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Workplace interventions to prevent musculoskeletal and visual symptoms and disorders among computer users: A systematic review

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Abstract *Background*: The literature examining the effects of workstation, eyewear and behavioral interventions on musculoskeletal and visual symptoms among computer users is large and heterogeneous. *Methods*: A systematic review of the literature used a best evidence synthesis approach to address the general question "Do office interventions among computer users have an effect on musculoskeletal or visual health?" This was followed by an evaluation of specific interventions. *Results*: The initial search identified 7313 articles which were reduced to 31 studies based on content and quality. Overall, a *mixed level of evidence* was observed for the general question. *Moderate* evidence was observed for: (1) no effect of workstation adjustment, (2) no effect of rest breaks and exercise and (3) positive effect of alternative pointing devices.

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For all other interventions *mixed* or *insufficient* evidence of effect was observed. *Conclusion*: Few high quality studies were found that examined the effects of interventions in the office on musculoskeletal or visual health.

Keywords Office · Ergonomics · Interventions · Systematic review · Computers · Musculoskeletal · Visual

Introduction

The most common occupational health problems among computer users are visual and musculoskeletal symptoms and disorders [12]. Health problems include eye discomfort, sustained pain in the neck and upper extremities and regional disorders, such as wrist tendonitis, epicondylitis and trapezius muscle strain. The workplace risk factors include hours of computer use, sustained awkward head and arm postures, poor lighting conditions, poor visual correction, and work organizational factors [5, 8, 13, 16–18, 20, 21, 23]. The Institute of Medicine recently called for more intervention research to provide scientifically credible evidence to practitioners who are responsible for risk reduction among computer users [19].

The literature describing interventions intended to prevent or alleviate visual and musculoskeletal symptoms and disorders among computer users has grown in recent years. A broad literature search for participatory ergonomic interventions revealed a twofold increase in the number of articles from 1990 to 2004 [6]. However, the studies conducted to evaluate the effects of workstation, eyewear and behavioral interventions on upper body disorders and visual symptoms are of mixed quality [14]. The methodological heterogeneity challenges researchers attempting to synthesize the evidence. The systematic review process provides a structured approach for evaluating the literature and synthesizing evidence regarding prevention strategies [7, 9, 24]. Furthermore, systematic reviews provide an opportunity to critically reflect on research methods and identify fruitful directions for future research.

The purpose of the systematic review was to identify published studies that evaluated the effects of workplace interventions on visual or upper body musculoskeletal symptoms or disorders among computer users. Studies which met *a priori* design and quality criteria were evaluated in detail and results were extracted and synthesized. The review included both primary and secondary prevention studies. Based on the evidence synthesis, recommendations were made for primary and secondary prevention and for future intervention studies.

Materials and methods

Primary and secondary intervention studies were systematically reviewed using a consensus process developed by Cochrane [4] and Slavin [24] and adapted by the review team. A review team of 9 researchers from North America (paper co-authors) were identified and invited to participate. Each was identified based on his/her expertise in conducting epidemiologic or intervention studies related to musculoskeletal or visual disorders among computer users or his/her experience conducting systematic reviews. The expertise covered the fields of epidemiology, ergonomics, occupational medicine, safety engineering and optometry.

The basic steps of the systematic review were:

- Step 1 – Formulate research question and search terms
- Step 2 – Identify articles relevant to the research question expected to be found by the search

- Step 3 – International experts contacted to identify key articles
- Step 4 – Conduct literature search and pool articles with those submitted by experts
- Step 5 – Level 1 review: Select articles for inclusion based on relevance to the review question and quality using 11 screening criteria
- Step 6 – Level 2 review: Assess quality of relevant articles with scoring on 19 criteria
- Step 7 – Level 3 review: Extract data from relevant articles for summary tables
- Step 8 – Evidence synthesis

The rules or actions for each review step were achieved through a consensus process. For step 1, the review team reached consensus on the primary question "Do office interventions among computer users have an effect on musculoskeletal or visual health?". The review team also considered studies focused on the effects of specific intervention types (e.g., training, alternative keyboard, glasses, etc.). Three terms from the primary question, "Office", "Intervention" and "Health", were defined and used to develop literature search criteria.

"Office" was defined according to work setting and technology. The definition was limited to traditional office settings where computers (either desktop or laptop) were used to process information. Studies involving non-traditional office settings, such as airports, rent-an-office, home offices or traveling offices of sales people or in a setting where the work primarily involved manufacturing or material handling were excluded. Laboratory-based experimental studies were also excluded.

"Intervention" was broadly defined by using the traditional hazard control tiers of engineering controls, administrative controls and personal protective equipment.

"Health" was defined broadly to include musculoskeletal and visual symptoms as well as clinical musculoskeletal and visual disorders or diagnoses. Visual diagnoses included: binocular disorders, accommodative disorders and conditions related to dry eye if specific to computer uses in office environments. Visual diagnoses excluded were: cataracts, retina disorders (e.g., diabetic retinopathy) and infection (e.g., conjunctivitis and/or inflammation - uveitis). Studies which reported only health outcome data from OSHA 200/300 logs or workers' compensation records were excluded. While muscle loading research (e.g., electromyography) was recognized as defining a plausible pathway, field studies with only muscle loading as the outcome were excluded.

The review was limited to articles published or in press in the English language, peer-reviewed, scientific literature from 1980 forward. This year corresponds to the time when computers began to be used widely in office settings. Book chapters and conference proceedings were excluded. The primary reasons for the limitations were language proficiency of the team and time to complete the review steps.

Literature search

Based on the research question, literature search terms were identified and combined to search the following databases: Medline, Embase, CINAHL and Academic Source Premier. The search terms fell into three broad categories: intervention, work setting and health outcomes (Table 1). Overall the search categories were chosen to be inclusive. However, within the work settings category some terms were exclusive (e.g., non-office based). The specific disease terms: cataract, conjunctivitis, uveitis, diabetic retinopathy, neoplasms and the term muscle loading were used to exclude articles. The search strategy combined the three categories using the AND Boolean operator, while the terms within each category were combined with the Boolean OR operator.

Table 1 Search terms

Intervention terms	Intervention Studies, anthropometry, human engineering, ergonomic, human factor, forearm support, wrist rest, monitor, laptop computer, notebook computer, flat panel display, display, footrest, computer, workstation, training, exercise, VDT or VDU, progressive lens, bifocal, glasses, eyeglasses, spectacle, chair, equipment, lighting, keyboard, mouse, glare, computer terminals, "interior design and furnishings," "task performance analysis"
Work setting terms	Employ, hospitals, company, worker, office, knowledge worker, white collar worker, call center or call centre, telemarketing, computerized office, engineer, reporter, newspaper, office worker, student, editor, information technology, insurance, government, universities, classroom, computer terminals, computers, computer user, VDU operator, computer peripherals
Health outcome terms	Arm injuries, cumulative trauma disorders, tendonitis, tenosynovitis, neck injuries, synovitis, muscle weakness, forearm injuries, wrist injuries, hand injuries, osteoarthritis, "sprains and strains," soft tissue injuries, arthralgia, finger injuries, tendon injuries, bursitis, nerve compression syndromes, myofascial pain syndromes, neuralgia, causalgia, radiculopathy, polyradiculoneuritis, polyneuritis, muscular diseases, carpal tunnel syndrome, shoulder impingement syndrome, thoracic outlet syndrome, tennis elbow, epicondylitis, cervico-brachial neuralgia, ulnar nerve compression syndrome, musculoskeletal diseases, repetitive trauma, musculoskeletal system, musculoskeletal injuries, musculoskeletal symptom, visual symptom, eye strain, headache, RSI, accommodation, asthenopia, eyestrain, binocular disorder, convergence, ocular, ocular motility disorders, presbyopia, convergence insufficiency, accommodative insufficiency, dry eye syndrome, myopia, hyperopia, astigmatism, refractive errors, visual acuity, diplopia, anisometropia, orthoptics, "vision, binocular," eye protective devices, "adaptation, ocular," ocular, photophobia, eye movements, vision disorders, posture, neck pain, back pain, computer vision syndrome, upper extremity/AND pain, lower extremity/AND pain

Note. Search strategy: terms within one of the three categories are combined with OR and between categories with AND. Some terms were truncated.

A list of 28 relevant articles was identified by the review team prior to the literature search to test the sensitivity of the literature search procedure. A preliminary literature search missed 13 of the 28 articles due primarily to the absence of key words in the 'work setting' category (Table 1). The search was expanded to include the terms 'computer' and 'computer user.' The second search captured 25 of the 28 key articles identified by the team and was considered evidence of adequate search sensitivity.

International experts were identified and asked to submit relevant published articles or articles in press. The request also included articles accepted for review and from the grey literature (e.g., technical reports, book chapters, theses or dissertations, and conference presentations). The purpose for obtaining the grey literature was to review the bibliographies for relevant peer-reviewed articles. Twenty-eight articles identified by four outside experts were added to the articles reviewed after duplicate references were removed.

Level 1: Selection for relevance

The broad search strategy captured many non-relevant studies and the Level 1 review was designed to exclude them. The Level 1 review required reading of the article title and abstract and, if necessary, the full article. For efficiency, the Level 1 review was divided into two

Table 2 Level 1 – Screening questions and response that led to exclusion. An exclusionary response to any one question would exclude the article from further review

Level 1a	
1. Did an intervention occur?	No
2. Did intervention occur in office?	No
3. Was intervention related to computer work?	No
Level 1b	
4. A peer reviewed or in press publication?	No
5. From English language literature?	No
6. Control group used?	No
7. Individual health data?	No
8. Outcome musculoskeletal or visual symptoms/disorders?	No
9. Post only study?	Yes
10. OSHA log outcome data only?	Yes
11. Workers'compensation data only?	Yes

steps, Level la and Level Ib. Articles were screened for relevance at Level la using three criteria: 1) an intervention occurred, 2) the study took place in an office setting, and 3) the intervention was related to computer use. Articles not meeting Level la were excluded from further review. The Level 1b review was then used to screen for 8 article characteristics or qualities (Table 2). One research team member reviewed each article at Level la, while two members reviewed and reached consensus on each article at Level 1b. Articles not meeting Level 1b criteria were excluded from further review.

Since the Level la review was done by a single reviewer, biases could be introduced. Therefore, a quality control (QC) check of the Level la screen was done by an independent reviewer (QC reviewer) who had methodological and content expertise. Ten studies were randomly chosen from each of the eight reviewers and evaluated by the QC reviewer; five of the ten were among those that had been accepted by the reviewer and the remaining five had been excluded. The QC reviewer agreed with the reviewers' classifications of 70 of 80 articles. He identified four articles for inclusion that the review team excluded. Three of these articles [15, 25, 26] would have been excluded at Level la if the QC reviewer had been involved in group discussions regarding interpretation and application of the Level la screening criteria. The fourth article [22] was excluded at Level 1b. The reviewer also identified six articles for exclusion that the review team had included after Level la screening. Of these six articles, five were excluded by the review team at Level 1b. Overall, we considered the quality of the Level la review process acceptable.

Level 2: Quality assessment

Articles that passed the Level 1 review were scored for quality in the Level 2 review. The team developed a list of 19 methodological criteria (Table 3) to assess article quality. Each article was independently reviewed by two team members and rated as either meeting or not meeting each of these criteria. To reduce bias, review pairs were rotated randomly with at least two other team members. The reviewer pairs were required to reach consensus on quality criteria. Team members did not review articles they had consulted on, authored or co-authored.

Table 3 Level 2 – Quality assessment questions

1. Was the research question/objective clearly stated?
2. Was the primary hypothesis clearly stated?
3. Was the intervention allocation randomized?
4. Was the length of follow-up 1 month or greater?
5. Were concurrent comparison (control) group(s) used?
6. Were sample inclusion/exclusion criteria described?
7. Was participation rate reported and greater than 40% for employees/workers?
8. Were baseline characteristics of study participants presented?
9. Were baseline characteristics presented by group?
10. Was the loss to follow up reported?
11. Were differences between those employees/workers who remained in the study and those who dropped out analyzed?
12. Was the intervention implementation described?
13. Was there confirmation that the intervention took place?
14. Were the effects of the intervention on some exposure parameters documented?
15. Was the calendar duration of the intervention documented?
16. Was contamination between groups described or documented?
17. Were covariates/potential confounders for musculoskeletal or visual disorders ascertained (e.g., gender, age, eye wear, non-work activities)?
18. Was adjustment made for covariates/potential confounders?
19. Were statistical methods adequately described?

Reviewer pair disagreements were identified and reviewers discussed their differences to reach resolution. In cases where agreement could not be reached, a third reviewer was consulted to assist in obtaining consensus.

Summary quality scores for each article were based on a weighted sum score of the 19 criteria. The weighting values assigned to each of the 19 criteria ranged from “somewhat important” (1) to “very important” (3) based on an *a priori* group consensus process (see Table 4). The highest possible weighted score for an article was 43. Each article received a quality ranking by dividing the weighted score by 43 and multiplying by 100. For evidence synthesis articles were grouped into high (86% to 100%), medium (50% to 85%) and low (0% to 49%) quality categories. The categories were determined by team consensus with reference to review methodology literature [1, 4, 24].

Level 3: Data extraction

The data extracted from each study were used to build summary tables to enable evidence synthesis and the development of overall conclusions. Data extraction for each paper was performed independently by two reviewers and, again, reviewer pairs were rotated to reduce bias. Team members did not review articles they consulted on, authored or co-authored. Differences between reviewers were identified and resolved by consensus. Standardized data extraction forms were developed by the review team based on existing forms and data extraction procedures [9]. Reviewer pairs extracted data on: study design, intervention, musculoskeletal and visual outcome measures, statistical analyses and study findings (see Table 5). During data extraction, reviewers also re-evaluated the Level 2 methodological quality ratings. Changes made to the Level 2 quality ratings required approval by the entire review team.

Table 4 Methodological quality assessment ordered by quality ranking and author

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Quality ranking
Criteria weight	2	1	3	2	3	3	3	2	3	3	3	3	1	1	1	1	3	2	3	
High quality ranking																				
Amick, 2003	1	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	93.0%
Brisson, 1999	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	93.0%
Feuerstein, 2004	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	1	0	1	93.0%
Gerr, 2005	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	88.4%
Ketola, 2002	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	93.0%
Rempel, 1999	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	1	1	1	1	90.7%
Rempel, 2005	1	0	1	1	1	1	1	1	1	1	1	1	1	0	1	0	1	1	1	95.3%
Tittiranonda, 1999	1	0	1	1	1	1	0	1	1	1	0	1	1	1	1	1	1	1	1	86.0%
van den Heuvel, 2003	1	0	1	1	1	1	1	1	1	1	0	1	1	1	1	0	1	1	1	90.7%
Criteria Met	9	2	8	9	9	9	8	9	9	9	3	9	8	7	8	5	9	8	9	
Percent criteria met	90%	20%	80%	90%	90%	90%	80%	90%	90%	90%	30%	90%	80%	70%	80%	50%	90%	80%	90%	

Table 4 Continued

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Quality ranking
Criteria weight	2	1	3	2	3	3	3	2	3	3	3	3	1	1	1	1	3	2	3	
Medium quality ranking																				
Aaras, 2001	1	1	0	1	1	0	0	1	1	1	1	1	1	1	1	0	1	0	1	74.4%
Aaras, 1999	1	0	1	1	1	1	0	1	1	0	0	1	0	0	0	0	1	0	1	65.1%
Biswas, 2003	1	1	1	1	1	1	0	1	1	0	0	1	0	0	0	0	0	0	1	60.5%
Bohr, 2000	1	0	1	1	1	1	0	1	0	1	0	1	0	1	1	0	1	1	1	74.4%
Butzon, 1997	1	0	0	0	1	1	1	1	0	1	0	1	0	1	1	0	1	0	1	65.1%
Butzon, 2002	1	0	0	0	1	1	0	1	0	1	0	1	0	0	1	0	1	1	0	53.5%
Cook, 2004	1	0	1	1	1	1	1	1	0	1	0	1	1	1	1	0	1	0	0	72.1%
Fostervold, 2001	1	1	1	1	1	0	0	0	1	0	0	1	0	1	1	0	1	0	1	60.5%
Galinsky, 2000	1	0	1	0	1	0	0	1	0	1	0	1	1	0	1	1	0	0	1	53.5%
Greene, 2005	1	1	1	0	1	1	0	1	1	1	0	1	1	1	1	1	1	0	1	79.1%
Henning, 1997	1	0	1	1	1	0	0	1	0	1	0	1	1	0	1	0	0	0	1	55.8%
Hladky, 1998	1	1	0	1	1	0	0	1	1	1	0	1	0	0	1	0	1	1	1	67.4%
Horgen, 2004	1	0	0	1	1	1	0	0	0	1	1	1	0	0	1	0	1	1	1	67.4%
Kamwendo, 1991	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1	83.7%
Lintula, 2001	1	0	1	1	1	0	0	1	1	0	0	1	1	1	1	0	1	0	1	65.1%
Martin, 2003	1	1	1	1	1	1	0	1	1	1	0	1	1	1	1	0	1	0	1	81.4%
Mclean, 2001	1	1	1	0	1	1	0	1	1	0	0	1	0	1	1	0	1	0	1	67.4%
Mekhora, 2000	1	0	1	1	1	1	1	1	1	1	0	1	1	0	1	0	1	0	1	83.7%
Nelson, 1998	1	0	0	1	1	0	1	1	1	0	0	1	0	0	0	0	1	0	1	58.1%
Peper, 2004	1	0	1	1	1	0	0	1	1	1	0	1	1	1	1	0	1	0	1	72.1%
Psihogios, 2001	1	0	0	0	1	1	0	1	0	0	0	1	1	1	1	0	1	0	1	53.5%
Skilling, 2005	1	1	1	0	1	1	1	1	1	1	0	1	1	0	1	0	0	0	1	74.4%
Criteria Met	22	9	15	15	22	14	6	20	14	15	2	22	12	11	19	2	18	4	20	
Percent Criteria Met	100%	43%	71%	71%	100%	67%	29%	95%	67%	71%	10%	100%	57%	52%	90%	10%	86%	19%	95%	

Table 5 Data extraction questions

1. State the research question/objective.
2. State the primary hypothesis.
3. State additional hypotheses not listed in question #2.
4. Write the last name of the first author and the year of publication.
5. List the jurisdiction where the study was completed.
6. What industry/sector was the study conducted in?
7. Describe the job titles/classification of participants that participated in the study.
8. List the inclusion and exclusion criteria described in the study.
9. What is the study design?
10. What type of prevention did the study investigate?
11. What was the duration of the intervention in months/days/hours?
12. Indicate time period between baseline measurement and all subsequent follow up measurements.
13. Describe intervention group.
14. Describe the referent group.
15. Describe overall (study) group - Answer only if paper did not provide information to answer questions 13 and 14.
16. What was the intervention evaluated?
17. Describe the intervention.
18. Was there confirmation the intervention occurred?
19. How long after the intervention did the confirmation occur?
20. Select from the list all types of covariates/confounders that were evaluated for inclusion in the final analysis.
21. Provide a list of covariates/confounding variables that were controlled for in the final test of the intervention effectiveness.
22. Describe the significant differences in covariates/confounders for those that participated in the study vs. those that were invited but did not participate by experimental group.
23. Describe the significant differences in covariates/confounders for those that participated in the study vs. those that were lost to follow-up by experimental group.
24. Describe how the musculoskeletal health outcomes (symptoms) were measured.
25. Describe whether musculoskeletal symptoms were measured consistently at the same time of day over different measurement periods.
26. Describe whether musculoskeletal symptoms were measured consistently on the same day of the week over different measurement periods.
27. Describe how the visual health outcomes were measured.
28. Describe whether visual symptoms were measured consistently at the same time of day over different measurement periods.
29. Describe whether visual symptoms were measured consistently on the same day of the week over different measurement periods.
30. List all the non-musculoskeletal and non-visual outcomes and how they were measured.
31. Check all body regions where specific clinical disorders were ascertained by physical examination or laboratory test.
32. Was masking to physical assessment done?
33. Please check the type of analysis done for testing the observed effect of the intervention.
34. Describe for each outcome of interest the observed intervention effect.

Evidence synthesis

The evidence synthesis was based on a best evidence synthesis approach [7, 9, 24]. Studies reviewed were heterogeneous: they came from different countries; employed different kinds of interventions; used different study designs; focused on different health outcomes (visual or musculoskeletal); used different health measures; and, conducted substantially different kinds

Table 6 Best evidence synthesis guidelines

Level of evidence	Minimum quality	Minimum quantity	Consistency
Strong	High (>85%)	$\geq$ 3 studies	All high quality studies converge on the same findings
Moderate	Medium (50–85%)	$\geq$ 2 studies	Majority of medium quality studies converge on the same findings
Mixed	Medium (50–85%)	$\geq$ 2 studies	Medium and better quality studies have inconsistent findings
Partial	Low (0–49%)	$\geq$ 2 studies	Majority of low quality studies converge on the same findings
Insufficient	The above criteria are not met		

of statistical analyses. Such a high level of heterogeneity required a synthesis approach most commonly associated with Slavin and known as "best evidence synthesis" [24]. The team's approach was adapted from systematic reviews of workplace-based return to work interventions [9] and prevention incentives of insurance and regulatory mechanisms for occupational health and safety [27].

The best evidence synthesis approach considers article quality, quantity of evidence and the consistency of the findings among the articles (Table 6) to classify the evidence as strong, moderate, mixed, partial or insufficient [24]. The synthesis approach first answered the general question about all office ergonomic interventions and then, in a series of post-hoc evaluations, summarized the evidence for each specific intervention category (e.g., VDT glasses). Where specific data values were not reported, the team abstracted data from figures. When multiple findings were reported, the team indicated whether appropriate multiple comparisons were considered. Finally, both significant and non-significant trends were considered and reported. Initially, the plan was to calculate effect sizes for each article in order to apply a uniform method to evaluating the strength of associations. However, this plan was abandoned due to the heterogeneity of outcome measures and study methods and the failure of many articles to present the data necessary to calculate effect sizes. Synthesis conclusions were accepted by review team consensus. The review team classified a study with any positive results and no negative results as a positive effect study. That is, a study with both positive effects and no effects (i.e., no differences between groups) was classified as a positive effect study. A study with only no effects was classified as a no effect study.

Results

Literature search and selection for relevance

The literature search, using the terms in Table 1, identified 7313 articles after the results from the different databases were merged and duplicates were removed (Fig. 1). The Level la review resulted in exclusion of 6948 articles. The remaining 365 articles were then subjected to Level 1b review. The team excluded 332 articles leaving 33 to be reviewed for methodological quality at Level 2. Four of these articles: Gatty [51] and Martin et al. [50], as well as Aaras, 1999 and Aaras, 2002, were considered as just 2 articles because the pairs of articles reported findings from the same study. This left 31 articles for Level 2 review. The 31 studies were each reviewed by two reviewers using the quality assessment questions in Table 3. The team completed data

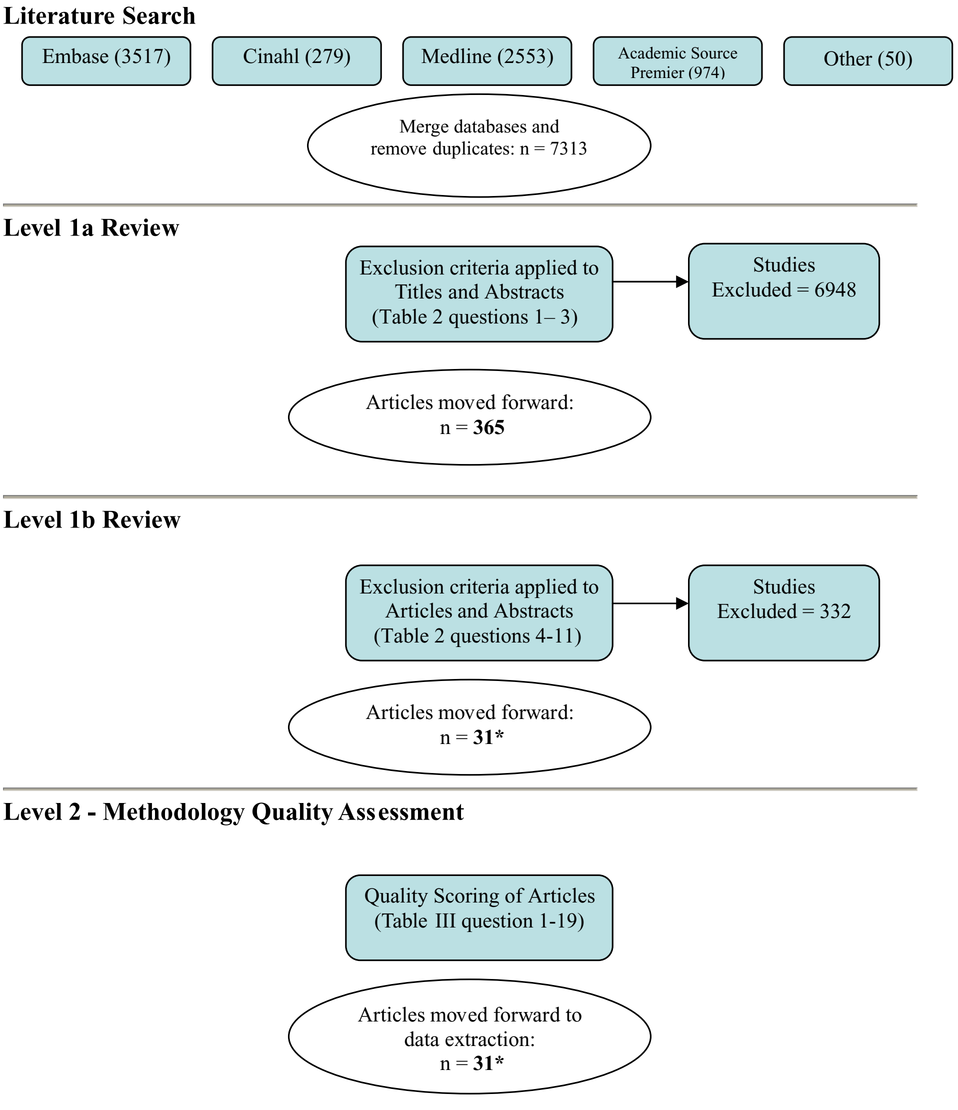

Fig. 1 Flowchart of systematic review process up to data extraction with tracking of number of articles associated with each step. While 33 articles were moved forward, two Aaras (1999 and 2002) articles were combined since the 2nd paper was determined to be supplemental to the primary paper. Martin, 2004 and Gatty, 2003 articles were combined since the papers reported results from the same study. Thus the 31 reflects studies not articles

extraction for all studies evaluated for quality to give a complete picture of the state of the literature.

Methodological quality assessment

The 31 studies that met the relevance criteria were assessed for methodological quality and assigned a quality ranking score. The studies were placed into three quality categories: high (86–100%), medium (50–85%) and low (0–49%).

Nine studies were classified as meeting criteria for high quality [32, 35, 39, 42, 48, 57, 58, 60, 61]. All but one were randomized trials [32]. Despite classification as high quality, most of these studies did not state a primary hypothesis (7 of 9), describe potential contamination between groups (4 of 9) or compare the differences between those who remained in the study and those who dropped out (6 of 9).

The remainder of the studies (22) were classified as medium quality. The most common differences between medium and high quality studies were related to random allocation (15 of 22), descriptions of inclusion/exclusion criteria (14 of 22), reporting a participation rate over 40% (6 of 22), reporting loss to follow up (15 of 22) and adjustment for the effect of covariates/confounders (4 of 22). The medium quality studies did not score as well as the high quality studies on the criteria: having a follow up longer than 1 month; describing baseline characteristics by experimental group; reporting loss to follow up; confirming the intervention took place; and describing the effect of the intervention on an exposure parameter (e.g. changes in posture). The medium quality studies generally scored well on the criteria: stating the research question, having concurrent comparison groups, presenting baseline characteristics, describing the intervention implementation, ascertaining covariates/confounders and describing statistical methods.

No studies were classified as low quality. Having no low quality studies was not surprising given that the Level 1b review included some quality criteria which resulted in the lower quality studies not progressing past Level 1.

Data extraction and evidence synthesis

Data were extracted for synthesis from the 31 studies rated for methodological quality. Data extraction results are presented by 15 consensus intervention categories. The 15 intervention categories and a detailed description of the interventions for each study are presented in Table 7 (additional data from the studies reviewed can be found in a detailed report of this review (http://www.iwh.on.ca/research/sr-wie.php)).

The most common interventions were training (9 of 31) and workstation adjustments (6 of 31). Studies that added new equipment such as arm supports, viewing screen filters, keyboards or pointing devices were not considered workstation adjustments. In many studies, participants receiving the intervention were compared to members of a control group who received either basic ergonomic training or a handout. For example, most of the workstation adjustment intervention groups also received an ergonomic training, while the control groups received just the ergonomic training. Fewer studies (two each) reported on the effectiveness of lenses/VDT glasses, arm supports, eye drops, keyboards, and screen filters. The remaining interventions were evaluated by single studies (see Table 7). Importantly, substantial heterogeneity was observed within the intervention categories for the specific equipment employed, training methods used, workstation adjustments made and intervention protocols.

Some of the study characteristics that were considered important when examining comparability and generalizability are shown in Table 8. The studies originated in various continents: Europe ($n = 9$), Asia ($n = 2$), Australia ($n = 1$), and North America ($n = 19$). A variety of industries and job titles were represented with no one industry or job title being dominant across the studies. However, most of the study participants' primary job duties involved data entry.

The study designs were predominantly randomized trials ($n = 23$); eight (of 9) high quality studies and 15 (of 22) medium quality studies were randomized trials. The sample sizes tended to be small but varied from 15 [52] to 577 [54]. The length of observation varied from 5 days [59] to 18 months [36]. The level of statistical analysis varied across studies; 12 studies (8 high quality and 4 medium quality) adjusted for one or more covariates in the final analysis.

Table 7 Description of interventions used in 31 studies for evidence synthesis, sorted by intervention

Intervention category	Author, year	Quality rating	Intervention description*	Study design	Prevention type
Exercise training	Kamwendo, 1999	Medium	I_1: traditional neck school (4 h): four trainings by a physiotherapist on active and stretching exercises and muscle relaxation. I_2: traditional neck school plus reinforcement (2 h): physiotherapist visited the workplace to discuss ergonomic changes and provide written instructions and a psychologist interviewed the user to develop a personal coping strategy. C: received no intervention.	Randomized trial	Both
Job stress mgmnt training	Feuerstein, 2004	High	I: received a worksite checklist evaluation by health professional, workstation adjustments (no new equipment), stretching exercises and access to the ErgoClinic website. In addition they received an interactive job stress management education during two 70 min meetings held 2 weeks apart followed by an email healthy computing tip every 2 weeks. C: received a worksite checklist evaluation by health professional, workstation adjustments (no new equipment), stretching exercises and access to the ErgoClinic website.	Randomized trial	Secondary
Ergonomics training	Brisson, 1999	High	I: received a training targeting 3 behaviors: adjusting the visual and postural components of the workstation and organizing work activities in preventive manner, in two 2 h sessions, two weeks apart, with workstation self-diagnosis between sessions. C: received the training at the end of the intervention.	Randomized trial	Both
Ergonomics training	Bohr, 2000	Medium	I_1: received a 2 h participatory training with problem solving. I_2: received a 1 h training consisting of lecture and handouts about office ergonomics. C: received no intervention.	Randomized trial	Secondary
Ergonomics training	Peper, 2004	Medium	I: received training of 6 weekly 2 h group sessions in ergonomic principles, psychophysiological awareness and control, sEMG practice at the workstation. C: received no intervention.	Randomized trial	Primary
Ergonomics training	Greene, 2005	Medium	I: received an active ergonomics training consisting of two, three hour training sessions in one week. IC: received the intervention after two weeks of follow-up. Both groups were followed for 1 year.	Randomized trial with delayed intervention	Secondary
Ergonomics training, new chair	Amick, 2003	High	I_1: received a highly adjustable chair and one time 90 m office ergonomics training workshop with 3 educational e-mail follow-ups I_2: received only the training workshop and e-mail follow-ups C: received the training session at the end of the intervention.	Non-randomized trial	Both

Table 7 Continued

Intervention category	Author, year	Quality rating	Intervention description*	Study design	Prevention type
Ergonomics training, workstation adjustment	Mekhora, 2000	Medium	I: received workstation adjustments based on anthropometry and software (IntelAd). IC: received the same after 12 weeks of follow-up and followed for an additional 13 weeks as a delayed intervention group.	Randomized Trial with Delayed Intervention	Secondary
Workstation adjustment	Ketola, 2002	High	I_1: received an ergo checklist and evaluated and adjusted their workstations with a physical therapist. New forearm and wrist rests were provided if needed. I_2: received the same ergo checklist and attended a 1 h group training session on ergonomics and rest breaks. C: received a leaflet on musculoskeletal health and VDT use.	Randomized Trial	Secondary
Workstation adjustment	Cook, 2004	Medium	I: received education about workstation set up and working posture and workstations were adjusted to support the forearm on the desk surface (no new equipment). Participants were monitored for the first few hours to ensure that they were not adopting postures of trunk flexion, shoulder elevation or increased wrist extension. C: received education about workstation set up and working posture and where required, adjustments to desk, chair and monitor height were made according to Australian Standards.	Randomized Trial	Primary
Workstation adjustment	Gerr, 2005	High	I_1: received training and workstation adjustments based on protective factors identified from prior studies. C received training and workstation adjustments based on OSHA, NIOSH and private industry standards. C: received no instruction, but received the same visits from the study staff.	Randomized Trial	Primary
Workstation adjustment (monitor position)	Psihogios, 2001	Medium	Participants were evenly dichotomized into two conditions based on normal (initial) gaze angle relative to horizontal (0° and −17.5°). I_1: the monitor was moved to shift gaze angle from −17.5° to 0° for two weeks. C_1: the monitor was maintained at a −17.5° gaze angle. I_2: the monitor was placed to shift gaze angle from 0° to −17.5° for two weeks. C_2: the monitor was maintained at a 0° gaze angle.	Quasi-Experimental within Subjects	Secondary
Arm support	Lintula, 2001	Medium	I_1: received one Ergorest arm support with a mouse pad for the hand that operated the mouse. I_2: received Ergorest arm supports for both hands and a mouse pad for the mousing hand. C: received no arm supports and was instructed not to change their workstations during the study period.	Randomized Trial	Primary

Pointing device, arm support	Rempel, 2005	High	I_1: received a trackball and ergonomics training. I_2: received forearm support board and ergonomics training. I_3: received forearm support board, trackball and ergonomics training C: received only the ergonomics training.	Randomized Trial	Both
Pointing device	Aaras, 1999 (Aaras, 2002)	Medium	I received the Anir (3M) mouse designed to reduce pronation. C: received the mouse 6 months later.	Randomized Trial	Secondary
Alternative keyboard	Tittiranonda, 1997	High	I_1: received Apple Adjustable Keyboard™ plus 1 h ergonomics training. I_2: received Comfort Keyboard System™ plus 1 h ergonomics training. I_3: received Microsoft Natural Keyboard™ plus 1 h ergonomics training. C: received conventional keyboard plus 1 h ergonomics training.	Randomized Trial	Secondary
Alternative keyboard	Rempel, 1999	High	I: received a keyboard with a keyswitch force-displacement profile having a greater travel distance until the key is "made" and greater "dampening" when the key reaches the bottom of its travel. C: received a conventional keyboard.	Randomized Trial	Secondary
Rest breaks, exercise	Henning, 1997	Medium	I_1: took 4 supplemental rest breaks every hour (three were 30s and one was 3 min) for 4 weeks. Indicator lights prompted the user to take the break. I_2: same as I_1 plus a trainer instructed participants on stretching exercises that were done during the short breaks. C: received no intervention.	Randomized Trial	Both
Rest breaks	Galinsky, 2000	Medium	IC: Workers alternated between an intervention and a control rest break schedule every 4 weeks. The control/conventional (C) schedule involved a break every 2 hours (15 min break in am and pm and 30 break for lunch). The intervention (I) schedule involved a break every hour (conventional schedule plus four 5 min breaks). Workers were prompted to take breaks by electrical timers.	Within Subject Repeated Measures with randomized order	Both
Rest breaks	McLean, 2001	Medium	I_1: received a workstation assessment and adjustments. Ergobreak software prompted users to take 30s break every 40 min. I_2: received a workstation assessment and adjustments. Ergobreak software prompted users to take 30s break every 20 min. C: received a workstation assessment and adjustments. Ergobreak software installed but provided no prompting; subjects told to take breaks whenever they wanted to.	Randomized Trial	Primary

Table 7 Continued

Intervention category	Author, year	Quality rating	Intervention description*	Study design	Prevention type
Rest breaks, exercise	van den Heuvel, 2003	High	I_1: Break reminder software. Software prompted user to take a 5 min break after 35 min of continuous computer usage and a 7 s break after 5 min of continuous computer usage. Also workstation adjustment and training. I_2: Break reminder software plus exercise. Same as 11 plus software prompted user to take exercises during the breaks. Also workstation adjustment and training. C: only received workstation adjustment and training.	Randomized Trial	Secondary
New office	Nelson, 1998	Medium	I: employees moved from old buildings to a new building with new lighting and equipment and received 1 h of ergonomics training. C: continued working in old buildings. Supervisors received ergonomics training.	Non-Randomized Trial	Both
Lighting, workstation adjustment, VDT glasses	Aaras, 2001 (Aaras, 1998)	Medium	I: Two groups (S&T) received a new lighting system and new table and chair which were adjusted to support forearms on the table, and single vision VDU glasses if necessary. C: received the lighting system after 3.5 years.	Non-Randomized Trial	Both
Ergonomics training & workstation adjustment	Martin, 2003 (Gatty, 2004)	Medium	I: received individualized training for 1 h per week for 4 weeks in body mechanics, workstations adjustments, task modification and stretches. C: received no intervention.	Randomized Trial	Primary

Lens types (Glasses)	Horgen, 2004	Medium	I_1: used Interview lens I_2: used Gradal RD lens I_3: used Technica lens C: used ordinary single vision lens (i.e., no progressives).	Randomized Trial	Primary
Lens types (Glasses)	Butzon, 1997	Medium	IC: used the AO Technica™ VDT glasses (IC_1) for three weeks then used the Datalite™ CRT trifocal (IC_2) for three weeks.	Non-Randomized Crossover	Secondary
VDT glasses	Butzon, 2002	Medium	I: was fitted with one of four types of task-specific glasses by an optometrist: AO Technica™, Access™, bifocal, and Datalite CRT trifocals and worked at their VDT for three weeks. After 3 weeks this group used the EAST intervention for 3 weeks. IC: was given an ergonomics self-assessment tool (ESAT) and their usual glasses for 3 weeks. The ESAT checklist determined likely environmental problems and suggested remedies. After 3 weeks this group used one of the 4, fitted, task-specific glasses for 3 weeks.	Crossover	Secondary
Screen filters	Hladky, 1998	Medium	I: received anti-glare screen filters, placed on the VDU. C: received no filters.	Non-Randomized Trial	Both
Screen filters	Fostervold, 2001	Medium	I: received a multi-coated, grounded, glass filter mounted on the VDU screen. IC: after 2.5 months received a micromesh filter mounted on the VDU screen.	Non-Randomized Trial with Delayed Intervention	Secondary
Herbal eye drops	Biswas, 2003	Medium	I_1: used herbal eye drops (two drops in both eyes four times daily for six weeks). I_2: used artificial tears (two drops in both eyes four times daily for six weeks). C: used a placebo solution (two drops in both eyes four times daily for six weeks).	Randomized Trial	Secondary
OtiZen eye drops	Skilling, 2005	Medium	I: used OptiZen™ eye drops twice a day for 5 days. C: used Visine® Original eye drops twice a day for 5 days.	Randomized Trial	Secondary

I = group(s) receiving intervention; C = control or concurrent comparison group; IC = group that is part of a crossover design where it is a control and an intervention group.

Table 8 Characteristics of 31 studies

Intervention category	Author, Year	Country	Industry/Sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Exercise training	Kamwendo, 1991	Sweden	Health Care and Social Assistance	Medical Secretaries	Randomized trial	I_1 $n=25$, I_2 $n=28$; C $n=26$	3.8% for study	7 months
Stress Mgmnt training	Feuerstein, 2004	USA	Professional, Scientific or Technical Services	Economists, computer specialists	Randomized trial	I $n=46$, C $n=47$	I_1 $n=12$, C_1 $n=11$	12 months
Ergonomics training	Brisson, 1999	Canada	Education	Clerical, administration, teaching	Randomized trial	I $n=284$, C $n=343$	19%	6 months
Ergonomics training	Bohr, 2000	USA	Centralized reservation center	Call center employees	Randomized trial	I_1 $n=50$, I_2 $n=51$, CC $n=53$	I_1 $n=24\%$, I_2 $n=23\%$, C_1 $n=11\%$	12 months
Ergonomics training	Peper, 2004	Not Provided	Education Services	Not provided	Randomized trial	I $n=16$, C $n=12$	Not provided	6 weeks
Ergonomics training	Greene, 2005	USA	Education Services	Library, Cont. Ed., Computer Networking, Family/ consumer Science	Randomized trial with delayed intervention	I $n=43$, IC $=44$	Not provided	2 weeks
Ergonomics training, new chair	Amick, 2003	USA	State dept of revenue services	sedentary computer-intensive jobs	Non-randomized trial	I_1 $n=87$, I_2 $n=52$, C $n=53$	12% (192–168)	12 months

Table 8 Continued

Training, workstation adjustment	Mekhora, 2000	Thailand	Office Based Companies	Word Processors and Data Entry	Randomized trial with delayed intervention	I $n = $ np, IC $n = $ np, Study Total $n = 85$	Study total $n = 5$	23 weeks
Workstation adjustment	Ketola, 2002	Finland	Public Administration	Secretaries, technicians, architects, engineers, drafts persons	Randomized trial	I_1 $n = 39$, I_2 $n = 35$, CC $n = 35$	I_1 $n = 5\%$, I_2 $n = 6\%$, C_1 14%	10 months
Workstation adjustment	Cook, 2004	Australia	Newspaper Call Center	Call center staff	Randomized trial	I $n = 30$, C $n = 29$	I_1 $n = $ ll	12 weeks
Workstation adjustment	Gerr, 2005	USA	Insurance, Education, Financial	Not provided	Randomized trial	I_1 $n = 121$(ah) & 126(ns), I_2 $n = 130$(ah) & 122(ns), CC $n = 119$(ah) & 113(ns)	I_1 $n = 83$(ah) & 90(ns), I_2 $n = 89$(ah) & 85(ns), C_1 $n = 87$(ah) & 84(ns)	6 months
Monitor position	Psihogios, 2001	USA	Professional, Scientific or Technical Services	Software developers, QA analysts, Managers, Technical support	Quasi-experimental within subjects	I_1 $n = 8$, I_2 $n = 8$, C_1 $n = 2$, C_2 $n = 2$	Not provided	4 weeks
Arm supports	Lintula, 2001	Finland	Not provided	Office employees & researchers	Randomized trial	I_1 $n = 7$, I_2 $n = 7$, C $n = 7$	Not Provided	6 weeks

Table 8 Continued

Intervention category	Author, Year	Country	Industry/Sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
Pointing device (trackball), arm support	Rempel, 2005	USA	Health Care and Social Assistance	Customer Service Workers	Randomized trial	I_1 $n=45$, I_2 $n=46$, I_3 $n=45$, CC $n=46$	I_1 $n=4$, I_2 $n=1$, $I_3=4$, $C_1=1$	12 months
Pointing device, (mouse)	Aaras, 1999 (and Aaras 2002)	Norway	Not provided	Software engineering, bookkeeping, secretarial work	Randomized trial	I $n=32$, C $n=$ 35	Not provided	12 months
Keyboard	Tittiranonda, 1999	USA	Professional, Scientific or Technical Services	Laboratory Workers	Randomized trial	I_1 $n=20$, I_2 $n=20$, I_3 $n=20$, CC $n=20$	I_1 $n=1$, I_2 $n=9$, I_3 $n=1$, C_1 n = 0	24 weeks
Alternative keyboard	Rempel, 1999	USA	Professional, Scientific or Technical Services	Administrative asst and Technical writers	Randomized trial	II $n=10$, CC $n=10$	I_1 $n=2$, C_1 $n=2$	12 weeks
Rest breaks	Henning, 1997	USA	Insurance	Claims processors	Randomized trial	Study Total = 73	Not provided	4 weeks
Rest breaks	Galinsky, 2000	USA	IRS	Seasonal Data Entry Operators	Within subjects repeated measures	IC $n=101$	58%	16 weeks (only first 8 weeks used in analysis)
Rest breaks/software	Mclean, 2001	Canada	Education Services	Not provided	Randomized trial	I_1 $n=$ np, I_2 $n=$ np, C $n=$ np and Study Total $n=15$	Not provided	2 weeks
Rest breaks/software	van den Heuvel, 2003	Netherlands	Public Administration	Not provided	Randomized trial	I_1 $n=97$, I_2 $n=81$, CC $n=90$	I_1 $n=18$, I_2 $n=15$, C_1 $n=16$	3 months

Table 8 Continued

Intervention category	Author, Year	Country	Industry/Sector	Job titles	Study design	Sample size	Loss to follow-up	Length of observation
New office	Nelson, 1998	USA	Public Administration	Clerical, Administrative	Non-randomized trial	II target $n = 1616$, matched $n = 577$, CC target $n = 187$, matched $n = 55$	I_1 $n = 42.2\%$	12 months
Lighting, workstation adjustment, VDT glasses	Aaras 1998 (and Aaras, 2001)	Norway	Professional, Scientific or Technical Services	VDU Operators	Non-randomized trial	II $n = 50$, CC $n = 50$	I_1 $n = 7$; C_1 $n = 6$	1 8 months
Ergonomics training, workstation adjustment	Martin, 2003 (and Gatty, 2004)	USA	Education Services	Clerical/Office Workers	Randomized trial	II $= 7$; CC $= 8$	$I_1 = 0$, $C_1 = 1$	5 weeks
Lenses, VDT glasses	Horgen, 2004	Norway	Telecom	Not provided	Randomized trial	I_1 $n = 35$, I_2 $n = 34$, I_3 $n = 36$, C $n = 34$	I_2 $n = 1$, I_3 $n = 2$, not classified $n = 6$	12 months

Table 8 Continued

VDT glasses	Butzon, 1997	USA	Professional, Scientific or Technical Services	Research and development personnel,	Non-randomized crossover	IC $n = 24$	Not provided	1 8 months
VDT glasses	Butzon, 2002	USA	Employee benefits administration	Administrative assistant, claims processor, secretary and safety personnel	Cross-over	I $n = 12$, IC $n = 14$	13%	6 weeks
Screen filters	Hladky, 1998	Czech Republic	Professional, Scientific or Technical Services	Data Entry, Information Retrieval	Non-randomized trial	I $n = 40$, C $n = 20$	0%	1 month
Screen filters	Fostervold, 2001	Norway	Insurance	Office Clerks	Non-randomized trial with delayed intervention	I $n = 30$, IC $n = 44$	Not provided	5 months
Herbal eye drops	Biswas, 2003	India	Not provided	Not provided	Randomized trial	$I_1 = 44$, $I_2 = 37$, C = 39	Not provided	6 weeks
OptiZen eye drops	Skilling, 2005	USA	Not provided	Not provided	Randomized trial	II $n = 25$, CC $n = 25$	I_1 $n = 4\%$, C_1 $n = 4\%$	5 days

Note: np = not provided.

A summary of the intervention effects are presented in Table 9. The Brisson et al. [35], Mekhora et al. [53], and Horgren et al. [46] studies were removed from consideration from evidence synthesis because they did not analyze between-group differences (just within-group differences). The review team did not find a negative or adverse effect for any intervention. The evidence is summarized by intervention category.

Exercise training

One medium quality study evaluated exercise training administered by a neck school approach [47]. No effect on musculoskeletal outcomes was found. There was *insufficient* evidence to determine whether exercise training has an effect on musculoskeletal outcomes since there was only one study.

Stress management training

One medium quality study found no effect on musculoskeletal outcomes for a stress management training intervention [39]. There was *insufficient* evidence to determine whether stress management training has an effect on musculoskeletal outcomes since there was only one study.

Ergonomics training

Four studies examined ergonomics training: one of high quality [32] and three of medium quality [34, 43, 55]. The high quality and one medium quality study [43] found no effect, while the two medium quality studies [34, 55] found both positive and no effects. The four studies implemented different types of trainings ranging from a one hour lecture on ergonomics to multiple participatory training sessions totaling four hours. The studies assessed different musculoskeletal endpoints. The four studies provided *mixed* evidence of the effect of ergonomics training on musculoskeletal outcomes. One medium quality study [55] examined visual outcomes. There was *insufficient* evidence with this single study to determine whether ergonomics training has an effect on visual outcomes.

Ergonomics training and workstation adjustment

One medium quality study examined training plus workstation adjustments and found a positive effect on musculoskeletal outcomes [50]. There was *insufficient* evidence to conclude that training and workstations adjustments together have an effect on musculoskeletal outcomes with only one study.

New chair

One high quality study [32] found a positive effect on musculoskeletal outcomes with the implementation of a highly adjustable new chair with ergonomics and chair training. There was *insufficient* evidence to conclude that a new chair with training has an effect on musculoskeletal outcomes with only one study.

Workstation adjustments

Two high quality [42, 48] and two medium quality studies [38, 56] examined the effects of a variety of workstation adjustments. The control groups received ergonomics training or no

Table 9 Intervention effects: 31 studies grouped by intervention categories

Intervention category	Author, Year	QA	Effect (positive, no, negative) on: musculoskeletal health outcomes	Effect (positive, no, negative) on: visual health outcomes
Exercise training	Kamwendo, 1991	M	*no* effect (I_1, I_2 vs C)on neck, shoulder and low back pain, neck or shoulder fatigue or headache	
Stress Mgmnt training	Feuerstein, 2004	H	*no* effect (I vs C) on level of pain and upper extremity symptom severity	
Ergonomics training	Bohr, 2000	M	*positive* (I_1 vs C) on upper body pain/discomfort and total body pain/discomfort no effect on lower body pain/discomfort	
Ergonomics training	Peper, 2004	M	*positive* (I vs C) on head, neck/shoulder, arms, wrists/hands symptoms, and overall tiredness no effect (I vs C) on back or leg symptoms	*no* effect (I vs C) on eye symptoms
Ergonomics training	Greene, 2005	M	*no* effect (I vs IC) on symptoms of upper back or upper extremities	
Ergonomics training, new chair	Amick, 2003	H	Training: *no effect* (I_2 vs C) on total body symptoms and symptom growth New Chair: *positive* (I_1 vs C) on total body symptoms and symptom growth	
Ergonomics training & workstation adjustment	Martin, 2003 (and Gatty, 2004)	M	*positive* (I vs C at 16 weeks) on elbow/forearm symptoms	*positive* (I vs C at 16 weeks) on headache intensity
Workstation adjustment	Ketola, 2002	H	*no* effect (I_1, I_2 vs C) on head, neck, area between neck and shoulders, shoulders, forearms, wrists, fingers, upper back, low back discomfort or overall musculoskeletal strain or pain	*no* effect (I_1, I_2 vs C) on eye discomfort

Intervention category	Author, Year	QA	Effect (positive, no, negative) on: musculoskeletal health outcomes	Effect (positive, no, negative) on: visual health outcomes
Workstation adjustment	Cook, 2004	M	*no* effect (I vs C) on neck, shoulder, forearm, wrist, back and "any" body regions	
Workstation adjustment	Gerr, 2005	H	*no* effect (I_1, I_2 vs C) for neck/shoulder and arm/hand case	
Workstation adjustment (Monitor position)	Psihogios, 2001	M	*no* effect (I vs C) on body part discomfort	*no* effect (I vs C) on visual discomfort or headache
Arm supports	Lintula, 2001	M	*no* effect (I_1 vs I_2 and I_1, I_2 vs C) on the neck/shoulder/arm region	
Arm supports, Pointing device (track ball)	Rempel, 2005	H	Arm support: *positive* (arm supports vs no arm supports) on neck/shoulder pain and disorders and right upper extremity pain. No effect on left upper extremity pain. No effect (arm supports vs no arm supports) on days of pain medication use Pointing device: *positive* on left upper extremity pain and disorders. No effect (trackball vs mouse) on neck/shoulder pain and disorders or right upper extremity pain. No effect (trackball vs mouse) on days of pain medication use	
Pointing device (mouse)	Aaras, 1999, (and Aaras, 2002)	M	*positive* (I vs C) on neck, shoulder, forearm, and wrist/hand pain no effect (I vs C) on headache or musculoskeletal sick leave	
Alternative keyboard	Tittiranonda, 1999	H	*positive* (I_3 vs C) on arm/hand symptoms and change in overall pain severity no effect (I_1, I_2 vs C) on arm/hand symptoms and change in overall pain severity	

Table 9 Continuted

Intervention category	Author, Year	QA	Effect (positive, no, negative) on: musculoskeletal health outcomes	Effect (positive, no, negative) on: visual health outcomes
Alternative keyboard	Rempel, 1999	H	*positive* (I vs C at 12 weeks) on hand pain reduction and on reducing Phalen's test time	
			no effect (I vs C at 12 weeks) on nerve conduction	
Rest breaks	Galinsky, 2000	M	*positive* (I vs IC) on symptoms in neck, back, R shoulder/upper arm, R elbow, R forearm hand, L shoulder/upper arm, L elbow, buttocks	*positive* (I vs IC) on eye soreness
			no effect (I vs IC) on left forearm hand symptoms	no effect (I vs IC) on visual blurring
Rest breaks	Mclean, 2001	M	*positive* (I_2 vs C) on forearm/wrist and back discomfort	
			no effect (I_1 vs C) on neck or shoulder discomfort	
			no effect (I_1 vs C) on neck, shoulder, forearm/wrist, and back discomfort	
Rest breaks, exercise	Henning, 1997	M	*no* effect (I_1, I_2 vs C) on neck/shoulder, arm/hand, back, legs/feet discomfort	
Rest breaks, exercise	van den Heuvel, 2003	H	*no* (I_1, I_2 vs C) on symptom frequency/severity	
New office	Nelson, 1998	M	*no* effect (I vs C) on hand/arm symptoms, leg symptoms or neck/shoulder symptoms	
Lighting, workstation adjustment, VDT glasses	Aaras, 2001 (and Aaras, 1998)	M	*positive* (I vs C) on shoulder pain (freq)	*positive* (I vs C) on visual discomfort (over last month and over last 6 months)
			no effect (I vs C) on neck, forearm/hand, or back pain	no effect (I vs C) on headache, stinging/itching/irritation, sensitivity to light, redness, gravelly sensation, or blurred/double vision

Lens types (glasses)	Butzon, 1997	M	*no* effect (IC_1 vs IC_2) on frequency or intensity of neck/shoulder symptoms or back pain	*positive* (IC_1 vs IC_2) on frequency and severity of blurred distance vision no effect (IC_1 vs IC_2) on frequency or intensity of eyestrain, blurred intermediate vision, loss of focus, blurred near vision, dry eyes, double vision, or headache
VDT glasses	Butzon, 2002	M	*positive* (I vs IC) on total symptom score (included musculoskeletal and visual outcomes)	*positive* (I vs 1C) on total symptom score (included musculoskeletal and visual outcomes)
Screen filters	Hladky, 1998	M	*positive* (I vs C) on total body symptoms no effect (I vs C) on analgesic use	*positive* (I vs C) on total eye symptoms
Screen filters	Fostervold, 2001	M	*no* effect (I vs IC) on upper back/shoulders symptoms or fatigue	*no* effect (I vs 1C) on ocular symptoms
Herbal eye drops	Biswas, 2003	M		*positive* (I_1 vs I_2 and C) on foreign body sensation and eyeache no effect (I_1 vs I_2 and C) on irritation, watering, redness, headache or tests/signs of examination
OptiZen eye drops	Skilling et al., 2005	M		*no* effect (I vs C) on visual/ocular discomfort

Note. The direction of the findings used in evidence synthesis is italicized. The review team considered a study with both positive results and no effects as a positive study for evidence synthesis.

intervention. None of the studies found an effect of workstation adjustments on musculoskeletal or visual outcomes. The studies provide *moderate* evidence for no effect of workstation adjustments on musculoskeletal outcomes. Two medium quality studies [48, 56] examined visual outcomes and found no effect on visual/eye discomfort. There was *moderate* evidence that workstation adjustments have no effect on visual outcomes.

Lighting, workstation adjustment and VDT glasses

One medium quality study evaluated the effects of new lighting, workstation adjustment and VDT glasses [30] and found both positive and no effects. There was *insufficient* evidence to conclude that lighting, workstation adjustment and VDT glasses have an effect on musculoskeletal or visual outcomes with only one study.

Arm supports

There were two studies on arm supports: the one of high quality [58] found positive effects and the one of medium quality [49] found no effects on musculoskeletal outcomes. These studies provide *mixed* evidence that arm supports have an effect on musculoskeletal outcomes.

Alternative pointing devices

Two studies examined the effect of alternative pointing devices on musculoskeletal outcomes in comparison to a conventional mouse. The one high quality study [58] found both positive effects and no effects for a trackball compared to a conventional mouse. The one medium quality study [28] found positive effects on musculoskeletal outcomes for an alternative mouse compared to a conventional mouse. These studies provide *moderate* evidence that pointing devices have an effect on musculoskeletal outcomes.

Alternative keyboards

Two high quality studies examined the effect of alternative keyboards on musculoskeletal outcomes [57, 60]. Tittiranonda et al. [60] found positive effects for one of three alternative geometry keyboards when compared to a conventional keyboard. Rempel et al. [57] found positive effects for a keyboard with a modified keyswitch force displacement profile. Although positive effects were found in both studies, the Tittiranonda study found no effects for two keyboards in independent comparisons with a placebo keyboard. Therefore we have a situation where two alternative keyboards in two different studies were shown to have positive effects and two keyboards from a single study were shown to have no effect. As a result the team felt these results represented a mixed level of evidence that alternative keyboards have an effect on musculoskeletal outcomes.

Rest breaks

Four studies, one of high quality [61] and three of medium quality [41, 44, 52], evaluated rest breaks. The high quality and one medium quality study [44] found no effect on musculoskeletal outcomes. The two other medium quality studies [41, 52] found both positive and no effects depending on the time between rest breaks and musculoskeletal outcomes. There was *mixed* evidence about the effect of breaks on musculoskeletal outcomes. Evidence was *insufficient* to conclude that rest breaks have an effect on visual outcomes with only one study examining this association [41] and finding both positive and no effects.

Rest breaks and exercise

Two studies, one of high quality and one of medium quality, examined the effects of rest breaks with stretching exercises [44, 61]. Neither study reported an effect on musculoskeletal outcomes. There was *moderate* evidence that rest breaks together with stretching exercises have no effect on musculoskeletal outcomes.

New office

A single medium quality study evaluated a new office as an intervention [54]. The intervention included a new office, new lighting, new equipment and ergonomics training. There was *insufficient* evidence to conclude that a new office has an effect on musculoskeletal outcomes since there is only one study.

Screen filters

Two medium quality studies examined the effects of screen filters; one [45] found a positive effect and one [40] found no effect on musculoskeletal and visual outcomes. There was *mixed* evidence that screen filters have an effect on musculoskeletal or visual outcomes.

VDT glasses

One medium quality study examined the effects of VDT glasses on musculoskeletal and visual outcomes [37]. The study compared VDT glasses to usual glasses. There was *insufficient* evidence to conclude that VDT glasses have an effect on musculoskeletal or visual outcomes when compared to usual glasses since there was only one study.

Lens types

One medium quality study evaluated the effects of lens type on musculoskeletal and visual outcomes [36]. One occupational lens design was compared to another occupational lens design. The single study provided *insufficient* evidence to conclude that a specific lens design has an effect on musculoskeletal or visual outcomes when compared to another lens type.

Herbal eye drops

One medium quality study evaluated the effect of herbal eye drops in comparison to two other types of eye drops [33]. There was *insufficient* evidence to conclude that herbal eye drops have an effect on visual outcomes when compared to conventional eye drops since there was only one study.

OptiZen™ eye drops

One medium quality study evaluated the effect of OptiZen™ eye drops in comparison to another type of eye drop [59]. The single study provided *insufficient* evidence to conclude that OptiZen™ eye drops have an effect on visual outcomes compared to conventional eye drops.

Discussion

This systematic review sought to answer the question, “Do office interventions among computer users have an effect on musculoskeletal or visual health status?,” and to consider the evidence for effectiveness of specific intervention categories. One major observation was that the office ergonomic intervention literature is heterogeneous in the interventions tested, the study designs employed, and the outcomes measured. Across the 31 studies evaluated in detail, the results suggested a *mixed level of evidence* for the effects of ergonomic interventions on musculoskeletal and visual outcomes. A mixed level of evidence means there were medium to high quality studies with inconsistent findings. The mixed level of evidence finding may be due to the broad range of interventions included in the review. Importantly, no evidence was found that any office ergonomic intervention had a negative or deleterious effect on musculoskeletal or visual health. The above conclusions do not change when considering only high quality studies.

When examining specific intervention categories, for no intervention was there a *strong level of evidence* that a specific office ergonomic intervention type improved musculoskeletal or visual health outcomes. The breadth of phrases like “workstation adjustment” and “office equipment”, which aggregate diverse interventions, coupled with a variety of operational definitions of musculoskeletal and visual outcome measures may preclude making strong conclusions.

A *moderate level of evidence* was found for three intervention categories.

- Moderate evidence was found that workstation adjustments as implemented in the studies reviewed have NO effect on musculoskeletal or visual outcomes.
- Moderate evidence was found that rest breaks together with exercise during the breaks have NO effect on musculoskeletal outcomes.
- Moderate evidence was found that alternative pointing devices have a positive effect on musculoskeletal outcomes.

It should be noted the workstation adjustment interventions were usually compared to ergonomic training. Based on these findings, care should be taken in making any generalizations about the positive role for either workstation adjustments or rest breaks together with exercises on improving musculoskeletal or visual health. However, the results should not discourage researchers and practitioners from continuing to develop and test new workstation adjustments or rest break patterns in combination with exercises.

While moderate evidence was found that alternative pointing devices improved musculoskeletal health, the team considered the devices studied (a trackball and Anir (3M) mouse) to be very different input devices. While both were designed to reduce wrist pronation, Rempel et al. [58] found positive effects only for the left side of the body. Given right handed dominance, the team does not consider the health effects as strongly as it would have if the effects had occurred on the right side of the body. Clearly, more high quality alternative pointing device studies are required.

Considerable diversity of office ergonomic interventions and musculoskeletal and visual endpoints were observed in the literature. The range of workplaces, countries and industries where the interventions were implemented was also diverse. The team found a *mixed level* *of evidence* (moderate and high quality studies with inconsistent findings) for a number of interventions.

- Evidence was mixed that ergonomics training, arm supports, alternative keyboards, and rest breaks have a positive effect on musculoskeletal outcomes.
- Evidence was mixed that viewing screen filters have a positive effect on visual outcomes.

The team considered the mixed evidence group of intervention categories to be of particular importance to researchers, funding agencies, organized labor, and employers participating in research. For several intervention categories, one or two additional high quality studies might allow for more definitive conclusions.

Finally, many office ergonomic interventions were unique (e.g., new chair) or a unique combination of interventions (e.g., lighting, workstation adjustment, VDT glasses) and were evaluated in just one study. With single studies, *evidence was insufficient* to make conclusions about intervention effectiveness.

- Evidence was insufficient to conclude that exercise training, stress management training, ergonomics training together with workstation adjustment, new chair, lighting plus workstation adjustment plus VDT glasses, new office, lens type or VDT glasses had effects on musculoskeletal outcomes.
- Evidence was insufficient to conclude that ergonomics training, rest breaks, lighting plus workstation adjustment plus VDT glasses, lens type, VDT glasses, herbal eye drops or OptiZen™ eye drops had an effect on visual outcomes.

Many interventions could provide fertile ground for additional high quality studies. Researchers, funders, employers and labor should attend to the effects (Table 9) and study quality (Table 3) when determining interest and investment in research topics.

The high quality studies reviewed shared common threads regardless of the intervention or outcome. All had concurrent comparison groups and all but one were randomized trials. Each was designed to limit threats to internal and external validity. However, dissimilar musculoskeletal and visual outcomes make integrating findings and calculating effect sizes for the interventions difficult. For musculoskeletal outcomes, the review group recommends that studies be 4 to 12 months in duration to allow for examining the persistence of effects. For visual outcomes, the time required to observe effects is uncertain. It may be that short duration studies are adequate to determine long-term health effects. When multiple changes are introduced with an intervention, it is a challenge to identify the component of the intervention that is driving the observed effects. For example, simultaneous implementation of lighting, workstation adjustment, and use of VDT glasses [30] does not allow determination of which intervention component contributes to the symptom improvement. One potential action that stakeholders could take is to convene a conference or a series of position papers advocating standards for office ergonomic intervention research.

The review team considers it important to continue to develop the office ergonomics systematic review literature in several ways. First, non-English language articles and the grey literature may be valuable to the process. Second, contacting the authors of published articles to clarify findings may also be useful. When possible, studies where between group comparisons were not made should be re-analyzed to provide evidence that can be included in data extraction. In an effort to calculate effect sizes, necessary data not provided in the articles should be obtained from researchers, if possible.

Recommendations

In the opinion of the review team, policy recommendations should be based on strong levels of evidence. A strong level of evidence requires consistent findings from a number of high quality studies. The review did not find this level of evidence. The team felt that with moderate levels of evidence it was possible to make recommendations for "practices to consider." For two of the intervention categories for which a moderate levels of evidence was found, that evidence showed NO effect of the interventions on musculoskeletal or visual outcomes. The third finding of a moderate level of evidence suggested that alternative pointing devices have a positive effect on musculoskeletal outcomes. However, the category of pointing devices is broad and aggregated results from an alternative mouse study and a trackball study make issuing practice recommendations difficult.

An important message to all stakeholders is that the current state of the peer reviewed literature provides relatively few high quality studies of the effects of office ergonomic interventions on musculoskeletal or visual health.

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