Analysis 5.2), and right forearm/wrist/hand (MD -0.19; 95% CI -0.45 to 0.08; Analysis 5.3) (Galinsky 2000; Galinsky 2007).

#### b. Reduced work hours versus normal work hours

The results comparing reduced work hours (37.5 hours/week) and normal work hours (40 hours/week) showed that there was no difference between the reduced and normal work hours groups in upper-extremity symptoms or pain at six months (MD 0.08; 95% CI -0.32 to 0.48; Analysis 6.1) or at 12 months (MD 0.22; 95% CI -0.22 to 0.66; Analysis 6.2) (von Thiele 2008). There was equally no difference between the reduced and normal work hours groups in work ability at six months (MD 0.41; 95% CI -0.28 to 1.10; Analysis 6.3) or at 12 months (MD 0.50; 95% CI -0.23 to 1.23; Analysis 6.4) (von Thiele 2008).

#### Secondary outcome

Galinsky 2000 found no significant difference between the two groups in productivity as measured by the mean number of keystrokes per hour and mean number of documents entered. McLean 2001 also found that no difference between the groups in productivity measured as number of words typed.

#### Quality of evidence

There was low-quality evidence from two studies that breaks produced no difference in neck, right shoulder/upper arm, or forearm/wrist/hand discomfort ratings at end of shift (Galinsky 2000; Galinsky 2007). There was low-quality evidence from one study that a reduced work hour intervention produced no difference in upper-extremity disorders or work ability (von Thiele 2008).

### 3. Studies evaluating the effectiveness of ergonomic training

#### Primary outcome: ergonomic training versus no intervention

Three studies evaluated the effect of ergonomic training. These studies compared a participatory education intervention versus traditional education versus no intervention (Bohr 2000); PRECEDE (predisposing, reinforcing and enabling causes in educational diagnosis evaluation) ergonomic training versus no intervention (Brisson 1999); and active ergonomic training versus no intervention (control) (Greene 2005). Greene 2005 only conducted the first three weeks as an RCT, with the control group given the same intervention after the third week (see Characteristics of included studies).

In the participatory education, PRECEDE ergonomic training, and active ergonomic training interventions, the intervention consists of the participants solving ergonomic issues at the workplace. All three studies were conducted on computer users who used computers at least five hours per week. We could not combine the studies' results data for meta-analysis as Bohr 2000 reported on upper body discomfort scores; Brisson 1999 reported on prevalence

of neck-shoulder pain and hand-wrist pain; and Greene 2005 only performed a follow-up for three weeks on the intensity, frequency, and duration of pain in the upper spine (head, neck, and upper back) and upper extremity (shoulder/upper arm, elbow/forearm, wrist and hand). Bohr 2000 also did not report a measure of variance and it could not be imputed from the information provided. The results for Brisson 1999 showed that over a six-month period there was no difference in the risk for neck-shoulder symptoms (RR 1.19; 95% CI 0.66 to 2.14; Analysis 7.1) or hand-wrist symptoms (RR 1.39; 95% CI 0.41 to 4.74; Analysis 7.2). Greene 2005 showed that there was no significant difference in the intensity (MD 0.08; 95% CI -0.22 to 0.38; Analysis 7.3), frequency (MD -0.03; 95% CI -0.45 to 0.39; Analysis 7.4), or duration (MD 0.13; 95% CI -0.25 to 0.51; Analysis 7.5) of upper extremity symptoms between the intervention and control group at the end of the third week.

#### Secondary outcome

Of these three studies, Bohr 2000 and Brisson 1999 assessed the compliance of the participants to the intervention. Bohr 2000 found no significant differences across groups for work area configuration, worker postures, or overall observation scores. Brisson 1999 found that the compliance to the intervention in the under 40 years of age group was higher than that for subjects over 40 years of age.

#### Quality of evidence

There was very-low-quality evidence from two studies that an ergonomic training intervention produced no difference in neck and upper extremity symptoms (Brisson 1999; Greene 2005).

### 4. Studies evaluating the effectiveness of ergonomic training and equipment

#### Primary outcome

One study (Gatty 2004) evaluated the combined effect of ergonomic training and equipment interventions. The study was conducted on clerical and office workers, and evaluated the effectiveness of a work injury prevention programme that included education, workstation redesign, and task modification compared to no intervention. Only the first 16 weeks of the study was performed as an RCT.

The results showed no significant difference in frequency of neck (MD -1.20; 95% CI -2.77 to 0.37; Analysis 8.1), shoulder (MD -1.10; 95% CI -2.65 to 0.45; Analysis 8.2), or wrist/hand ache or pain (MD -1.00; 95% CI -2.52 to 0.52; Analysis 8.3) at the end of 16 weeks comparing intervention versus no intervention. The result also showed no significant difference in the intensity of neck (MD -0.30; 95% CI -1.19 to 0.59; Analysis 8.4), shoulder (MD -0.20; 95% CI -0.91 to 0.51; Analysis 8.5), or wrist/hand ache or pain (MD -0.20; 95% CI -1.17 to 0.77; Analysis 8.6) at the end of 16 weeks comparing intervention versus no intervention. We could not estimate the results comparing the frequency and intensity of elbow or forearm ache or pain at the end of 16 weeks as the SD for the intervention groups were zero for both readings.

#### Secondary outcome

Gatty 2004 assessed the participants' compliance to the intervention. Self-reported compliance in the intervention group was high at the end of the study, with the greatest level of compliance obtained for ergonomic equipment.

#### Quality of evidence

There was very-low-quality evidence from one study that a work injury prevention programme yielded no difference in neck and upper-extremity symptoms among office workers (Gatty 2004).

### 5. Studies evaluating the effectiveness of lifting interventions

#### Primary outcome

One study (Yassi 2001) evaluated the effect of a lifting intervention to prevent patient lift and transfer injuries in healthcare workers. The study was conducted among nurses and unit assistants in medical, surgical, and rehabilitation wards. The study compared a no strenuous lifting programme and training versus a safe lifting programme and training versus usual practice for lifting patients in the wards.

The Yassi 2001 results at the end of one year showed no significant difference in the shoulder symptoms score comparing safe lifting with usual practice (MD 3.00; 95% CI -4.83 to 10.83; Analysis 9.1), and no strenuous lifting compared with usual practice (MD 0.10; 95% CI -7.62 to 7.82; Analysis 9.2). There was also no significant difference in the DASH score between safe lifting and usual practice (MD 1.00; 95% CI -2.32 to 4.32; Analysis 9.3) and between no strenuous lifting and usual practice (MD -0.80; 95% CI -3.75 to 2.15; Analysis 9.4).

#### Secondary outcome

Yassi 2001 also assessed the participants' compliance to the intervention, cost of all injuries, and time loss injuries. The authors noted a marked increase in the use of both mechanical and non-mechanical equipment six months into the study and a marked decline in patient handling without assistive devices in both the intervention groups. The authors noted that the cost of all injuries was highest for the control group (USD23,984), followed by the safe lifting (USD20,179), and no strenuous lifting (USD13,502)

groups. The cost for time loss injuries was highest for the control group (USD3426), followed by no strenuous lifting (USD3376), and safe lifting (USD2522) groups.

#### Quality of evidence

There was low-quality evidence from one study showing that a patient lifting intervention produced no difference in shoulder symptoms among nursing personnel (Yassi 2001).

## ADDITIONAL SUMMARY OF FINDINGS *[Explanation]*

**Patient or population:** patients with work-related musculoskeletal disorders of the upper limb and neck in adults
**Settings:** VDU users (> 20 hours per week)
**Intervention:** alternative mouse alone (no arm support)
**Comparison:** conventional mouse alone (no arm support)

| Outcomes | Illustrative comparative risks* (95% CI) | | Relative effect (95% CI) | No of participants (studies) | Quality of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Assumed risk | Corresponding risk | | | | |
| | Conventional mouse alone | Alternative mouse alone | | | | |
| **Incidence of upper body disorder (neck, shoulder, and upper extremity)** Questionnaire followed by medical examination Follow-up: 12 months | **Study population** | | **RR 0.79** (0.52 to 1.21) | 190 (2 studies) | ⊕⊕⊕○ **moderate**[1] | |
| | **333 per 1000** | **263 per 1000** (173 to 403) | | | | |
| | **Moderate** | | | | | |
| | **344 per 1000** | **272 per 1000** (179 to 416) | | | | |
| **Incidence of neck/shoulder disorder** Questionnaire followed by medical examination Follow-up: 12 months | **Study population** | | **RR 0.62** (0.19 to 2) | 182 (2 studies) | ⊕⊕⊕○ **moderate**[1] | |
| | **232 per 1000** | **144 per 1000** (44 to 463) | | | | |
| | **Moderate** | | | | | |
| | **250 per 1000** | **155 per 1000** (47 to 500) | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Incidence of right upper extremity disorder**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.91**<br>(0.48 to 1.72) | 182<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **185 per 1000** | **168 per 1000**<br>(89 to 318) | | | | |
| | **Moderate** | | | | | |
| | **184 per 1000** | **167 per 1000**<br>(88 to 316) | | | | |
| **Neck/shoulder discomfort score**<br>Questionnaire<br>Follow-up: 12 months | | The mean neck/shoulder discomfort score in the intervention groups was **0.04 standard deviations higher**<br>(0.26 lower to 0.33 higher) | | 195<br>(2 studies) | ⊕⊕○○<br>**low**[1,2] | SMD 0.04 (-0.26 to 0.33) |
| **Right upper extremity discomfort score**<br>Questionnaire<br>Follow-up: 12 months | | The mean right upper extremity discomfort score in the intervention groups was **0 standard deviations higher**<br>(0.28 lower to 0.28 higher) | | 195<br>(2 studies) | ⊕⊕○○<br>**low**[1,2] | SMD 0 (-0.28 to 0.28) |

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% CI) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
**CI:** confidence interval; **RR:** risk ratio; VDU: visual display unit.

GRADE Working Group grades of evidence
**High quality:** Further research is very unlikely to change our confidence in the estimate of effect.
**Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
**Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
**Very low quality:** We are very uncertain about the estimate.

[1] Total number of participants <300 (small sample size for categorical variable)
[2] Measure of outcome based on subjective symptoms (detection bias)

**Patient or population:** patients with work-related musculoskeletal disorders of the upper limb and neck in adults
**Settings:** VDU users (> 20 hours per week)
**Intervention:** arm support board (with conventional mouse)
**Comparison:** no arm support board (with conventional mouse)

| Outcomes | Illustrative comparative risks* (95% CI) | | Relative effect (95% CI) | No of participants (studies) | Quality of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Assumed risk | Corresponding risk | | | | |
| | Conventional mouse alone | Arm support with conventional mouse | | | | |
| **Incidence of upper body disorders**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.87**<br>(0.42 to 1.8) | 191<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **333 per 1000** | **290 per 1000**<br>(140 to 600) | | | | |
| | **Moderate** | | | | | |
| | **344 per 1000** | **299 per 1000**<br>(144 to 619) | | | | |
| **Incidence of neck/shoulder disorder**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.67**<br>(0.36 to 1.24) | 186<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **232 per 1000** | **155 per 1000**<br>(83 to 287) | | | | |
| | **Moderate** | | | | | |
| | **250 per 1000** | **168 per 1000**<br>(90 to 310) | | | | |
| **Incidence of right upper extremity disorders**<br>Questionnaire followed by medical examination | **Study population** | | **OR 1.09**<br>(0.51 to 2.29) | 178<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |

| | | | | | |
|---|---|---|---|---|---|
| Follow-up: 12 months | | | | | |
| | **185 per 1000** | **198 per 1000** (104 to 342) | | | |
| | **Moderate** | | | | |
| | **184 per 1000** | **197 per 1000** (103 to 341) | | | |
| **Neck/shoulder discomfort score** Questionnaire Follow-up: 12 months | | The mean neck/shoulder discomfort score in the intervention groups was **0.02 standard deviations higher** (0.26 lower to 0.3 higher) | 195 (2 studies) | ⊕⊕◯◯ **low**[1,2] | SMD 0.02 (-0.26 to 0.3) |
| **Right upper extremity discomfort score** Questionnaire Follow-up: median 12 months | | The mean right upper extremity discomfort score in the intervention groups was **0.07 standard deviations lower** (0.35 lower to 0.22 higher) | 195 (2 studies) | ⊕⊕◯◯ **low**[1,2] | SMD -0.07 (-0.35 to 0.22) |

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% CI) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
**CI:** confidence interval; **OR:** odds ratio; **RR:** risk ratio; **VDU:** visual display unit

GRADE Working Group grades of evidence
**High quality:** Further research is very unlikely to change our confidence in the estimate of effect.
**Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
**Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
**Very low quality:** We are very uncertain about the estimate.

[1] Total number of participants <300 (small sample size for categorical variable)

[2] Measure of outcome based on subjective symptoms (detection bias)

**Patient or population:** patients with work-related musculoskeletal disorders of the upper limb and neck in adults
**Settings:** VDU users (> 20 hours per week)
**Intervention:** alternative mouse with arm support
**Comparison:** conventional mouse with arm support

| Outcomes | Illustrative comparative risks* (95% CI) | | Relative effect (95% CI) | No of participants (studies) | Quality of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Assumed risk | Corresponding risk | | | | |
| | Conventional mouse with arm support | Alternative mouse with arm support | | | | |
| **Incidence of upper body symptoms**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.77**<br>(0.36 to 1.63) | 190<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **284 per 1000** | **219 per 1000**<br>(102 to 463) | | | | |
| | **Moderate** | | | | | |
| | **285 per 1000** | **219 per 1000**<br>(103 to 465) | | | | |
| **Incidence of neck/shoulder disorder**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.58**<br>(0.3 to 1.12) | 186<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **221 per 1000** | **128 per 1000**<br>(66 to 248) | | | | |
| | **Moderate** | | | | | |
| | **226 per 1000** | **131 per 1000**<br>(68 to 253) | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Incidence of right upper extremity disorders**<br>Questionnaire followed by medical examination<br>Follow-up: 12 months | **Study population** | | **RR 0.92**<br>(0.36 to 2.36) | 175<br>(2 studies) | ⊕⊕⊕○<br>**moderate**[1] | |
| | **163 per 1000** | **150 per 1000**<br>(59 to 384) | | | | |
| | **Moderate** | | | | | |
| | **169 per 1000** | **155 per 1000**<br>(61 to 399) | | | | |
| **Neck/shoulder discomfort score**<br>Questionnaire<br>Follow-up: 12 months | | The mean neck/shoulder discomfort score in the intervention groups was **0.39 standard deviations lower**<br>(0.67 to 0.1 lower) | | 193<br>(2 studies) | ⊕⊕○○<br>**low**[1,2] | SMD -0.39 (-0.67 to -0.1) |
| **Right upper extremity discomfort score**<br>Questionnaire<br>Follow-up: 12 months | | The mean right upper extremity discomfort score in the intervention groups was **0.27 standard deviations lower**<br>(0.55 lower to 0.02 higher) | | 193<br>(2 studies) | ⊕⊕○○<br>**low**[1,2] | SMD -0.27 (-0.55 to 0.02) |

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% CI) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
**CI:** confidence interval; **RR:** risk ratio; VDU: visual display unit.

GRADE Working Group grades of evidence
**High quality:** Further research is very unlikely to change our confidence in the estimate of effect.
**Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
**Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
**Very low quality:** We are very uncertain about the estimate.

[1] Total number of participants <300 (small sample size for categorical variable)

[2] Measure of outcome was based on subjective symptoms (detection bias)

**Patient or population:** patients with work-related musculoskeletal disorders of the upper limb and neck in adults
**Settings:** VDU users
**Intervention:** supplementary breaks
**Comparison:** conventional breaks

| Outcomes | Illustrative comparative risks* (95% CI) | | Relative effect (95% CI) | No of participants (studies) | Quality of the evidence (GRADE) | Comments |
|---|---|---|---|---|---|---|
| | Assumed risk | Corresponding risk | | | | |
| | Conventional breaks | Supplementary breaks | | | | |
| **Discomfort ratings for neck (all time) (4-8 weeks)**<br>Questionnaire<br>Follow-up: 4-8 weeks | | The mean discomfort ratings for neck (all time) (4-8 weeks) in the intervention groups was<br>**0.17 lower**<br>(0.39 lower to 0.06 higher) | | 186<br>(2 studies) | ⊕⊕◯◯<br>**low**[1,2,3,4] | |
| **Discomfort ratings of the right shoulder/upper arm (all time) (4-8 weeks)**<br>Questionnaire<br>Follow-up: 4-8 weeks | | The mean discomfort ratings of the right shoulder/upper arm (all time) (4-8 weeks) in the intervention groups was<br>**0.13 lower**<br>(0.35 lower to 0.08 higher) | | 186<br>(1 study) | ⊕⊕◯◯<br>**low**[1,2,3,4] | |
| **Discomfort ratings of right forearm/wrist/hand (all time) 4-8 weeks**<br>Questionnaire<br>Follow-up: 4-8 weeks | | The mean discomfort ratings of right forearm/wrist/hand (all time) 4-8 weeks in the intervention groups was<br>**0.12 lower**<br>(0.34 lower to 0.09 | | 186<br>(2 studies) | ⊕⊕◯◯<br>**low**[1,2,3,4] | |

| | | | | |
|---|---|---|---|---|
| | | higher) | | |
| **After shifts discomfort rating for neck (4-8 weeks)**<br>Questionnaire<br>Follow-up: 4-8 weeks | | The mean after shifts discomfort rating for neck (4-8 weeks) in the intervention groups was **0.25 lower** (0.53 lower to 0.02 higher) | 186<br>(2 studies) | ⊕⊕◯◯<br>**low**[1,2,3,4] |
| **After shifts discomfort ratings for right shoulder/upper arm (4-8 weeks)**<br>Questionnaire<br>Follow-up: 4-8 weeks | | The mean after shifts discomfort ratings for right shoulder/upper arm (4-8 weeks) in the intervention groups was **0.24 lower** (0.51 lower to 0.03 higher) | 186<br>(2 studies) | ⊕⊕◯◯<br>**low**[1,2,3,4] |
| **After shifts discomfort ratings for right forearm/wrist/hand (4-8 weeks)**<br>Questionnaire<br>Follow-up: 4-8 weeks | | The mean after shifts discomfort ratings for right forearm/wrist/hand (4-8 weeks) in the intervention groups was **0.19 lower** (0.45 lower to 0.08 higher) | 186<br>(2 studies) | ⊕⊕◯◯<br>**low**[1,2,3,4] |

*The basis for the **assumed risk** (e.g. the median control group risk across studies) is provided in footnotes. The **corresponding risk** (and its 95% CI) is based on the assumed risk in the comparison group and the **relative effect** of the intervention (and its 95% CI).
**CI:** confidence interval; VDU: visual display unit.

GRADE Working Group grades of evidence
**High quality:** Further research is very unlikely to change our confidence in the estimate of effect.
**Moderate quality:** Further research is likely to have an important impact on our confidence in the estimate of effect and may change the estimate.
**Low quality:** Further research is very likely to have an important impact on our confidence in the estimate of effect and is likely to change the estimate.
**Very low quality:** We are very uncertain about the estimate.

[1] Possibility of cross-over effects of cross-over trials
[2] Measured of outcome was based on subjective symptoms (detection bias)
[3] There was no information on sequence generation (selection bias)
[4] Small number of participants (<400)

# DISCUSSION

The objective of this review was to assess the effects of workplace ergonomic interventions for the prevention of WRULDs in adults.

## Summary of main results

This systematic review identified 13 RCTs of workplace ergonomic design and training interventions for the prevention of WRULDs in adults.

We found that the use of an arm support with alternative mouse for VDU users reduced the symptoms of upper limb and neck discomfort and incidence of neck or shoulder disorders. However, there was no difference in the incidence of right upper limb and upper body disorders. This single positive result could be a chance finding as we performed multiple comparisons comparing four different interventions and three different outcomes. Using an alternative mouse alone or an arm support alone did not demonstrate any benefit when compared to using a conventional mouse alone. There was moderate- to low-quality evidence to support this (Conlon 2008; Rempel 2006).

There was low-quality evidence that supplementary breaks were not effective in reducing discomfort of the neck, right shoulder, or upper limb or right forearm or wrist or hand (Galinsky 2000; Galinsky 2007). There was very-low- to moderate-quality evidence that other ergonomic interventions were not effective in preventing WRULDs (Bohr 2000; Brisson 1999; Gatty 2004; Gerr 2005; Greene 2005; Lintula 2001; von Thiele 2008; Yassi 2001).

## Overall completeness and applicability of evidence

We consider that the studies included in this review form the best available evidence for the review question. We have conducted an extensive search of the literature in all relevant medical databases and we have included 13 studies on workplace interventions for preventing MSDs of the upper limb and neck in adults. Not all studies reported on the outcomes that were relevant to this review and some of the studies presented results in a way that could not be used for meta-analysis.

The review found that there is moderate evidence for the use of an arm support together with an alternative mouse for reducing the symptoms of upper limb and neck discomfort and incidence of neck or shoulder disorders among VDU users. Using an alternative mouse alone or an arm support alone did not demonstrate any benefit when compared to using a conventional mouse alone. The alternative mouse designs that were used in these studies were a mouse with a neutral forearm posture (Conlon 2008) and a track ball (Rempel 2006). However, given there were multiple comparisons made involving a number of interventions and outcomes, high-quality evidence is needed to determine the effectiveness of these interventions clearly.

There was low- to moderate-quality evidence that the other interventions investigated in this review did not demonstrate any benefit in terms of preventing work-related MSDs of the right upper limb and neck. The reason for the absence of benefit may be because of lack of statistical power to detect relevant changes. The interventions on supplementary breaks demonstrated a reduction in discomfort scores but the results were not statistically significant. This may have been because of the inadequate sample size of these studies. We were unable to pool more studies in meta-analyses - which would have increased power - because the workplace, outcome measures, or type or duration of interventions were not comparable.

## Quality of the evidence

We included a total of 13 studies in this review, including five different types of interventions each containing several subtypes of intervention. As a result, each subtype of intervention was only assessed in between one and three studies and we performed meta-analyses only on subtypes containing two or more studies that had comparable outcomes. We assessed the quality of evidence for each subtype regardless of whether it was included in meta-analyses. We assessed the quality of evidence per outcome using the GRADE profiler software (GRADE 2008).

There was moderate- to low-quality evidence on the effectiveness of ergonomic equipment interventions and low- to very-low-quality evidence on the effectiveness of supplementary breaks or reduced work hours, ergonomic training, and ergonomic training offered together with equipment. The quality of evidence was downgraded owing to small sample size, lack of information on ITT, use of subjective outcome measures (detection bias), lack of information on sequence generation (selection bias), and lack of information on allocation concealment (selection bias). The main quality concerns were small sample sizes and use of subjective outcome measures (detection bias), which occurred for all the interventions.

Although all the studies were RCTs, the majority of the studies did not report the methods for random sequence generation and allocation concealment. This has led us to the downgrade the quality of evidence because of the possibility of selection bias. Future studies should use random sequence generation and adequate allocation concealment and provide a clear description of how each was achieved to minimise selection bias.

## Potential biases in the review process

We have conducted a comprehensive and transparent review. We conducted the entire process of study selection, data extraction, and assessment of risk of bias of included studies was independently by two review authors and we resolved any disagreements through consensus. We minimised selection bias in our search by

screening references of identified trials and systematic reviews, by contacting experts in the research field, and by not restricting our search strategy by language or publication date. Even though our search strategy was comprehensive, there is always a risk that relevant studies may not have been identified in the review process. We were unable to assess the risk of publication bias adequately as there were limited studies assessing similar interventions and outcomes. We avoided duplicate publication bias by using study data only once. In our included studies, there were two studies that were each reported twice. We combined the results from the two reports and only used the data that were appropriate for this review. We were able to obtain missing data for three studies.

This review included only RCTs since methodologically weaker designs can easily lead to bias. In the field of occupational health, randomisation is sometimes difficult to perform. From the 'Risk of bias' tables it can be noted that there were high number of studies with a classification of unclear in the sequence generation and allocation concealment domains. This implies that the primary publication does not supply enough information to assess bias. We did not seek further information from the authors for the course of simplicity and resources. Instead, we chose to complete the 'Risk of bias' assessment solely based on information provided in the published reports.

We only included studies where 75% or more of the participants were free of WRULDs at baseline. Nine studies were excluded because more than 25% of the participants at baseline reported musculoskeletal symptoms of the upper limb or neck, or both (Cook 2004; Faucett 2002; Fostervold 2006; Haukka 2008; Ketola 2002; Meijer 2009; Mekhora 2000; Rempel 2007; Veiersted 2008). The strict criteria used are likely to have reduced the number of studies included in this review.

### Agreements and disagreements with other studies or reviews

The results of this review differ from two earlier systematic reviews by Boocock 2007 and Kennedy 2010. Our review focused on prevention of MSDs and excluded studies where 25% or more of the participants had MSDs of the upper limb or neck. What is more, Boocock 2007 and Kennedy 2010 classified interventions differently and included also study designs other than RCTs. Because of their looser inclusion criteria, Boocock 2007 included 31 studies and Kennedy 2010 included 36 studies.

Boocock 2007 concluded that there was some evidence to support the use of mechanical and modifier interventions for preventing and managing neck or upper extremity musculoskeletal conditions. They found that there was moderate evidence that mouse and keyboard design can lead to positive health benefits in VDU workers with neck or upper extremity musculoskeletal conditions. Kennedy 2010 found moderate evidence for arm supports and limited evidence for ergonomics training plus workstation adjustments, new chairs, and rest breaks on upper-extremity MSD outcomes.

## AUTHORS' CONCLUSIONS

### Implications for practice

The current available evidence demonstrates moderate-quality evidence to suggest that the use of an arm support together with an alternative mouse may reduce the incidence of neck or shoulder MSDs, but not right upper limb MSDs among VDU users. Moreover, there is moderate-quality evidence to suggest that the incidence of neck or shoulder and right upper limb MSDs is not reduced by using an alternative mouse as compared to a conventional mouse, with and without arm support. However, given that we made multiple comparisons involving a number of interventions and outcomes, high-quality evidence is needed to clearly determine the effectiveness of these interventions.

While there was very-low- to low-quality evidence to suggest that other ergonomic interventions do not prevent WRULDs, this was limited by the number and heterogeneity of available studies.

### Implications for research

Given this review identified only a small number of studies with low risk of bias and significant heterogeneity between the studies, there is a need for high-quality RCTs examining ergonomic interventions for upper limb and neck disorders. Most of the studies were conducted in the US, with only three studies from Canada, and one each from Finland and Sweden. Studies from other parts of the world - especially from developing countries - are lacking. It is important to conduct these studies also in developing countries as differences in culture and work practices need to be also considered. Conducting multicentre studies in both developed and developing countries will further increase the usefulness of the findings.

The main risk for bias identified in this review was blinding (performance and detection bias). Although blinding of participants and personnel (performance bias) is difficult to achieve for ergonomic interventions, researchers need to consider minimising detection bias by having independent blinded assessors for diagnosing upper limb and neck MSDs. Future studies also need to consider including independent medical examinations for diagnosis or using injury records, workers' compensation records or other injury reporting systems to obtain more objective outcome measures to minimise detection bias.

Studies used a number of different outcomes to measure discomfort and disability. The lack of standardisation in the methods used to assess these outcomes is obvious. Future research should there-

fore use standardised methods or validated instruments especially when assessing discomfort and disability.

The 13 identified studies consisted of only workers who used a computer or conducted data processing and worked in healthcare settings. Future research should include workers with other exposures or other industries where the risks for work-related MSDs are different.

The majority of studies did not report details of random sequence generation or allocation concealment. Future studies should have a clear description of the randomisation process and include both random sequence generation and allocation concealment to minimise selection bias.

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**Smith 2004**
Smith DR, Leggat PA. Musculoskeletal disorders among rural Australian nursing students. *Australian Journal of Rural Health* 2004;**12**(6):241–5. [PUBMED: 15615575]

**Szeto 2009**
Szeto GP, Ho P, Ting AC, Poon JT, Cheng SW, Tsang RC. Work-related musculoskeletal symptoms in surgeons. *Journal of Occupational Rehabilitation* 2009;**19**(2):175–84. [MEDLINE: 19381790]

**Tittiranonda 1999**
Tittiranonda P, Rempel D, Armstrong T, Burastero S. Effect of four computer keyboards in computer users with upper extremity musculoskeletal disorders. *American Journal of Industrial Medicine* 1999;**35**(6):647–61. [PUBMED: 10332518]

**Tullar 2010**
Tullar JM, Brewer S, Amick BC, Irvin E, Mahood Q, Pompeii LA, et al.Occupational Safety and Health Interventions to Reduce Musculoskeletal Symptoms in the Health Care Sector. *Journal of Occupational Rehabilitation* 2010;**20**(2):199–219.

**USBJD 2008**
United States Bone, Joint Decade. *The Burden of Musculoskeletal Diseases in the United States*. Rosemont, IL: American Academy of Orthopaedic Surgeons, 2008.

**Verhagen 2009**
Verhagen AP, Karels CC, Bierma-Zeinstra SMA, Burdorf LL, Feleus A, Dahaghin SSD, et al.Ergonomic and physiotherapeutic interventions for treating work-related complaints of the arm, neck or shoulder in adults (Withdrawn). *Cochrane Database of Systematic Reviews* 2009, Issue 3. [DOI: 10.1002/14651858.CD003471.pub4]

**Werner 2005**
Werner RA, Franzblau A, Gell N, Hartigan A, Ebersole M, Armstrong TJ. Predictors of persistent elbow tendonitis among auto assembly workers. *Journal of Occupational Rehabilitation* 2005;**15**(3):393–400. [MEDLINE: 16119229]

**Wynne-Jones 2009**
Wynne-Jones G, Mallen CD, Mottram S, Main CJ, Dunn KM. Identification of UK sickness certification rates, standardised for age and sex. *British Journal of General Practice* 2009;**59**(564):510–6. [MEDLINE: 19566999]

**Yassi 1997**
Yassi A. Repetitive strain injuries. *Lancet* 1997;**349**(9056): 943–7. [MEDLINE: 9093264]

* *Indicates the major publication for the study*

## CHARACTERISTICS OF STUDIES

### Characteristics of included studies *[ordered by study ID]*

**Bohr 2000**

| | |
|---|---|
| Methods | RCT. The participants were randomly assigned to 1 of 3 study groups |
| Participants | The sample of 154 subjects was selected at random from a list of volunteers who were employed as agents at the centralised reservation facility for a large international transportation company. These individuals used computers at least 5 hours per work day. All of these individuals performed similar work tasks at similar workstations |
| Interventions | The study compared participatory education intervention, traditional education intervention, and no intervention<br>a. Participatory education intervention<br>It involved active learning sessions, incorporating discussions and problem-solving exercises to aid the participants in applying ergonomic concepts to the work environment. It should be noted that the content was similar to that provided to the traditional group but the method of presenting the information differed. The educational sessions for this group lasted approximately 2 hours<br>The first portion of the educational session incorporated hands-on demonstration of workstation evaluation and modification. Through case studies, the participants used a problem-solving approach to recognise ergonomic problems and recommend solutions to address the problem<br>The second portion of the session paired participants and returned them to their work areas to evaluate and modify the areas according to the information received during the first portion of the session. The modifications were made under the supervision of the instructor for the course who provided assistance to ensure that the newly arranged work areas were consistent with the principles taught in the class<br>b. Traditional education<br>It involved a 1-hour education session that consisted of a lecture and informational handouts about office ergonomics. The education for this group included information about basic muscle physiology, ideal neutral postures, basic task analysis, recommended office equipment location, recognition of problems related to incorrect equipment placement, and general wellness information related to exercise, nutrition, and smoking<br>A brief question and answer session was included at the end of the session<br>c. Control group/no intervention<br>The control group did not participate in any education sessions |
| Outcomes | Primary outcome:<br>upper body pain/discomfort composite scores at baseline and at 3, 6, and 12 months' postintervention. The discomfort scores range from 1 to 4 for each body part for pain and discomfort during the past week (1 = never, 2 = occasional, 3 = several times per week, 4 = several times per day). The upper body composite score included neck, upper back, shoulder/upper arm, forearm, and wrist/hand)<br>Secondary outcome:<br>compliance - work area configuration composite score at baseline and at 3, 6, and 12 months' post-intervention |

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| Notes | - |

***Risk of bias***

| Bias | Authors' judgement | Support for judgement |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | The method of randomisation was not described in the study. The only information provided is: "The participants were randomly assigned to one of three study groups" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | Blinding of participants and personnel not possible as intervention included educational sessions |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | Upper body pain/discomfort composite score was self-reported and subjective |
| Incomplete outcome data (attrition bias)<br>All outcomes | High risk | The attrition rate was not even across the 3 groups. No ITT analysis mentioned. The attrition rate for both of the intervention groups was more than double that of the control group (23%-24% for the intervention groups vs 11% for the control group) |
| Selective reporting (reporting bias) | Low risk | Reported on all findings. According to the authors: "there were no significant differences noted across groups for work area configuration, worker postures, or overall observation scores" |
| Other bias | High risk | 1. Cross-contamination of intervention effects owing to close proximity of the workstations<br>2. There was no information on baseline characteristics comparing the 2 intervention groups and the control group |

**Brisson 1999**

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| Methods | Cluster RCT. Workers were assigned to the experimental or reference group (no intervention) on the basis of the units in which they worked. 40 administrative and geographic units were randomised to the experimental group or reference group. The units were stratified before randomisation on the basis of the number of clerical workers (< 20 and ≥ 20) and type of services (administrative and teaching) in order to ensure equal distribution of these features in each group |
| Participants | The study population composed of workers employed in a large university (90%) and in other institutions involved in university services (10%). Eligible workers were those working 5 hours or more per week with a VDU<br>627 workers (81% of the people eligible at baseline) participated in both data collection periods (baseline and 6 months). They consists of:<br>• PRECEDE intervention group (n = 284)<br>• reference/no intervention group (n = 343) |
| Interventions | The study compared PRECEDE intervention vs no intervention<br>a. PRECEDE intervention group<br>The ergonomic training programme was developed according to the PRECEDE model. The objective of the programme was to act on characteristics of the work environment and the workers that determine behaviour in order to motivate and to enable the workers to improve the ergonomic features of their workstation<br>• Predisposing factors relate to knowledge, beliefs, attitudes, and values<br>• Enabling factors relate to skills and material resources and<br>• - Reinforcing factors relate to support provided by the environment<br>The programme targeted the following 3 types of behaviour:<br>• adjusting the postural components of the workstation correctly;<br>• adjusting the visual components of the workstation correctly; and<br>• organising work activities in a preventive manner<br>The programme composed of 2 sessions of 3 hours each with a 2-week interval<br>1. The sessions involved demonstrations, simulations, discussions, and lectures. In addition, each worker had to do a self-diagnosis of his (her) workstation using a photograph taken of him (her) at work before the programme started. Each session was presented to about 15 workers with their supervisor at one time<br>2. The presence of the supervisor aimed at providing an organisational environment that was supportive of actions taken by the workers<br>3. The 2-week interval allowed the workers to apply knowledge and skills learned at the first session and to return to the second training session with questions and experiences to discuss<br>4. The trainers were 4 occupational health and safety professionals working for the employer and 1 occupational health and safety union representative<br>b. Reference/no intervention group<br>The reference group did not receive the training until the completion of the study |
| Outcomes | Primary outcome:<br>Neck-shoulder and hand-wrist musculoskeletal symptoms were assessed using a self-administered questionnaire and by physical examination. The measurements were performed 2 weeks before and 6 months after the intervention in both groups. The prevalent MSDs on the questionnaire were defined as those that were present on 3 days or more during the last 7 days and for which the intensity of pain was greater than half the VAS among subjects with no history of inflammatory disease or acute injury at the relevant |

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| | anatomical site<br>The physical examination was performed on workers who reported symptoms meeting the case definition. The physical examination was conducted according to a standard protocol by a trained occupational therapist blinded to the participant's assigned group. The physical examination was performed 2 to 5 weeks after the completion of the self-administered questionnaire<br>Secondary outcome:<br>Compliance with the intervention |
| Notes | The information for the neck-shoulder and hand-wrist musculoskeletal symptoms was available for the 2 groups combined comparing before and after intervention, and for 3 anatomical regions combined (including lower back) comparing intervention and reference before and after intervention<br>No information was available for neck-shoulder and hand-risk alone comparing the effect of intervention and reference group |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no information on sequence generation. The method for randomisation was clearly described |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | Participants were not blinded to the allocation as the intervention consisted of training |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | Although the physical examination was performed by trained occupational therapists blinded to the subjects' assigned group, the examination was only performed on workers who reported symptoms meeting the case definition which was based on self-reporting/subjective symptoms |
| Incomplete outcome data (attrition bias)<br>All outcomes | Low risk | Although there was no mention of ITT, the percentages of participants were high at each measurement (88% and 94%). And according to the author "The percentages and reasons for non-participation were comparable in the experimental and reference groups" |
| Selective reporting (reporting bias) | Low risk | All outcomes were reported in the results |

**Brisson 1999** (*Continued*)

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| Other bias | High risk | There was no information on baseline characteristics comparing the 2 groups, so the success of randomisation could not be ascertained |

**Conlon 2008**

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| Methods | RCT. Participants were randomised into 1 of 4 intervention groups. The randomisation was done by means of a computer-generated permuted-block sequence |
| Participants | Participants consists of employees working at a large aerospace engineering firm in California, US that estimated working at a computer for at least 20 hours per week and employed as an member of the engineering staff (93%) or a professional position supporting engineering (7%) and have completed the health questionnaire and at least 4 weekly surveys. Since 1 of the mouse interventions could only be used right-handed, only those who agreed to use their right hand for the mouse pointing device intervention were eligible for the study<br>206 people volunteered out of total 437 eligible employees. The participants were randomised into 4 groups:<br>1. alternative mouse with a forearm support board (n = 51);<br>2. conventional mouse with a forearm support board (n = 51);<br>3. alternative mouse alone (n = 52);<br>4. conventional mouse alone (n = 52);<br>154 people volunteered for the nerve conduction testing |
| Interventions | The study compared 4 different interventions for computer workstations<br>1. Alternative mouse with a forearm support board: the forearm support board was a large butterfly-shaped board (36 by 21 inches) that was attached to a desk and provided padded forearm support (ButterflyBoard, Metamorphosis Design and Development, Atlanta, GA, US). The board was inclined upwards at approximately 5° and the surface could accommodate a keyboard and mouse, and the alternative mouse was a 3M product that had a vertical handle for grasping and a flat base to support the ulnar side of the hand and used a roller ball for tracking. The forearm was in approximately 15° of pronation during use (Renaissance Mouse, 3M Corporation, St Paul, MN, US)<br>2. Conventional mouse with a forearm support board: forearm support board (as in (1)) and conventional mouse used an optical LED for tracking the mouse movement and required the hand to be in an almost fully pronated posture during operation (IntelliMouse Optical, Microsoft Corporation, Redmond, WA, US)<br>3. Alternative mouse alone: the alternative mouse was a 3M product that had a vertical handle for grasping and a flat base to support the ulnar side of the hand and used a roller ball for tracking. The forearm was in approximately 15° of pronation during use (Renaissance Mouse, 3M Corporation, St Paul, MN, US) (as in (1)<br>4. Conventional mouse alone: conventional mouse using an optical LED for tracking the mouse movement and required the hand to be in an almost fully pronated posture during operation (IntelliMouse Optical, Microsoft Corporation, Redmond, WA, US) (as in (2)) |

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| Outcomes | Primary outcome:<br>1. Incidence of MSD: subject reported a discomfort intensity level of > 5 on the weekly survey, or used a pain medication for ≥ 2 days per week for upper body discomfort that they thought was related to computer work was referred for an examination. The examination protocol focused on the body region with discomfort and was performed by 1 physician who was blinded to the intervention status. The examination protocol assessed for the presence of 40 upper extremity and neck MSDs<br>2. Mean discomfort score: the discomfort scores were assessed for 3 body regions, the neck/shoulders, right elbow/forearm/wrist/hand, and left elbow/forearm/wrist/hand, were assessed for the worst discomfort during the preceding 7 days using a 0 to 10 point scale (0 = no discomfort; 10 = unbearable discomfort). Subjects were asked whether they thought the discomfort was the result of (a) working on a computer, (b) an acute injury at work, or (c) activities or an injury away from work. Only discomfort reported by the subject as a result of working on their computer was included in the data analysis. The mean discomfort scores for pre-intervention and post-intervention (pre-intervention mean discomfort scores were obtained from the weekly surveys before intervention by averaging all the pre-intervention scores for each subject to a single value; post-intervention discomfort scores were obtained from the weekly surveys after intervention. These scores were collapsed into a single postintervention score by body region. The first 8 weeks of post-intervention scores were left-censored) |
| Notes | The study was reported in 2 papers (see Conlon 2008) |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Low risk | "Participants were randomised into one of four intervention groups. The randomisation was done by means of a computer-generated permuted-block sequence" |
| Allocation concealment (selection bias) | Unclear risk | No information provided |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | Blinding of participants not possible given that different equipment was tested in the 4 groups |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | MSDs: although the examination was performed by 1 physician who was blinded to the intervention status, the pre-examination criteria for inclusion in the examination was determined by subjective discomfort levels |
| Incomplete outcome data (attrition bias)<br>All outcomes | Low risk | The analysis followed an ITT protocol. As participant exited the study they completed the exit questionnaire |

**Conlon 2008** (*Continued*)

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| Selective reporting (reporting bias) | Low risk | All the results for musculoskeletal discomfort, MSDs, and distal motor latency were reported |
| Other bias | High risk | Those who volunteered for the study were different:<br>1. "females were more likely to volunteer for the study than males (P < 0. 01)"<br>2. "participants had higher levels of right arm and neck/shoulder discomfort (P < 0.01)"<br>3. "participants were also more likely to take medications for discomfort related to work and had higher estimates of the number of days at work that were affected by discomfort (P = 0.05)"'<br>Owing to this the effect may be larger than expected |

**Galinsky 2000**

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| Methods | Cross-over RCT. Data was collected over a 16-week period. The 16-week period was divided into 4, 4-week phases in which participants alternated between the conventional (C) and supplementary (S) rest break schedules. Half of the volunteers from each shifts (day and night) were assigned at random to experience the C-S-C-S order of rest break schedules and the other half were assigned at random to experience the opposite (S-C-S-C) order. As a result of attrition, data from just the first 2 phases of the study were sufficient for analyses (i.e. the C-S phases) |
| Participants | Data-entry operators (seasonal employees) working at an Internal Revenue Service centre. The data-entry task entailed keying mostly numeric data from paper tax forms using a standard keyboard with a right-sided numeric keypad. A total of 101 data-entry operators provided written voluntary, informed consent to participate in the study. Each data-entry operator had been hired as a 'seasonal' employee under an agreement that the job was temporary. The time at which each operator was released from employment was determined by the workload demands of the facility |
| Interventions | The study compared supplementary breaks with conventional breaks<br>1. Control: the conventional break schedule included one 15-minute break in the middle of the first half of the work shift and one 15-minute break in the middle of the second half of the work shift<br>2. Intervention: the supplementary break schedule included the same 15-minute breaks, and also included a 5-minute break during each hour of the work shift that otherwise did not contain a break. For each 8-hour shift, the supplementary schedule provided 4 extra 5-minute breaks for a total of 20 extra minutes of break time. Under each schedule, a 30-minute lunch period, additional to the 8-hour work and break time, occurred in the middle of the shift |

**Galinsky 2000** (*Continued*)

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| Outcomes | Primary outcome:<br>1. musculoskeletal discomfort ratings for several parts of the body, including the neck, shoulders, upper arms, elbows, forearms, wrists, hands, back, buttocks, and legs. Each rating was made using a 5-point category rating scale in which the whole numbers 1 to 5 indicated ratings of 'none at all', 'a little', 'moderate', 'quite a bit', and 'extreme', respectively<br>Secondary outcome:<br>1. data entry productivity: 2 measures of productivity, keystrokes per hour and the total number of documents entered by each participant on each day of the study. This measure, which was affected by factors such as the length of tax documents entered and the number of hours worked per day, permitted an assessment of work output<br>2. data accuracy: 2 measures of data-entry accuracy were used for this study. One was the number of errors made per day by each participant. The other was a daily measure of accuracy percentage, which took into account the number of documents entered per day |
| Notes | - |

***Risk of bias***

| Bias | Authors' judgement | Support for judgement |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no information on sequence generation. The only information available was: "A within-subjects/repeated measures design was used … Half of the volunteers from each shift (day and night) were assigned at random to experience the C-S-C-S order of rest break schedules, and the other half were assigned at random to experience the opposite (S-C-S-C) order" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | Low risk | Blinding not possible, but the risk of performance bias was assessed as low as the intervention consisted of a strict protocol. The study participants "...use custom-made electrical timers, attached to the top of each video display terminal, to automatically signal their scheduled breaks" |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcome has only subjective symptoms, i.e. musculoskeletal discomfort ratings (feeling state) |

**Galinsky 2000** (*Continued*)

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| Incomplete outcome data (attrition bias) All outcomes | High risk | Out of the 101 people who volunteered to participate in the study only 42 participants were included in the final analysis. Only the data from the first (first cross-over) of the 2 phases were sufficient for analysis. Data from the second phase (second cross-over) were not analysed. Loss to follow-up amounted to 38 participants and the reasons cited were release from employment and resignation from employment. Questionnaires from 21 participants were too incomplete for analyses |
| Selective reporting (reporting bias) | Low risk | The outcomes listed in the methods section were reported in the results |
| Other bias | Low risk | The authors reported that "to minimize the potential influence of carry-over effects and 'Hawthorne effects'… Data from the first 2 weeks of each 4-week phase were excluded from analyses of the feeling state questionnaire items" |

**Galinsky 2007**

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|---|---|
| Methods | Cross-over RCT. Approximately half (23) of the volunteers in each exercise condition were assigned at random to work for 4 weeks under conventional schedule and then switch to the supplementary schedule for the second 4-week phase. The remaining 22 volunteers in each exercise condition were assigned at random to experience the opposite sequence of rest break conditions |
| Participants | Data-entry operators (seasonal employees) working at an Internal Revenue Service centre, Cincinnati, OH, US. The study sample was recruited from 1 area of the centre containing workstations for 101 individuals, 90 of whom volunteered to follow the study protocol |
| Interventions | The study compared supplementary breaks with conventional breaks<br>Half of the 90 volunteers were assigned at random to the stretching exercise condition and half were assigned to the no stretching exercise condition. The 8-week study period was divided into two 4-week phases in which all participants alternated between the conventional and supplementary rest break schedules<br>1. The conventional break schedule included one 15-minute break in the middle of the first half of the work shift and one 15-minute break in the middle of the second half of the work shift<br>2. The supplementary break schedule included those same 15-minute breaks, and also included a 5-minute break during each hour of the work shift that otherwise did not contain a break. For each 8-hour shift, the supplementary schedule provided 4 extra 5-minute breaks for a total of 20 extra minutes of break time<br>All participants were encouraged to get up and walk away from their workstations during |

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| | each break, regardless of their assigned break schedule or exercise condition<br>Under each schedule, a 30-minute lunch period, additional to the 8 hours of work and break time, occurred in the middle of the shift<br>Participants in the exercise condition viewed a demonstration of the stretching exercises performed by the principal investigator with opportunities for questions and answers. They also kept a paper copy of exercise instructions at their workstations. They were instructed to do the stretches at the beginning of each break in the order specified in the instructions. The first 6 stretches were performed while seated and the last 3 stretches could be done while standing or walking. The 9 stretches required no more than 2 minutes to complete |
| Outcomes | Primary outcome:<br>Musculoskeletal discomfort ratings (feeling state) for several parts of the body, including the neck, shoulders, upper arms, elbows, forearms, wrists, hands, back, buttocks, and legs. The musculoskeletal discomfort was made using a 5-point category rating scale in which the whole numbers 1 to 5 indicated ratings of 'none at all', 'a little', 'moderate', 'quite a bit', and 'extreme', respectively |
| Notes | The data for the conventional and supplementary break cycle consists of the combination of participants in both exercise and no exercise groups. The effect of breaks alone cannot be isolated |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no information on sequence generation. The only information available is that "… the exercise group and the non-exercise group… were assigned at random to work for 4 weeks under the Conventional schedule and then switch to the Supplementary schedule for the second 4-week phase" and "approximately half (23) of the volunteers in each exercise condition were assigned at random to work for 4 weeks under the Conventional schedule and then switch to the Supplementary schedule for the second 4-week phase" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | Low risk | Blinding was not possible but the risk of performance bias was deemed low for a rest-break cycle as the implementation consisted of a strict protocol. The participants "use custom-made electrical timers, attached to the top of each video display ter- |

**Galinsky 2007** (*Continued*)

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| | | minal, to automatically signal their scheduled breaks". However, as this study compared 2 exercise regimens that were not blinded, the risk of bias was deemed high for the combination of the 2 interventions |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcome has only subjective symptoms, i.e. musculoskeletal discomfort ratings (feeling state) |
| Incomplete outcome data (attrition bias)<br>All outcomes | High risk | Out of the 90 who volunteered to follow the study protocol only 51 were deemed to have complete data for analysis. According to the text "An individual's data set was deemed incomplete if more than 4 consecutive days of questionnaires were missing, or if more than a total of 8 days of questionnaires were missing from either the first or second 4-week period of the study" |
| Selective reporting (reporting bias) | Low risk | The risk of selective reporting (reporting bias) was deemed low as all outcome were reported, the author reported on non-significant outcome: "In the stretch group, workers reported stretching during only 25% of conventional breaks and 39% of supplementary breaks, and no significant effects of stretching on discomfort or performance were observed" |
| Other bias | High risk | There was no comparison of the 2 intervention groups<br>There was no mention of differences between participants and non-participants<br>Potential of carry-over effect, as the authors did not state having used a wash-out period |

**Gatty 2004**

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| Methods | RCT. The participants were randomly assigned to 1 of 2 groups |
| Participants | "All participants were female and met the inclusion criteria by being employed as full-time clerical/office workers at a small western Pennsylvania college, and having no newly (within the last three months) diagnosed MSD". 15 workers participated in the study |
| Interventions | The study compared individualised WIPPs vs no intervention<br>1. Individualised WIPPs (group A): the WIPP were designed by the WIPP team (3 master of occupational therapy students and the principle investigator) was based on |

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| | the worksite analyses. Treatment sessions spanned weeks 1 through to 4. Each participant received 1 hour of treatment per week. During these 4 sessions the workers were actively engaged in education, workstation redesign, and task modification<br>i) Education - occupational therapy students and clerical workers discussed current work conditions as they related to experienced symptoms; for example, improperly bending to lift boxes may contribute to low back pain or excessive wrist extension may contribute to wrist pain<br>ii) Workstation redesign - based on worksite analyses and input from the workers<br>iii) Task modification - demonstrated by the occupational therapy student, practiced by the worker, and feedback was provided<br>2. No intervention (control) (group B): this group received no intervention<br>All participants (intervention and control group) received the symptom evaluation measure (measured the reported frequency and intensity of symptoms), stress and energy scale (10-cm VAS to measure perceived stress energy levels), and follow-up survey (to identify changes in work status) |
| Outcomes | Primary outcome:<br>1. frequency of symptoms: neck ache/pain, shoulder ache/pain, elbow-forearm ache/pain, wrist-hand ache/pain, upper back ache/pain, and lower back ache/pain defined as the number of days, 0 to 5, they experienced symptoms during the week while at work (data was collected at weeks 0, 5, and 16)<br>2. symptom intensity: rated using a 4-point Likert scale 1 to 4: 1 = none, 2 = mild, 3 = moderate, or 4 = severe<br>Secondary outcome:<br>Compliance survey - for group A (intervention) only - about: how often they used the issued ergonomic equipment, how often they performed recommended stretches and whether or not they performed their job duties differently based on recommendations. Responses were elicited on a 4-point Likert scale with choices of 1 = never, 2 = sometimes, 3 = usually, 4 = always when I should |
| Notes | The study was reported in 2 papers (see Gatty 2004);<br>1. Martin SA, Work 2003;21:185-96, reported results for weeks 0 and 5<br>2. Gatty CM, Work 2004;23:131-7, reported results for weeks 0, 5, and 16.<br>Worksite analyses were conducted for group B (control) workers during week 17, they received individualised WIPPs during weeks 18 to 21 and measures were repeated at week 22 (suspension of randomisation process) |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no mention of sequence generation. The only information given was: "This was a two-phased randomized control pilot study with between and within subject comparisons … Participants were randomly assigned to one of two groups, A (intervention) or B (control)" |

**Gatty 2004** (*Continued*)

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| Allocation concealment (selection bias) | Unclear risk | No information provided on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | There was no information on blinding and since the intervention consists of education, workstation redesign, and task modification, there was high risk for bias |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcome was subjective reporting of symptoms frequency and intensity |
| Incomplete outcome data (attrition bias)<br>All outcomes | High risk | In group A (intervention), "one non-compliant worker at week zero remained non-compliant at week five and was dropped from the study. One person was no longer employed by week 16 and membership decreased to six"<br>In group B (control) "…Although there were originally eight participants, two different workers were non-compliant with surveys, one at week zero and one at week five. By week 16, one person had left employment"<br>Owing to the small number of participants, i.e. 16, the attrition of 3 participants was considered to induce a high risk of bias |
| Selective reporting (reporting bias) | Low risk | All the outcomes were reported |
| Other bias | High risk | 1. Difference in baseline data: group A (intervention) reported lower average wrist-hand ache/pain and upper back ache/pain intensities than group B (control)<br>2. There was no mention of differences between participants and non-participants |

**Gerr 2005**

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| Methods | RCT. Randomisation occurred following evaluation of workplace and ergonomic variables. The use of a random number table assured that each subject entering the study had an equal probability of being assigned to each of the 3 groups. Randomisation was done in blocks of 6 to assure equal numbers of participants in each of the study groups |
| Participants | A person eligible for inclusion in this study was: a newly hired worker who: anticipated using a single computer workstation for 15 hours or more per week and anticipated using a computer workstation for at least as many hours per week as in his/her previous job |

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| | working at insurance and financial companies, food product producers, and universities in metropolitan Atlanta, GA, US who had reported experiencing arm or hand symptoms during the week prior to intervention<br>Of the 447 eligible for health screening, a total of 379 individuals were eligible for inclusion into 1 or both cohorts (those who did not report experiencing arm or hand pain and neck or shoulder pain during the week prior to the study. 375 people were randomised into the arm and hand cohort and 356 were randomised into the neck and shoulder cohort |
| Interventions | The study compared alternate intervention, conventional intervention, and no intervention<br>A study staff member reconfigured the subject's workstation if the subject was randomly assigned to either the alternative or conventional interventions (groups A or B)<br>Verbal and written instructions describing the desired posture were provided to all group A and B participants<br>At 3 days and 1 week after the intervention, study staff returned to the participant's workplace to check on continued maintenance of the posture. If the posture had changed from the intervention, additional workstation changes were made and additional instruction given<br>1. Group A: alternate intervention: the workstation was adjusted according to the following configuration:<br>i) Head tilt angle $\leq 3^{o}$ (head tilt angle is defined as the angle formed between a line defined by the tragion of the ear and the infraorbitale of the eye and the horizon. To clarify the meaning of head tilt angle values, increasing neck extension results in larger values for head tilt angle and increasing neck flexion results in smaller (including negative) values)<br>ii) head rotation < $15^{o}$ in either direction (L/R)<br>iii) J key at least 2 cm below elbow height<br>iv) keyboard inner elbow angle of > $120^{o}$<br>v) J key at least 12.5 cm from edge of desk or work surface<br>vi) keyboard wrist ulnar deviation of $0^{o}$ to $220^{o}$ (i.e. up to $20^{o}$ radial deviation)<br>vii) armrest present<br>viii) keyboard wrist rest present<br>ix) mouse wrist ulnar deviation of $25^{o}$ to $5^{o}$<br>x) mouse wrist extension of $20^{o}$ to $30^{o}$<br>xi) mouse next to keyboard<br>xii) high-quality chair present. Characteristics of high-quality chair: easily (pneumatically) adjustable for height, adjustable height backrest, full contoured backrest, adjustable seat pan angle, round waterfall seat pan edge, 5-legged base<br>2. Group B: conventional intervention: the workstation was adjusted according to the following configuration:<br>i) eye height level with top of monitor screen<br>ii) head rotation < $15^{o}$ in either direction (L/R)<br>iii) J key at least 3 cm above elbow height<br>iv) keyboard shoulder flexion of $210^{o}$ to $20^{o}$<br>v) keyboard shoulder abduction of $210^{o}$ to $20^{o}$<br>vi) keyboard inner elbow angle of $80^{o}$ to $100^{o}$<br>vii) keyboard wrist ulnar deviation of $210^{o}$ to $10^{o}$<br>viii) keyboard wrist extension of $210^{o}$ to $10^{o}$ |

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| | ix) keyboard wrist rest present<br>x) mouse wrist ulnar deviation of 210° to 10°<br>xi) mouse wrist extension of 210° to 10°<br>xii) armrest present<br>xiii) high-quality chair present<br>3. Group C: no intervention: instructed to continue keying in their usual posture and no changes were made to their workstations |
| Outcomes | Primary outcome:<br>• Time to event: symptoms of pain or discomfort - participants were classified as having experienced musculoskeletal symptoms if they (1) reported musculoskeletal discomfort on any day of the week with a severity of ≥ 6 on the 0 to 10 VAS or (2) reported musculoskeletal discomfort on any day of the week for which they took medication (over-the-counter or prescription). Study participants were followed for each outcome separately until they became symptomatic (censored). Development of a symptom in 1 anatomic area did not stop the collection of data for the other anatomic area. 2 separate, overlapping cohorts were then defined to examine separately the risks of neck or shoulder symptoms and the risks of arm or hand symptoms<br>Secondary outcome:<br>• Compliance: using a standard checklist, each workstation was evaluated for presence of specific items (e.g. mouse or other pointing device), and the adjustability of specific equipment. Following completion of the checklist, dimensional and angular measurements (e.g. seated elbow height, table surface height, keyboard inner elbow angle) were recorded |
| Notes | Gerr 2005 consists of 2 overlapping cohorts. The effect of the intervention was assessed as arm/hand and neck/shoulder pain |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Low risk | The use of a random number table assured that each subject entering the study had an equal probability of being assigned to each of the 3 groups. Randomisation was done in blocks of 6 to assure equal numbers of participants in each of the study groups |
| Allocation concealment (selection bias) | Unclear risk | No information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | There was no mention of blinding and the methods of intervention consisted of 2 distinct workstation and postural interventions |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | Outcomes consisted of subjective symptoms measured with a check-list |

**Gerr 2005** (*Continued*)

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| Incomplete outcome data (attrition bias) All outcomes | Low risk | Participants contributed data to their assigned intervention group regardless of compliance (i.e. data were analysed by ITT) |
| Selective reporting (reporting bias) | Low risk | Key findings: there were no significant differences in the incidence of musculoskeletal symptoms among the 3 intervention groups |
| Other bias | High risk | Large number of drop-outs. "There were a large number of drop-out/lost to follow-up in arm/hand cohort - 147 (41% of those followed) were lost during the six month follow up period … No differences were observed in dropout rates (i.e. incomplete follow-up) across the three intervention groups". Although the drop-out rates were similar across the 3 randomised groups, there were a large number of drops-outs in each group (36 to 42 across all 6 groups) for which the authors did not provide a reason |

**Greene 2005**

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|---|---|
| Methods | RCT. A prospective 2-group experimental design with a delayed intervention for the control group was used (see Figure 1). Because the size of the training classes was limited to no more than 25, participants were randomly assigned to 1 of 4 training groups. 2 training groups were combined to form the intervention group and 2 training groups formed the control group. The RCT design was implemented only for the first 3 weeks of intervention. After the third week (week 4) the control group was given the active ergonomic training sessions. The participants were followed up for 1 year |
| Participants | Participants included all employees in the unit who worked at a computer at least 10 hours per week in an organisational unit of a large state university in southeast US. Employees diagnosed by a physician as having an acute musculoskeletal injury or trauma to the trunk or upper extremities within the previous 6 months were excluded from participation. Employees being treated by a healthcare professional for cervical or upper extremity disorders were excluded from participation<br>87 employees participated in the study |
| Interventions | The study compared active ergonomic training with no intervention<br>1. AET: the AET programme consisted of a total of 6 hours of didactic interactions, discussion, and problem-based activities. The AET group met on 2 days in the same week for 3 hours per session. The AET programme occurred during working hours and employees participated on company time. Key elements of the AET programme were:<br>i) skill development in problem-solving for ergonomic workstation issues<br>ii) active participation and |

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| | iii) integration of multiple prevention strategies<br>2. No intervention (control): the participants did not received intervention until week 4 of the study |
| Outcomes | Primary outcome:<br>1. musculoskeletal symptoms: participants were first asked if they had experienced musculoskeletal symptoms in the past year in: (a) head, (b) neck, (c) shoulder and upper arm, (d) elbow/forearm, (e) wrist, hands/fingers, or (f) upper back. Regional composite scores were computed to provide an impression of symptoms in a functional region. Scores from the head, neck, and upper back were combined to describe symptoms in the upper spine. Scores from the shoulder/upper arm, elbow/forearm, wrist, and hand were combined to describe symptoms in the upper extremity<br>2. intensity of pain: for each symptomatic body region, an ordinal scale was used ranging from 1 = mild pain to 4 = worst ever. A score of 0 was assigned for asymptomatic body regions<br>3. frequency of pain: an ordinal scale that ranged from 1 = once in the past week to 4 = daily in the past week was used. If no discomfort was present in a body region, a score of 0 was assigned<br>4. duration of pain: an ordinal scale that ranged from 1 = < 1 hour to 4 = > 3 days to 1 week was used. If no discomfort was present in a body region, a score of 0 was assigned |
| Notes | The authors reported results for both the randomised and delayed intervention given to the control group (at week 4). From week 0 to week 3 the groups were treated according to their randomisation to the AET programme group and the control group. On week 4 the control group were also given the AET programme. We only included data from week 3 |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | High risk | There was no information on sequence generation and the randomisation was not adhered to in the allocation of participants. "After participants were randomly assigned to groups, the physical proximity of participant work locations in the intervention and control groups was assessed. To minimize the diffusion of treatment effects, participants from the same work location were assigned to the same study group (intervention or control)" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |

**Greene 2005** (*Continued*)

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|---|---|---|
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | The participants and personnel were not blinded. The purpose of this study was to evaluate the effectiveness of an (AET programme in computer users. Subjects participated in a 6-hour training intervention at their workplace |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcome consists of subjective symptoms of pain or discomfort |
| Incomplete outcome data (attrition bias)<br>All outcomes | Unclear risk | There was no information on ITT analysis and loss to follow-up for the RCT part of the study. After the third week the control group were given the same intervention |
| Selective reporting (reporting bias) | Low risk | No significant differences were found for intensity of symptoms, frequency of symptoms, or duration of symptoms in any body region immediately post intervention |
| Other bias | Unclear risk | There was no information on differences between participants and non-participants |

**Lintula 2001**

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| Methods | RCT. After the first measurements the participants were randomly assigned to 3 groups of 7 participants |
| Participants | The participants were 21 healthy female VDU users without acute musculoskeletal symptoms. They were office employees and researchers with a mean age of 38 years (range 26 to 54 years). The participants had worked with a VDU for more than 20 hours a week for an average of 5 years (range 4 months to 13 years). All the participants were right-handed but 3 of them operated their mouse with their left hand |
| Interventions | The study compared Ergorest articulating arm supports with no arm support<br>"Ergorest articulating arm supports (Ergorest Ltd, Finland) were used in this study. The arm supports are attached to the table, and the height of the supports can be adjusted. Both arms are settled in the grooves and there is easy mobility. Ergorest arm supports have been developed particularly to reduce static load in the neck and shoulder area"<br>• Group 1: "used the basic Ergorest arm support with the mouse pad with the hand that operated the mouse"<br>• Group 2: "had Ergorest arm supports for both hands (a basic arm support with the mouse pad for the mouse hand and the basic arm support for the other hand)"<br>• Group 3 (control): "had no arm supports, and they were asked to maintain their usual work technique and to avoid all redesign measures at work during the intervention" |

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| Outcomes | Primary outcome:<br>Musculoskeletal strain: the participants recorded the severity of their musculoskeletal strain using a VAS, each VAS was reported in millimetres (range 0 to 100 mm with end points of no strain and extreme strain). The mean value of the VAS lines obtained from the 6 body regions (neck, shoulder, upper arm, forearm, wrist, and hand and fingers) were calculated for the right and left sides |
| Notes | - |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no information on sequence generation. The authors only mentioned that: "After the first measurements the participants were randomly assigned to three groups of 7 participants" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | There was no mention of blinding and it may not even be possible as the intervention included supply of new equipment |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcome measure was subjective symptoms for muscle strain |
| Incomplete outcome data (attrition bias)<br>All outcomes | Low risk | There was no loss to follow-up |
| Selective reporting (reporting bias) | Low risk | No statistically significant changes were observed in the musculoskeletal strain scores either between the groups or within the groups |
| Other bias | High risk | 1. No comparison of groups on baseline characteristics specific to the outcome measures<br>2. No comparison with non-participants |

**McLean 2001**

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|---|---|
| Methods | RCT. Participants were randomly assigned to 1 of 3 experimental groups |
| Participants | 15 participants were recruited by word of mouth from the accounting (n = 6) and library (n = 6) offices at the University of New Brunswick and from New Brunswick Provincial Government Offices (n = 3) in Fredericton, NB, Canada. All participants were recruited based on their performance of jobs that involved sustained sitting postures in conjunction with keying and data entry tasks. 15 participants participated in the study |
| Interventions | The study compared 3 different micro-break intervals<br>Upon obtaining informed consent, each participant's workstation was examined for major problems in terms of ergonomic setup and such problems were corrected at least 1 month prior to participation<br>Ergobreak version 2.2 was installed on each participant's computer at least 2 weeks prior to the data collection period. The programme was set to prompt users to take breaks based on fixed time intervals<br>Participants were randomly assigned to 1 of 3 experimental groups according to their set time interval between micro-breaks: all micro-breaks were of 30 seconds duration<br>Participants took part in the study over a 4-week period. For the first 2 weeks of participation (the 'No Break' protocol), subjects performed their usual work while minimising the amount of time spent away from their workstation. For the second 2-week period of participation each subject performed their assigned micro-break protocol with the assistance of the Ergobreak software. The programme was set to prompt participants to take breaks at their prescribed time intervals<br>1. Group 1: 40-minute interval group: all micro-breaks were of 30 seconds' duration with the assistance of the Ergobreak software<br>2. Group 2: 20-minute interval group: all were of 30 seconds duration with the assistance of the Ergobreak software<br>3. Group 3: control group (where participants took breaks whenever they felt they needed to): the Ergobreak software was not set to prompt members of the control group |
| Outcomes | Primary outcome:<br>Discomfort scores: "based on vertical visual analogue scales (VAS), The vertical scale was 100mm in length, and had no numerical anchors along its length with anchors at the top (Worst Possible Discomfort) and at the bottom (No Discomfort). VAS scores were measured by measuring the distance in millimetres between the 'No Discomfort' anchor and the location of the participant's mark on the line. Four scales were placed on the same page and labelled 'Neck', 'Low Back and Buttock', 'Shoulder and Upper Arm' and 'Forearm, Wrist and Hand'. For each body part, the difference in VAS scores (calculated as the VAS score at each measurement time during the No Breaks protocol minus the VAS score at that time during the Breaks protocol)"<br>Secondary outcome:<br>Productivity: the number of words typed (sets of 5 keystrokes) over the course of each 3-hour myoelectrical signal recording session. Word count data were collected at the end of each recording session only |
| Notes | - |
| ***Risk of bias*** | |

**McLean 2001** (*Continued*)

| Bias | Authors' judgement | Support for judgement |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no information on sequence generation. The only information available is… "Participants were randomly assigned to one of three experimental groups" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | Low risk | There was no mention of blinding but the implementation of the micro-breaks followed a strict protocol: "Ergobreak version 2.2 was installed on each participant's computer … the program was set to prompt users to take breaks based on fixed time intervals" |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The discomfort outcome was subjective; "the discomfort score data were collected at 40 min intervals throughout the recording session" |
| Incomplete outcome data (attrition bias)<br>All outcomes | Unclear risk | There was no information on the total participants analysed in each group. Limited information on drop-outs. No statistical information on dealing with loss to follow-up |
| Selective reporting (reporting bias) | Low risk | All findings were reported including non-significant findings. For example, "no significant change in the frequency of MNF [mean frequency] cycling was noted at the shoulder" |
| Other bias | High risk | There was no information on the comparability of the VAS score at baseline between the groups and there was no data on the success of randomisation and comparability between the participants. The differences between all participants were presented and they showed very large differences in age and years of experience. "All participants were female (although this was not a requirement for participation), between the ages of 23 and 50 (median age 34). The number of years of experience working at a computer terminal or word processor ranged from two to 18 years (me- |

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| | | dian 10 years)." This is hardly surprising as there were only 15 participants in total |

**Rempel 2006**

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| Methods | RCT. This was a 1 year, randomised intervention trial with 4 treatment arms |
| Participants | Employees at 2 customer service centre sites (sites A and B) of a large healthcare company were eligible for participation if they performed computer-based customer service work for more than 20 hours per week and did not have an active workers' compensation claim involving the neck, shoulders, or upper extremities. 182 workers participated in the study |
| Interventions | The study compared 4 intervention arms<br>All the 4 treatment arms included ergonomics training. The ergonomics training involved conventional recommendations, which included maintaining an erect posture while sitting, adjusting the chair height so that the thighs were approximately parallel to the floor, adjusting the arm support and work surface height so that the forearms were approximately parallel to the floor, adjusting the mouse and keyboard location to minimise reaching, adjusting the monitor height so that the centre of the monitor is approximately 15º degrees below the visual horizon and a reminder to take scheduled breaks<br>The computer workstations used at the sites had independently adjustable keyboard and monitor support surfaces and were typically equipped with a conventional keyboard, computer mouse, and a telephone headset. Use of wrist rests at this workplace was optional. Subjects who were assigned to use the forearm support board could not continue to use a wrist rest owing to the design of the forearm support. Subjects not receiving the forearm support were allowed to continue using a wrist rest if they desired. Chairs were adjustable in height with adjustable height arm rests<br>1. Trackball with forearm support board: "the trackball (16.5 cm depth, 8.6 cm width, 4.6 cm height, with a 4 cm diameter ball; Marble Mouse, Logitech, Fremont, CA, US) was installed next to the keyboard. The armboard was a wraparound, padded arm support that attaches to the top, front edge of the work surface (30.5 cm depth, 76.2 cm width, 2.5 cm height; MorencyRest, R&D Ergonomics, Freeport, ME, US)<br>2. Forearm support board only: the armboard was a wraparound, padded arm support that attached to the top, front edge of the work surface (30.5 cm depth, 76.2 cm width, 2.5 cm height; MorencyRest, R&D Ergonomics, Freeport, ME, US)<br>3. Trackball only: the trackball (16.5 cm depth, 8.6 cm width, 4.6 cm height, with a 4-cm diameter ball; Marble Mouse, Logitech, Fremont, CA, US) was installed next to the keyboard<br>4. No intervention |
| Outcomes | Primary outcome:<br>1. incidence of upper extremity and neck MSDs: if subjects recorded on the weekly survey a pain intensity level of > 5 or they used medications for ≥ 2 days for upper extremity or neck pain that was not associated with an acute traumatic event (e.g. laceration, fall), then a physical examination of the upper extremities or neck/shoulders was performed by 1 physician who was blinded to intervention status. "An incident disorder was defined as a disorder diagnosed on the physical examination only if the |

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| | participant did not report pain > 5 in that body region (neck/shoulder, right upper extremity, left upper extremity) on the weekly questionnaire before the intervention"<br>2. worst pain during the preceding 7 days for neck/shoulder, right elbow/forearm/wrist/hand, and left elbow/forearm/wrist/hand assessed using a 0- to 10-point scale (0 = no pain; 10 = unbearable pain)<br>3. acute injury events during the week - weekly survey<br>Secondary outcome:<br>1. "The effect of the intervention on employee productivity was also assessed using the employer tracked measures of productivity" |
| Notes | - |

***Risk of bias***

| Bias | Authors' judgement | Support for judgement |
|---|---|---|
| Random sequence generation (selection bias) | Low risk | Randomisation: "this was a one year, randomised intervention trial with four treatment arms"<br>Sequence generation: "the randomisation was done by means of a computer generated permuted-block sequence and administered by a research associate" |
| Allocation concealment (selection bias) | Unclear risk | No information provided |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | There was no blinding of participants or personnel. "This one year, randomised controlled intervention trial evaluated the effects of a wide forearm support surface and a trackball on upper body pain severity and incident musculoskeletal disorders among 182 call centre operators at a large healthcare company. Participants were randomised to receive (1) ergonomics training only, (2) training plus a trackball, (3) training plus a forearm support, or (4) training plus a trackball and forearm support" |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcomes included "worst pain during the preceding seven days". Those who reported "pain intensity level of more than 5, or they used medications for two days" were subjected to a physical "examination protocol focused on the body region of pain and was performed by one physician who was blinded to intervention status." Although the second part was blinded, it depended on the subjective reporting |

**Rempel 2006** (*Continued*)

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| Incomplete outcome data (attrition bias) All outcomes | Low risk | The analysis followed an ITT approach. The unavailability of 7 participants for a physical examination may have biased the findings. However, the hazard model for incident neck/shoulder disorders was repeated including these 7 participants as incident cases and the conclusions regarding the armboard were unchanged |
| Selective reporting (reporting bias) | Low risk | Reported on all findings |
| Other bias | Low risk | The baseline characteristics of the participants did not significantly differ by intervention group |

**von Thiele 2008**

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| Methods | Cluster RCT. Workplaces with a high (n = 3) and a low (n = 3) sickness absence were matched according to the number of employees. The matching resulted in 3 pairs that were randomly allocated to 1 of the 3 intervention groups |
| Participants | Participants consisted of female employees from 6 workplaces in a large public dental healthcare organisation in Stockholm, Sweden. In all, 197 women employed at the 6 workplaces were invited to take part in the study. Of the women invited, 195 volunteered to participate |
| Interventions | The study compared 3 intervention arms<br>1. Reduced work hours group: full-time weekly hours were reduced from 40 hours/week to 37.5 hours/week (reduced by 2.5 hours/week). For part-physical exercise and reduced work hours group, time for exercise/reduced work hours were set at 2 hours for those working 30 to 39 hours/week (39% of employee), 1.5 hours for 21 to 29 hours/week (14%), and 1 hour for < 20 hours/week (2%). Mandatory physical activity involved exercise of medium- to high-intensity corresponding to 55% to 89% of the person's maximum heart rate. The employees were free to choose any type of physical exercise<br>2. Physical-exercise group: full-time employees with whom 2.5 hours weekly work hours were allocated to mandatory physical exercise on 2 different days<br>3. Reference group: no intervention |
| Outcomes | Primary outcome:<br>1. musculoskeletal symptoms in the upper extremities: neck, shoulder, and hand-wrist were measured with the Standardized Nordic questionnaire. "For all items, the respondents were asked to indicate whether they had experienced symptoms or pain during the past 6 months." Sum scores were then computed. These ranged from 0 to 3, a high score indicating more symptoms<br>2. Workability was measured using a single item. The respondents were asked to rate their current work ability as compared with their work ability at its best on a 10-point scale ranging from 'completely lacking work ability' (1) to 'work ability at its best' (10) |

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| Notes | This report consists of 2 interventions (physical exercise and reduced work hours) and 1 control (reference group). For this review we only considered reduced work hours compared to reference group |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no information on sequence generation: "three workplaces with a high level of sickness absence and three with low levels, each employing at least 25 persons, were selected. Workplaces with a high and a low sickness absence were matched according to the number of employees. This matching resulted in three pairs that were randomly allocated to one of the following three groups" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | The was no blinding. This study examined the health-related effects of 2 work-site interventions, physical exercise and reduced work hours, on women employed in dentistry |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcomes were assessed as subjectively reported musculoskeletal symptoms |
| Incomplete outcome data (attrition bias)<br>All outcomes | High risk | There was no mention of ITT. The number volunteered (195 people) and analysed (177 people) was different. The distribution of participants in each group was uneven (physical exercise = 62 women, reduced work hours = 50 women, reference group = 65 employees/women). There was no description or comment on the unequal distribution. The total number of participants in each group who responded to the question on upper extremity disorder were different compared to the initial participants (exercise = 58 women, reduced hours = 43 women, reference = 59 women) |
| Selective reporting (reporting bias) | Low risk | All data were reported |

**von Thiele 2008** (*Continued*)

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| Other bias | Unclear risk | Differences between workplaces may have influenced the intervention |

**Yassi 2001**

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| Methods | Cluster RCT. 3 wards each from medical (n = 3), surgical (n = 3), and rehabilitation (n = 3) were selected based on similarity with respect to type of patient, size of ward, staffing, and previous injury rates. Each of the 3 wards within a service area was then randomly assigned to 1 arm of the study. Thus, each arm consisted of 1 surgical unit, 1 medical unit, and 1 rehabilitation unit |
| Participants | Nurses and unit assistants employed in medical, surgical, and rehabilitation wards at the Winnipeg's Health Science Centre, an acute and tertiary care hospital in Manitoba, Canada. This study is based on the 346 nurses and unit assistants employed on the 3 wards on July 1, 1998 |
| Interventions | The study compared 3 intervention arms<br>Recommended equipment and techniques for patient handling tasks used on the study arm<br>1. Arm C: (no strenuous lifting programme)<br>i) moving patient from floor to bed/chair - mechanical total body lift,<br>ii) moving patient from bed to chair/bed - sit-stand lift/mechanical total body lift,<br>iii) moving patient from bed to stretcher/stretcher to bed - slide devices,<br>iv) moving patient from bed - slide devices,<br>v) walking with patient - not addressed by equipment of training<br>2. Arm B: (safe lifting programme)<br>i) moving patient from floor to bed/chair - mechanical total body lift,<br>ii) moving patient from bed to chair/bed - transfer belt/mechanical total body lift,<br>iii) moving patient from bed to stretcher/stretcher to bed - slide devices,<br>iv) moving patient from bed - slide devices,<br>v) walking with patient - transfer belts<br>3. Arm A: (control)<br>Usual practice for all procedures<br>Training<br>Staff received training in body mechanics or lifting techniques only on request and received training only for equipment in regular use on those wards<br>Equipment provided:<br>1. 1 mechanical total body lift (in ward)<br>2. access to sliding devices (from a central equipment depot on request only)<br>Training<br>Completed before the start of the study. Received 3 hours of intensive problem-based hand-on education on back care, patient assessment, handling techniques, and practice of using equipment in wards<br>Equipment provided:<br>1. 1 mechanical total body lift available on the ward<br>2. Transfer belts were available in each room |

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| | 3. 2 large and 4 small sliding devices (in each ward)<br>Training<br>Completed before the start of the study. Received 3 hours of intensive problem-based hand-on education on back care, patient assessment, handling techniques, and practice of using equipment in wards<br>Equipment provided:<br>1. new mechanical total body lifts<br>2. new sit-stand lifts<br>3. a set of sliding devices in each room<br>The number of mechanical lifts allocated to each arm C ward was determined by an evaluation that considered the patient population on that ward and the types of lifts and transfers commonly used:<br>1. rehabilitation wards were provided with 3 sit-stand lifts and 2 total body lifts<br>2. medical wards received 2 sit-stand lifts and 2 total body lifts and<br>3. surgical wards received 1 of each |
| Outcomes | Primary outcome:<br>1. musculoskeletal symptoms: shoulder pain was measured with the question "As a result of work, in the past week how often have you experienced shoulder pain?" Responses were given on a 0-100 VAS, which was scored such that lowest safety/ comfort was 0 and highest was 100<br>2. musculoskeletal injuries: "All reported musculoskeletal injuries between July 1, 1998 and June 30, 1999 incurred during patient-handling task …. Only reports documenting an incident involving a patient lift or transfer were included in this analysis ... The number of reported musculoskeletal injuries, injury rate for all injuries, time loss injuries per 100,000 paid hours, total costs associated with injuries, and cost per time loss injury were calculated for the nine wards during the year of the study, during the previous year, and averaged over the 3 years before the study"<br>3. DASH questionnaire: the details of the measure were not available in the paper or in the article referred to by the authors (Hudak 1996)<br>Secondary outcomes:<br>1. cost of musculoskeletal injuries, total, and time lost injuries: "data from Workers Compensation Board files (includes wage replacement, medical, rehabilitation for injured workers) ... The number of reported musculoskeletal injuries, injury rate for all injuries, time loss injuries per 100,000 paid hours, total costs associated with injuries, and cost per time loss injury were calculated for the nine wards during the year of the study, during the previous year, and averaged over the 3 years before the study"<br>2. compliance: number of equipment used |
| Notes | The study assessed the effect of the intervention on the low back and shoulder regions. For this review we only considered the shoulder region |

***Risk of bias***

| **Bias** | **Authors' judgement** | **Support for judgement** |
|---|---|---|
| Random sequence generation (selection bias) | Unclear risk | There was no information on sequence generation. "Each of the three wards within a service area was then randomly assigned |

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|---|---|---|
| | | to one arm of the study. Thus, each arm consisted of one surgical unit, one medical unit, and one rehabilitation unit. The nine wards in this study are physically separate within the facility" |
| Allocation concealment (selection bias) | Unclear risk | There was no information on allocation concealment |
| Blinding of participants and personnel (performance bias)<br>All outcomes | High risk | Blinding was not possible as the intervention was based on training and equipment "…The nine wards in this study are physically separate within the facility … Arm A wards were designated as control, Arm B wards adopted a "safe lifting" program; "usual practice," as per HSC practice; Arm C wards adopted a "no strenuous lifting" program" |
| Blinding of outcome assessment (detection bias)<br>Musculoskeletal disorders | High risk | The outcomes assessed were subjective musculoskeletal symptoms and self-perceived frequency and intensity of physical discomfort. Injury data consisted of: "All reported musculoskeletal injuries between July 1, 1998 and June 30, 1999 incurred during patient-handling tasks were followed up. Only reports documenting an incident involving a patient lift or transfer were included in this analysis. Injured participants were interviewed to determine their ratings of self-perceived pain (VAS scale) and disability (Oswestry and DASH) " |
| Incomplete outcome data (attrition bias)<br>All outcomes | High risk | There was no information on ITT. The distribution of the 3 groups is different and the attrition from each measurement time was not discussed<br>Arm A: baseline n = 103, 6 months n = 95, 1 year n = 82<br>Arm B: baseline n = 116, 6 months n = 99, 1 year n = 85<br>Arm C: baseline n = 127, 6 months n = 109, 1 year n = 94 |
| Selective reporting (reporting bias) | Low risk | All results were reported including non-significant results. "Musculoskeletal injury rates were not significantly altered ... The fact that injury rates were not statistically |

| | | |
|---|---|---|
| | | significantly reduced may reflect the less sensitive nature of this indicator compared with the subjective indicators" |
| Other bias | High risk | The baseline demographic data was not reported, so the success of randomisation cannot be ascertained |

AET: active ergonomic training; DASH: Disability of the Arm, Shoulder and Hand; ITT: intention to treat; LED: light-emitting diode; PRECEDE: predisposing, reinforcing and enabling causes in educational diagnosis evaluation; RCT: randomised controlled trial; VAS: visual analogue scale; VDU: visual display unit; vs: versus; WIPP: work injury prevention programme.

## Characteristics of excluded studies *[ordered by study ID]*

| Study | Reason for exclusion |
|---|---|
| Aaras 1998 | The study was a parallel group design. There was no mention of randomisation in the method section. The intervention groups were allocated according to where they work: "Two groups, one from Technical division (T group) and one from Software delivery (S group) ..." |
| Cook 2004 | The aim of this study was to determine whether providing forearm support when using a normal computer workstation would decrease musculoskeletal discomfort in intensive computer users in a call centre and 75% of the participants reported discomfort in the 7 days preceding study commencement |
| Earl-Richardson 2006 | There is no separate outcome for neck and the upper limb |
| Faucett 2002 | 73% of participants reported symptoms of pain, stiffness, or numbness at baseline |
| Faucett 2007 | There is no separate outcome for neck and the upper-limb, only for musculoskeletal symptoms |
| Fostervold 2006 | > 25% of the participants had neck and shoulder symptoms at baseline. The prevalence of neck and shoulder symptoms at baseline was 73.5% in the intervention group and 75% in the comparison group |
| Haukka 2008 | > 25% of the participants had neck pain, shoulder pain, and forearm/hand pain at baseline. The prevalence of neck pain, shoulder pain, and forearm/hand pain at baseline ranged from 34% to 79% in the intervention and control groups |
| Ketola 2002 | The study included subjects with musculoskeletal symptoms: "One hundred and twenty-four subjects with musculoskeletal symptoms were selected" |
| Meijer 2009 | > 25% of the participants had upper extremity musculoskeletal symptoms at baseline. Prevalence for the control group was 49% and 36% for the intervention group |

(*Continued*)

| | |
|---|---|
| Mekhora 2000 | 1. The participants were randomised in the first part of study, then the 'control' group was given the same intervention. Data were not available for the first part of the study to compare between intervention and control group<br>2. The participants were selected based on "those with above average discomfort and who had discomfort around the neck and shoulder areas for more than 1 day in the previous year" |
| Melhorn 1996 | The report aimed to look at change in risk level for upper-extremity cumulative trauma disorders and did not report on musculoskeletal symptoms |
| Pillastrini 2007 | This is not an RCT. The allocation of intervention consists of "… randomly assigned 100 participants from the first building to group E (which received an ergonomic intervention plus an informative brochure) and randomly assigned 100 participants from the second building to group I (which received only the brochure) ." There was no information on the methods they used to select the buildings as intervention and control |
| Rempel 2007 | The participants only included those who reported neck/shoulder pain in the past month at baseline |
| Veiersted 2008 | > 25% of the participants had neck and shoulder discomfort or pain at baseline. The prevalence for neck pain or discomfort in the last 7 days was 28% (intervention group I) and 20% (Intervention group II). The prevalence for shoulder pain or discomfort, or both, in the last 7 days was 39% (intervention group I) and 30% (intervention group II) |

RCT: randomised controlled trial.

## Characteristics of ongoing studies *[ordered by study ID]*

**Driessen 2008**

| | |
|---|---|
| Trial name or title | Stay@Work |
| Methods | Cluster RCT |
| Participants | Participants are workers, both blue and white collar workers, recruited from the departments of 4 large Dutch companies with at least 3000 workers each. The companies included are a railway transportation company, an airline company, a university including its university medical hospital, and a steel company |
| Interventions | Intervention group: workers allocated to the intervention departments watch the same movies about the prevention of LBP and NP as the control group. In addition, they receive the Stay@Work PE programme. One of the main characteristics of PE is the formation of a 'working group' in which both workers and management participate as members. The 6 steps of the Stay@Work PE programme are followed during 2 meetings with the working group<br>• Step 1: inventory of the workplace<br>• Step 2: analysis of risk factors<br>• Step 3: finding of ergonomic measures<br>• Step 4: preparation of an implementation plan<br>• Step 5: implementation of ergonomic measures<br>• Step 6: evaluation and control of the ergonomic measures |

**Driessen 2008** (*Continued*)

| | |
|---|---|
| | Control group: workers allocated to the control departments are asked to watch 3 short (45 seconds) web-based educative movies about the prevention of LBP and NP at the campaign web site of 'Lighten the load, a European Campaign on Musculoskeletal Disorders' developed by the European Agency for Safety and Health at Work |
| Outcomes | Primary outcome:<br>1. an episode of NP: the presence of NP during a recall period of 3 months followed and preceded by a recall period of 3 months without NP. The transition from a symptom free period to a new episode of NP is modelled as the outcome<br>2. intensity of pain: the intensity of pain (i.e. pain at the moment of filling out the questionnaire, average pain, and most severe pain experienced in the past 3 months), and the pain duration (total days of pain experienced in the past 3 months) owing to NP is measured using von Korff scales<br>Secondary outcome:<br>1. sick leave and work productivity<br>2. actual use of ergonomic equipment |
| Starting date | Data collection started in November 2007 |
| Contact information | Maurice T Driessen* - m.driessen@vumc.nl<br>Johannes R Anema - h.anema@vumc.nl<br>Karin I Proper - ki.proper@vumc.nl<br>Paulien M Bongers - paulien.bongers@tno.nl<br>Allard J van der Beek - a.vanderbeek@vumc.nl |
| Notes | - |

LBP: low back pain; NP: neck pain; PE: participatory ergonomics; RCT: randomised controlled trial

## DATA AND ANALYSES

**Comparison 1. An arm support together with an alternative mouse versus a conventional mouse alone**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Incidence of neck/shoulder disorder | 2 | 186 | Risk Ratio (M-H, Random, 95% CI) | 0.52 [0.27, 0.99] |
| 2 Incidence of right upper limb disorder | 2 | 181 | Risk Ratio (M-H, Random, 95% CI) | 0.73 [0.32, 1.66] |
| 3 Incidence of upper body disorders (neck, shoulder, and upper limb) | 2 | 191 | Risk Ratio (M-H, Random, 95% CI) | 0.66 [0.42, 1.04] |
| 4 Neck/shoulder discomfort score | 2 | 194 | Std. Mean Difference (IV, Random, 95% CI) | -0.41 [-0.69, -0.12] |
| 5 Right upper extremity discomfort score | 2 | 194 | Std. Mean Difference (IV, Random, 95% CI) | -0.34 [-0.63, -0.06] |

**Comparison 2. An alternative mouse alone versus a conventional mouse alone**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Incidence of neck/shoulder disorder | 2 | 182 | Risk Ratio (M-H, Random, 95% CI) | 0.62 [0.19, 2.00] |
| 2 Incidence of right upper extremity disorder | 2 | 182 | Risk Ratio (M-H, Random, 95% CI) | 0.91 [0.48, 1.72] |
| 3 Incidence of upper body disorder (neck, shoulder, and upper extremity) | 2 | 190 | Risk Ratio (M-H, Random, 95% CI) | 0.79 [0.52, 1.21] |
| 4 Neck/shoulder discomfort score | 2 | 195 | Std. Mean Difference (IV, Random, 95% CI) | 0.04 [-0.26, 0.33] |
| 5 Right upper extremity discomfort score | 2 | 195 | Std. Mean Difference (IV, Random, 95% CI) | 0.00 [-0.28, 0.28] |

**Comparison 3. An arm support together with a conventional mouse versus a conventional mouse alone**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Incidence of neck/shoulder disorder | 2 | 186 | Risk Ratio (M-H, Fixed, 95% CI) | 0.67 [0.36, 1.24] |
| 2 Incidence of right upper extremity disorders | 2 | 178 | Odds Ratio (M-H, Random, 95% CI) | 1.09 [0.51, 2.29] |

| | | | | |
|---|---|---|---|---|
| 3 Incidence of upper body disorders | 2 | 191 | Risk Ratio (M-H, Random, 95% CI) | 0.87 [0.42, 1.80] |
| 4 Neck/shoulder discomfort score | 2 | 195 | Std. Mean Difference (IV, Random, 95% CI) | 0.02 [-0.26, 0.30] |
| 5 Right upper extremity discomfort score | 2 | 195 | Std. Mean Difference (IV, Random, 95% CI) | -0.07 [-0.35, 0.22] |

**Comparison 4. An alternative mouse with an arm support versus a conventional mouse with an arm support**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Incidence of neck/shoulder disorder | 2 | 182 | Risk Ratio (M-H, Random, 95% CI) | 0.76 [0.22, 2.63] |
| 2 Incidence of right upper limb disorder | 2 | 175 | Risk Ratio (M-H, Random, 95% CI) | 0.76 [0.37, 1.59] |
| 3 Incidence of upper body disorders (neck, shoulder, and upper limb) | 2 | 190 | Risk Ratio (M-H, Random, 95% CI) | 0.77 [0.36, 1.63] |
| 4 Neck/shoulder discomfort score | 2 | 193 | Std. Mean Difference (IV, Random, 95% CI) | -0.39 [-0.67, -0.10] |
| 5 Right upper extremity discomfort score | 2 | 193 | Std. Mean Difference (IV, Random, 95% CI) | -0.27 [-0.55, 0.02] |

**Comparison 5. Supplementary breaks versus normal breaks**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 After shifts discomfort rating for neck (4-8 weeks) | 2 | 186 | Mean Difference (IV, Fixed, 95% CI) | -0.25 [-0.53, 0.02] |
| 2 After shifts discomfort ratings for right shoulder/upper arm (4-8 weeks) | 2 | 186 | Mean Difference (IV, Random, 95% CI) | -0.24 [-0.51, 0.03] |
| 3 After shifts discomfort ratings for right forearm/wrist/hand (4-8 weeks) | 2 | 186 | Mean Difference (IV, Random, 95% CI) | -0.19 [-0.45, 0.08] |

**Comparison 6. Reduce work hours versus normal work hours**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Upper extremity disorder (6 months) | 1 | 102 | Mean Difference (IV, Fixed, 95% CI) | 0.08 [-0.32, 0.48] |
| 2 Upper extremity disorder (12 months) | 1 | 102 | Mean Difference (IV, Random, 95% CI) | 0.22 [-0.22, 0.66] |
| 3 Work ability (6 months) | 1 | 104 | Mean Difference (IV, Fixed, 95% CI) | 0.41 [-0.28, 1.10] |
| 4 Work ability (12 months) | 1 | 104 | Mean Difference (IV, Fixed, 95% CI) | 0.5 [-0.23, 1.23] |

**Comparison 7. Ergonomic training versus no intervention**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Neck/shoulder musculoskeletal symptoms by medical examination | 1 | 499 | Risk Ratio (M-H, Fixed, 95% CI) | 1.19 [0.66, 2.14] |
| 2 Hand/wrist symptoms by medical examination | 1 | 509 | Risk Ratio (M-H, Fixed, 95% CI) | 1.39 [0.41, 4.74] |
| 3 Intensity of upper extremity pain | 1 | 82 | Mean Difference (IV, Fixed, 95% CI) | 0.08 [-0.22, 0.38] |
| 4 Frequency of upper extremity pain | 1 | 82 | Mean Difference (IV, Fixed, 95% CI) | -0.03 [-0.45, 0.39] |
| 5 Duration of upper extremity pain | 1 | 82 | Mean Difference (IV, Fixed, 95% CI) | 0.13 [-0.25, 0.51] |

**Comparison 8. Work injury prevention programme versus no intervention**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Frequency of neck ache or pain | 1 | 13 | Mean Difference (IV, Fixed, 95% CI) | -1.2 [-2.77, 0.37] |
| 2 Frequency of shoulder ache or pain | 1 | 13 | Mean Difference (IV, Fixed, 95% CI) | -1.1 [-2.65, 0.45] |
| 3 Frequency of wrist/hand ache or pain | 1 | 13 | Mean Difference (IV, Fixed, 95% CI) | -1.0 [-2.52, 0.52] |
| 4 Intensity of neck ache or pain | 1 | 13 | Mean Difference (IV, Fixed, 95% CI) | -0.30 [-1.19, 0.59] |
| 5 Intensity of shoulder ache or pain | 1 | 13 | Mean Difference (IV, Fixed, 95% CI) | -0.20 [-0.91, 0.51] |
| 6 Intensity of wrist/hand ache or pain | 1 | 13 | Mean Difference (IV, Fixed, 95% CI) | -0.20 [-1.17, 0.77] |

**Comparison 9. Patient lifting/transfer intervention versus normal practice**

| Outcome or subgroup title | No. of studies | No. of participants | Statistical method | Effect size |
|---|---|---|---|---|
| 1 Shoulder pain (safe lifting versus usual practice) | 1 | 166 | Mean Difference (IV, Fixed, 95% CI) | 3.0 [-4.83, 10.83] |
| 2 Shoulder pain (no strenuous lifting versus usual practice) | 1 | 175 | Mean Difference (IV, Fixed, 95% CI) | 0.10 [-7.62, 7.82] |
| 3 DASH (no lifting versus usual practice) | 1 | 166 | Mean Difference (IV, Fixed, 95% CI) | 1.0 [-2.32, 4.32] |
| 4 DASH (no strenuous lifting) | 1 | 175 | Mean Difference (IV, Fixed, 95% CI) | -0.80 [-3.75, 2.15] |

# FEEDBACK

## Feedback from Traci Galinsky, 29 March 2013

### Summary

1. The review evaluated 15 reports out of 937 potentially relevant references and 30 potentially eligible references. Thus, the review evaluated only 1.6 % of the potentially relevant research reports, and only 50% of the potentially eligible reports. It raises the question of whether it is appropriate to apply your RCT review approach to this area of research, in which it is usually not possible to employ randomized controlled trials (RCTs).

2. Evaluating prevention effectiveness, especially in the case of many work-related musculoskeletal disorders, is not comparable to evaluating treatment effectiveness. In the latter case, researchers can typically measure reactions to treatment using objective, physiological tests over a relatively short period of time. Many work-related musculoskeletal disorders are associated with accumulation of musculoskeletal trauma over a long period of time in which the worker is chronically exposed to low-force, repetitive motions and awkward, constrained postures. Evaluating the effectiveness of interventions to prevent such disorders using an RCT approach would require long-term, prospective studies of large samples of workers, using control groups and clinical diagnostic outcome measures. Since that type of study is in most cases practically impossible to conduct, we have relied on briefer and smaller studies using discomfort ratings as indicators of strain or trauma accumulation (Galinsky 2000; Galinsky 2007).

3. In our publications, we did not describe our studies as RCTs. In the review, however, they were identified as meeting the Cochrane RCT inclusion criteria because our studies were randomized cross-over trials. No other similar studies were included because no other studies met the inclusion criteria.

4. This Cochrane review re-analyzed our studies' data and found that the discomfort ratings under the supplementary rest break schedule were not significantly lower than ratings under the conventional schedule. That finding is in contrast to the results of the more statistically powerful within groups multivariate analyses of variance we conducted, which revealed statistical significance for both the main effects of rest break schedule and the interactions between rest break schedule and rating time. In both publications, we discussed the meaningfulness of these small differences in a theoretical context.

5. We disagree with the statement in the review that the two cross-over RCTs (Galinsky 2000; Galinsky 2007), had the potential for carry-over effect because we did not report on the wash-out period between the two data collection periods. We found that mean discomfort ratings over the course of the four weeks of alternative work-schedules were very stable and inferred that carry-over effects were not of concern.

6. For updates of this review in the future, it would be helpful to describe one or more detailed examples of how high-quality RCTs examining the prevention of MSDs of the upper limb and neck could feasibly be conducted. Since in our experience such studies are generally not feasible.

I agree with the conflict of interest statement below:

I certify that I have no affiliations with or involvement in any organization or entity with a financial interest in the subject matter of my feedback.

### Reply

We would like to thank Traci Galinsky for her comments and interest in our review.

1. It is a common misunderstanding that the results of the search could be interpreted as all the available evidence. In fact, the results of the search are more dependent on the sensitivity of the search strategy, which we try to make as sensitive as possible to not miss any relevant research. What we actually wanted to find is the proportion of search results that in the end fulfil our inclusion criteria. The search strategy employed for this review was based on the approach recommended by the Cochrane Collaboration, which is to use a highly sensitive search to retrieve all potential studies. The search retrieved the 937 references from nine electronic databases and five websites. We then included studies that directly addressed our topic of interest and met our inclusion and exclusion criteria. We included studies regardless of their quality. We excluded most of the studies identified with the systematic search as they did not address the topic of interest or did not meet our inclusion and exclusion criteria. For example, some papers assessed a modality of treatment other than ergonomic design and training intervention, examined sites other than the neck or the upper limb, or reported on interventions for treatment, not prevention, of neck and upper limb musculoskeletal disorders. Thus, we reviewed all of the relevant literature after excluding studies that were not focussed on our topic of ergonomic design and training for preventing work-related musculoskeletal disorders of the upper limb and neck in adults.

The number of references retrieved with our search strategy was comparable to, and in some cases higher than, other systematic reviews addressing effectiveness of interventions on treatment or prevention of musculoskeletal disorders; e.g. Karjalainen et al's review on multidisciplinary biopsychosocial rehabilitation for neck and shoulder pain among working age adults (Karjalainen 2001). They retrieved 1808 references and only included two studies (0.11%) in the review. Tullar et al's search strategy for their review on occupational safety and health interventions to reduce musculoskeletal symptoms in the health care sector identified 8,465 articles, and included 16 studies (0.18%) in the review (Tullar 2010). Kennedy et al's 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 retrieved 15,279 articles and identified 36 relevant studies (0.24%) (Kennedy 2010).

Our review identified 13 studies of which eight were RCTs, three were cluster-randomised and two were of a randomised cross-over design. We believe that we have shown with the results of our review that randomised trials are feasible and also carried out in practice. Randomised trials can be conducted in the workplace setting to assess the effect of ergonomic intervention on neck and upper-limb musculoskeletal disorders but the RCT study design is less common in the workplace setting.

2. We agree that work-related musculoskeletal disorders can be associated with a single traumatic event or accumulation of trauma over a long period, and evaluating the effectiveness of interventions using an RCT approach to prevent such disorders could require long-term, prospective studies of a large samples of workers, control groups and assessment of clinical diagnostic outcomes. Our review did identify studies that had a follow-up period of between six and 12 months (Bohr 2000; Brisson 1999; Conlon 2008; Gerr 2005; Rempel 2006; von Thiele 2008; Yassi 2001), and two of those studies (Conlon 2008; Rempel 2006) included physical examination as an outcome measure. We don't consider pain or discomfort ratings as outcomes that are only proxy of some unmeasurable long-term outcome. In our view, these are the outcomes to be prevented.

3. We included the Galinsky 2000 and Galinsky 2007 studies in our review as they fulfilled the inclusion criteria of a randomised trial. A cross-over trial is considered a randomised trial if the participants are randomly allocated to the intervention and control groups for the first phase of the trial or, in other words, if the sequence of intervention and control is randomised. Since the Galinsky 2000 and Galinsky 2007 studies allocated the participants randomly to the intervention and control groups, we included them in our review.

4. We agree that the method of analysis used in our Cochrane review produced different results from those obtained by Galinsky 2000 and Galinsky 2007. We obtained a less sensitive result as we used the unpaired test. With a cross-over trial the mean difference between the intervention and the control is the same as in another type of trial but the test should be a paired t-test which is more sensitive than the unpaired test. Although, when requested, Traci Galinsky provided additional data, we did not request for the paired mean differences of discomfort scores of before and after shifts, or the means, SDs and paired t-test results for the differences between the two intervention periods. We plan to conduct the more sensitive analysis in the update given that these data are available.

5. We would like to apologise for not including the additional information provided by Traci Galinsky via email in our review. Although there were several efforts to minimise the carry-over effect in the Galinsky 2007 study, there was no wash-out period which is the normal practice for a cross-over study and this may have the potential of a carry-over effect. To address this in the updated review, we will include Galinsky et al's additional information of their methods employed to minimise the Hawthorne effect. However we still consider it possible that there may be a carry-over effect because essentially we don't know what is the most appropriate wash-out period and the effects of the first period could last longer and then influence the effects in the second period. This usually leads to an underestimation of the overall effect because for those participants for whom the control condition comes after the intervention the control rates will look more favourable.

6. We believe that it is possible to organise high quality RCTs in the field. We rated one of the RCTs that we included as having a low risk of bias, which means high quality. Also for prevention of other musculoskeletal disorders such as back pain there are numerous examples of high quality intervention and prevention studies with long-term follow-up and sufficient number of participants such as Daltroy 1997 and Lavender 2007.

## Contributors

Victor Hoe, Donna Urquhart, Helen Kelsall, Malcolm Sim

## WHAT'S NEW

Last assessed as up-to-date: 31 October 2010.

| Date | Event | Description |
|---|---|---|
| 19 June 2013 | Feedback has been incorporated | Feedback from Traci Galinsky, received on 29 March 2013, has been incorporated and the authors have provided a thorough response |
| 28 July 2010 | Amended | The order of the authors has been amended. |

## CONTRIBUTIONS OF AUTHORS

The principal author (VCWH) initiated and planned the review and administrated the review process.

All authors (VCWH, HLK, DMU, and MRS) were involved in writing the protocol. The principal author (VCWH) developed the search strategy in association with Lesley Gillespie of the Cochrane Bone, Joint and Muscle Trauma Group.

Two review authors (VCWH and MRS) participated in the decision-making process regarding the inclusion and exclusion of the studies. Two review authors (VCWH and DMU) conducted the data extraction, 'Risk of bias' assessment and quality assessment. One review author conducted the data synthesis (VCWH). All authors (VCWH, HLK, DMU, and MRS) were involved in writing the review.

## DECLARATIONS OF INTEREST

None known.

## SOURCES OF SUPPORT


### Internal sources

- University of Malaya, Kuala Lumpur, Malaysia.
- Department of Epidemiology & Preventive Medicine, Monash University, Melbourne, Australia.

### External sources

- Ministry of Higher Education's Academic Training Scheme, Malaysia.
- National Health and Medical Research Council's Public Health Postdoctoral Fellowship, Australia.
- National Health and Medical Research Council's Public Health Capacity Building Grant, Australia.

## DIFFERENCES BETWEEN PROTOCOL AND REVIEW

The Cochrane Occupational Health Field's register has been changed to Cochrane Occupational Safety and Health review group database. We excluded the Current Controlled Trials database as the ICTRN databases included all the databases in the Current Controlled Trial database. The grading of the quality of evidence by the Grade approach was included.

## INDEX TERMS

### Medical Subject Headings (MeSH)

*Neck; *Upper Extremity; Computer Peripherals; Equipment Design; Human Engineering [*methods]; Musculoskeletal Diseases [*prevention & control]; Occupational Diseases [*prevention & control]; Orthotic Devices; Patient Education as Topic [methods]; Randomized Controlled Trials as Topic; Rest

### MeSH check words

Adult; Humans