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Title: Workplace interventions to improve sitting posture: A systematic review

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Abstract

Evaluate the effectiveness of workplace interventions to improve sitting posture of workers that spend long periods of time seated at a visual display terminal. A systematic review of randomised controlled trials, non-randomised controlled trials and single-group intervention trials featuring workplace interventions with pre- and follow-up measurements of sitting posture was conducted (registered in PROSPERO, CRD#42015027648). Nine databases were searched for studies available between January 2005 and February 2016. 2,519 articles were screened with 12 studies meeting the inclusion criteria. The included studies featured various ergonomic workplace interventions and comprised 4 randomised controlled trial (n = 457), 2 non-randomised controlled trials (n = 416) and 6 single-group intervention trials (n = 328). Due to clinical and methodological heterogeneity, pooling of data was not completed and a narrative summary of findings was developed using the Grading of Recommendations Assessment Development and Evaluation (GRADE) framework. The evidence for four review outcomes was assessed with medium to large positive improvements obtained for the majority of studies investigating changes to gross sitting posture, whereas mixed findings were obtained for more specific local segment assessments of sitting posture. The overall evidence quality for all review outcomes were identified as either 'low' or 'very low'. There is evidence which is limited in quality to indicate that ergonomic workplace interventions can improve gross sitting posture. More high quality research across a range of intervention types is required with longer follow-up durations and more advanced methods to assess sitting posture with greater frequency and less bias.

Highlights:

- First systematic review to investigate interventions designed to improve workplace sitting posture.
- Low quality evidence obtained to suggest that ergonomic interventions can create medium to large improvements in gross sitting posture
- More research is required with longer follow-up durations and less biased assessments of posture

Abbreviations:
GRADE, Grading of Recommendations Assessment Development and Evaluation; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-Analyses; RULA, Rapid Upper Limb Assessment; REBA, Rapid Entire Body Assessment; VDT, video display terminal; WMSDs, work related musculoskeletal disorders.

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Introduction

The number of individuals employed in sedentary occupations that involve the use of a video display terminal (VDT) has steadily increased over the last two decades (Lapointe et al. 2013). Research has shown that VDT users are highly susceptible to work related musculoskeletal disorders (WMSDs), with prevalence of symptoms ranging from 7-30% in the lower back (Juul-Kristensen 2004; Wu et al. 2012; Dick et al. 2015) and above 50% in the upper extremities (Wu et al. 2012). The aetiology of musculoskeletal symptoms experienced by VDT users is believed to be multi-factorial and influenced by the interaction of mechanical, psychological and social factors (Tittiranonda et al. 1999). However, research has predominantly focused on mechanics and identification of postural risk factors (Pincus et al. 2013). It has been suggested that repetitive low-level activation of muscles, adoption of non-neutral postures and prolonged sitting can lead to the development of musculoskeletal symptoms (O'Sullivan et al. 2012). Systematic reviews of VDT users conducted by Gerr et al. (2006) and IJmker et al. (2007) provide evidence of a positive association between sitting duration and incidence of WMSD symptoms experienced in the upper extremities. In contrast, multiple systematic reviews have concluded that occupational sitting duration alone is not associated with low back pain (Hartvigsen et al. 2000; Lis et al. 2007; Roffey et al. 2010) and that a relationship is only apparent when sitting is combined with sustained awkward postures (e.g., lordosed, kyphosed or slouched; Lis et al. 2007). However, it is acknowledged that identifying underlying associations between factors that are prevalent in the general population can be challenging when using epidemiological methods (Pillastrini et al. 2010).

Despite existence of contradictory findings of VDT users sitting practices and the association with WMSDs, interventions to reduce workplace sitting duration and improve seated posture are common (NIOSH 2001). Recently, two systematic reviews were conducted to investigate the effectiveness of interventions aimed at reducing sitting duration at work (Tew et al. 2015; Shrestha et al. 2016). The reviews focused on interventions designed to replace portions of inactive sitting with more physically active tasks such as standing (Tew et al. 2015) or performance of light exercise (Shrestha et al. 2016). Both systematic reviews concluded that there was insufficient evidence regarding the effectiveness of standard interventions such as the use of height-adjustable or active workstations, especially with regards to long-term behaviour change. To the authors' knowledge, there has been no systematic review of the effectiveness of interventions aimed at improving workplace sitting posture. Evaluation of the evidence in this area is important for practitioners that currently implement workplace posture interventions and for future research.

Methods

Criteria for considering studies for this review

Types of studies: The review included randomised controlled trials, non-randomised controlled trials and single-group intervention trials to provide a comprehensive review of the evidence base. The rigour of each research design was considered in the final assessment of the evidence. **Types of participants:** The review included studies conducted with participants 18 years and older in office environments where workers spend a minimum of four hours per day sitting at a VDT. No stipulations were made regarding participants' history of musculoskeletal disorders. **Types of interventions:** The review sought to include studies that featured interventions from the following categories: 1) Exercise; 2) Ergonomic behaviour training; 3) Biofeedback training; 4) Workstation adjustment combined with familiarisation; and 5) Cognitive behavioural training. **Comparator(s)/control:** Where comparator(s) existed, these included control groups not assigned to an intervention or to reduced forms of an intervention. **Types of outcome measures:** The review included studies that evaluated sitting posture using biomechanical or ergonomic assessment methods. Biomechanical assessments of sitting posture were required to provide direct or indirect measurements of the curvature of spinal segments. Ergonomic assessments of sitting posture were required to compare the orientation of body segments (either the neck, trunk, or spine) relative to standardised norms in relation to ergonomic risk. Examples of commonly used ergonomic assessments include the Rapid Upper Limb Assessment (RULA) index (McAtamney and Corlett 1993) and the Rapid Entire Body Assessment (REBA) Index (Hignett and McAtamney 2000)

Search methods for identification of studies

A search for published and unpublished trials in the English language from 2005 onwards was made using the following sources up to 13 February 2016: 1) AMED; 2) CINAHL; 3) Cochrane Register of Controlled Trials; 4) EMBASE; 5) MEDLINE; 6) Web of Science; 7) Dissertation abstracts; 8) Networked Digital Library of Theses and Dissertations; and 9) Conference proceedings. Tailored searches for each source using terms related to three broad areas comprising work setting (e.g. office OR computer user OR visual display terminal), outcome measures (e.g. posture OR erect sitting, neutral position) and intervention (e.g. intervention* OR treatment OR training) were combined with the Boolean operator "AND". Finally, forward and reverse tracking of citations were completed on all included studies and related systematic reviews.

Data collection and analysis

Selection of studies

Two review authors (PAS & KC) independently screened the titles and abstracts of all studies obtained from database searches with potentially eligible citations marked as 'retrieve' and those believed to be non-eligible marked as 'do not retrieve'. Full-text versions were then accessed and independently reviewed by the same authors. Citations were removed from the screening process at the point where information provided (title, abstract or full-text) indicated that criteria for inclusion in the review were not met. Disagreements between the authors (PAS & KC) regarding studies selected for full-text retrieval and inclusion in the final review were resolved through discussion. The selection process was recorded to provide a Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram (Moher et al. 2009).

Data extraction

Two review authors (PAS & KC) independently extracted the following information regarding study characteristics and outcome data. **Methods:** date of publication, type of study design. **Participants:** sample size, mean age, age range, gender, inclusion and exclusion criteria, number of hours spent sitting, occupation, presence or not of WMSD, country of recruitment. **Intervention:** description of intervention and control, duration of intervention, duration of follow-up. **Outcomes:** posture outcome measure(s) used, posture as a primary or secondary outcome measure, summary of results (including means and standard deviations).

Assessment of risk of bias

Two review authors (PAS & KC) independently critically appraised each study and assessed risk of bias using adapted versions of JBI MASTARI critical appraisal forms (Joanna Briggs Institute 2014, Table 1). Thirteen criteria were appraised for randomised control trials. Similar criteria were appraised for non-randomised control trials, with modifications reflecting the context of randomisation and removal of the need to conceal allocation. A total of nine criteria were appraised for single-group intervention trials (Table 1). Each criterion was identified as 'yes', 'no', 'unclear' or 'not applicable', with disagreements resolved by discussion. A consensus was reached that studies had to meet the minimum response of 'yes' for question 5 (was follow-up carried out over a sufficient period?) and question 8 (were outcomes measured in a reliable way?) to be included in the review. A consensus was also reached that 4 weeks represented the minimum duration deemed to represent a sufficient period for follow-up measurements.

Data synthesis

Values for standardised mean change (intervention only and control corrected) were calculated for all studies where data were available. Effect size and sampling variance calculations were made according to the methods described by Morris and DeShon (2002). Meta-analysis of effect sizes was not completed due to clinical and methodological heterogeneity and a narrative summary of findings was developed. In total, four review outcomes based on the assessment method (ergonomic or biomechanical) and follow-up time (short term [less than 3 months] or medium to long term [greater than 3 months]) were considered. A 'summary of findings' table was created and the Grading of Recommendations Assessment Development and Evaluation (GRADE) framework used to assess quality of evidence (Balshem et al. 2011; Guyatt et al. 2011a; Guyatt et al. 2011b). For each review outcome, an a priori ranking of 'high', 'moderate', or 'low' was assigned depending on whether the majority of studies were categorised as randomised controlled trials, non-randomised controlled trials or single-group intervention trials, respectively. Evidence quality was downgraded a level if a single study was identified to present a high risk of bias (failure to achieve ‘yes’ on two or more assessment criteria including: randomisation, allocation concealment, outcomes objective & outcome assessors blind, outcomes of withdrawals included) or the majority of studies suffered from the same risk of bias. Evidence quality was also downgraded if inconsistent findings were obtained. Application of the GRADE framework resulted in the evidence quality for each review outcome being classified as 'high', 'moderate', 'low' or 'very low'.

Results

Results of search

The results of the search are summarised in Figure 1. The initial search yielded a total of 3712 references which was reduced to 63 studies obtained in full-text after removal of duplicates and screening of titles and abstracts. Large numbers of references were excluded in the screening process due to database searches retrieving studies that did not assess sitting posture or include an intervention. Details of criteria not met to warrant exclusion were recorded for studies obtained in full-text. Thirty-six studies were excluded based on initial inclusion criteria (no intervention/acute only = 17; does not include suitable posture measures pre- and post-intervention = 13; does not meet study participant criteria = 3; does not include intervention matching inclusion criteria = 2; duplication of results = 1). Of the remaining 27 studies, 15 were excluded based on secondary inclusion criteria related to critical appraisal (does not meet follow-up duration criteria = 14; does not meet reliable assessment of posture criteria = 1). Forward and reverse citation tracking of the remaining 12 studies identified a further 8 potential sources, which after removal of duplicates reduced to 2 studies that were retrieved in full-text. One study was removed as it duplicated data already included in the review and the other was removed after critical appraisal identified that follow-up duration was not of sufficient length.

Methods and assessment measures

Four of the 12 included studies were randomised controlled trials (Table 2), 2 were non-randomised controlled trials and 6 were classified as single-group intervention trials. Each of the randomised controlled-trials assessed posture with ergonomic methods including three instances of the RULA technique (Zeidi 2011; Tavafian 2012; Dropkin 2015) and a posture checklist comprising seven items scored as satisfactory or not satisfactory according to set criteria (Mahmud 2015). Similarly, both non-randomised controlled-trials included ergonomic assessments of posture including the REBA index (Pillastrini 2010) and RULA index (Robertson 2009). A greater variety of outcome measures features in the single-group intervention trials. Meinert 2013 assessed head inclination angle from photos taken, whereas Konarska 2005 and Horgen 2005 measured flexion/extension angles of the neck and trunk using sensors from dual-axis inclinometers. The single-group intervention trials also featured three instances of ergonomic assessments of posture including two instances of the RULA technique (Mirmohammadi 2012; Dalkilnic 2014) and a safety checklist that assessed the orientation of the neck, trunk and lumbar region (Culig 2008).

Participants

In total, the included studies collected pre-intervention posture data from 1201 participants and follow-up data for 1127 participants. Studies were conducted across a range of countries including Germany, Iran, Italy, Malaysia, Norway, Poland, USA and Turkey. The percentage split between males and females across the included studies was 65.5% female and 34.5% male, with all female cohorts recruited by three of the single-group intervention studies (Horgen 2005; Konarska 2005; Culig 2008).

Interventions

All interventions featured in the included studies were classified as ergonomic interventions (Table 2). Five of the studies employed interventions comprising a single ergonomic training session with posture related education and supply or modification of workstations (Horgen 2005; Konarska 2005; Robertson 2009; Mirmohammadi 2012; Mahmud 2015). Two studies developed web-based ergonomic education resources that could be repeatedly accessed (Meinert 2013; Dalkilinc 2014). The remaining interventions featured education sessions and a range of additional support with Pillastrini 2010 and Dropkin 2015 providing one-to-one consultations, whereas Zeidi 2011 and Tavafian 2012 incorporated continuous encouragement and motivation with staged-matched training sessions according to the transtheoretical model of behaviour change. Finally, Culig 2008 employed a performance management intervention that provided periodic feedback of individual posture data and praise for improvements.

The only study to feature multiple interventions was Robertson 2009 which included two intervention groups, the first received ergonomic training only and the second received ergonomic training and a highly adjustable office chair. Six of the seven controlled studies included a no-intervention control, whereas Pillastrini 2010 provided both the intervention and control group with an information brochure describing appropriate workstation adjustments and behaviours.

Data collection

All studies assessed pre- and follow-up sitting posture during acute measuring sessions. Five of the studies included a single follow-up assessment approximately 1 month post-intervention (Horgen 2005; Konarska 2005; Mirmohammadi 2012; Meinert 2013; Dalkilinc 2014). Tavafian 2012 and Dropkin 2015 included a single follow-up assessment 3 months and 7 months post-intervention, respectively. Zeidi 2011 and Mahmud 2015 included two follow-up assessments (3 and 6 months; 6 and 12 months, respectively). Robertson 2009 and Pillastrini 2010 included three follow-up assessments (2, 6 and 12 months; 5, 12 and 30 months, respectively) and Culig 2008 included a multiple baseline design with serial collection of post-intervention data up to 10 months following intervention. Follow-up assessments were classified as short term (less than 3 months), medium term (3 months to less than a year) or long-term (year +) similar to previous research (Shrestha et al. 2016).

Critical appraisal and risk of bias

Assessment of risk of bias for included studies is presented in figure 2. Three of the 4 randomised controlled trials (Zeidi 2011; Dropkin 2015; Mahmud 2015) described the procedures used to randomise group allocation and therefore were judged to demonstrate low risk of bias. In contrast, only 3 of the 8 non-randomised controlled trials and single-group intervention trials obtained participants randomly from a larger population in order to minimise the effects of selection bias. Dropkin 2015 described their allocation concealment procedures, whereas Mahmud 2015 identified that researchers were aware of group allocation thus presenting a high risk of bias. Information regarding allocation concealment was not reported by Zeidi 2011 or Tavafian 2012.

Horgen 2005, Konarska 2005 and Meinert 2013 assessed posture through objective biomechanical measurement of segment angles. Conversely, all other studies employed more subjective ergonomic assessments of posture that may be more susceptible to detection bias. The requirement to blind outcome assessment was therefore deemed important for studies employing ergonomic assessments with multiple groups. It was identified that 3 of the 6 studies (Pillastrini 2010; Zeidi 2011; Tavafian 2012) comprising multiple groups blinded outcome assessors. From reporting it was unclear if outcome assessors were blinded in Robertson 2009 and clearly stated that outcome assessors were not blinded in Dropkin 2015 and Mahmud 2015.

Loss to follow-up across studies was relatively low and equal to 6.2%. Two of the randomised controlled trials (Dropkin 2015, Mahmud 2015) experienced loss to follow-up and employed intention to treat analyses to minimise the effects of attrition bias. Loss to follow-up occurred in both non-randomised controlled trials, with Pillastrini 2010 employing intention to treat analysis whereas Robertson 2009 did not. Other potential sources of bias reviewed with the modified critical appraisal tools included baseline comparability and standardisation of outcome assessment. All 6 studies that included multiple groups employed the same assessment procedures across groups and only a single study (Mahmud 2015) identified group differences in participant characteristics. However, the factors identified (level of education and hours of exercise per week) were not judged as important confounders by the authors of the original study, and therefore low risk of bias was identified for this domain. Loss to follow-up was obtained for 3 of the 6 single-group intervention trials. It was reported in a related study (Dainoff et al. 2005) that Horgen 2005 and Konarska 2005 employed intention to treat principles for all outcome variables. Conversely, of the 118 participants to complete the ergonomic intervention in Dalkilinc 2014, only data for 102 participants were included in the final analysis presenting a high risk of attrition bias.

The remaining critical appraisal items related to precision of results obtained. The only study not to include clear inclusion criteria was Meinert 2013. Six of the included studies recruited participants specifically with WMSDs or related symptoms (Horgen 2005; Konarska 2005; Meinert 2013; Robertson 2009; Dalkilinc 2014; Dropkin 2014). Pillastrini 2010, Zeidi 2011 and Tavafian 2012 included mixed participant samples with Zeidi 2011 and Tavafian 2012 applying as part of their exclusion criteria a maximum musculoskeletal symptom score on a visual analogue scale. Only Culig 2008 did not present inferential statistics, with all other studies judged to include appropriate methods of statistical analysis.

Effects of interventions

Studies that included ergonomic assessments of sitting posture with short term follow-up (Robertson 2009; Mirmohammadi 2012; Dalkilnic 2014) reported significant improvements post-intervention with moderate effect sizes calculated for Mirmohammadi 2012 and Dalkilnic 2014 (Table 3). The quality of evidence for this review outcome was downgraded from an a priori level of low to very low on the basis of Robertson 2009 failing to include data from withdrawals and not reporting whether outcome assessors were blinded (Table 4). Five of the 6 studies (Pillastrini 2010;

Zeidi 2011; Tavafian 2012; Mahmud 2015; Culig 2008) that included an ergonomic assessment with follow-up longer than 3 months reported improvements in sitting posture, with those studies employing a control group reporting significantly greater improvements for those allocated to the intervention. A medium effect size was calculated for Tavafian 2012 and large effect sizes calculated for Pillastrini 2010, Zeidi 2011 and Mahmud 2015 (Table 3). In contrast, Dropkin 2015 reported no significant difference between the intervention and control group for RULA scores assessed specifically for the spine and lower extremities. An a priori evidence quality of high was downgraded to medium on the basis of Mahmud 2015 failing to report on allocation concealment and blinding of assessors. The quality of evidence was further downgraded to low on the high risk of bias due to selective reporting by Zeidi 2011 and Tavafian 2012 on issues of allocation concealment, method of randomisation and existence of withdrawals (Table 4).

Mixed findings were reported for the 2 studies (Horgen 2005; Meinert 2013) featuring biomechanical assessments of posture with short-term follow-up. Meinert 2013 reported no significant change in neck angle post-intervention, whereas significant changes in neck angle were reported by Horgen 2005. However, results reported by Horgen 2005 exhibited substantial variation across international cohorts (Poland, Norway and USA) with data demonstrating significant increases, significant decreases, and no significant changes in flexion angles, respectively. The quality of evidence for this outcome was downgraded from an a priori level of low to very low based on the inconsistent findings. The only study to include a biomechanical measure of sitting posture over the long-term was Konarska 2005. The authors reported substantial individual variation of flexion angles of the neck and trunk following intervention, with group data providing large and medium effect sizes, respectively (table 3). The quality of evidence for this review outcome was reduced from an a priori level of low to very low due to selective reporting and failure to include inferential statistics.

Discussion

Summary of main results

This systematic review sought to investigate the effectiveness of interventions designed to improve workplace sitting posture. Twelve studies met the inclusion/exclusion criteria (n = 1201) with only ergonomic interventions featured. Given the heterogeneity across interventions and measurement strategies, pooling of data for a statistical meta-analysis was not completed and a narrative summary of findings with four review outcomes was developed. The strongest evidence of an intervention effect was obtained for review outcomes comprising ergonomic assessments of sitting posture. Significant post-intervention improvements were obtained for eight of the nine studies with effect sizes ranging from medium to large. However, the overall quality of evidence was rated as low to very-low based on multiple factors including failure to include control groups and selective reporting of key methodological issues. In contrast, mixed findings of very low quality were obtained for review outcomes comprising studies investigating specific local segment changes to sitting posture with biomechanical measurements.

Limitations of the systematic review

There are several limitations of this review that should be considered. First, despite inclusion of an extensive search strategy there may be missed research studies, particularly as posture assessment was frequently identified as a secondary outcome within large testing batteries and therefore may not be identified in all abstracts. In addition, searches were limited to studies published in English, further increasing the potential for missed studies and the possibility of a language bias. Second, the heterogeneity of studies precluded statistical pooling of data. Generalisability of findings is primarily limited by the extensive range in ergonomic interventions with regards to level of support and inclusion of behavioural change theory. Third, the overall quality of evidence was low, with six of the twelve studies presenting a serious risk of bias due to non-inclusion of a control group.

Implications for practice

There is low and very low quality evidence that ergonomic interventions can result in medium to large improvements in various aspects of gross sitting posture including orientation of the trunk and upper extremities in both the short- and medium- to long-term. Due to the large variation in practices investigated it is not clear the extent to which the content of an ergonomic intervention influences improvements in sitting posture. Substantial positive changes were obtained with interventions requiring limited resources (single day education sessions or access to web resources) and interventions featuring multiple support structures with embedded behavioural change theory. However, the low and very low overall quality of the evidence in this regard should be acknowledged.

In contrast, there is currently insufficient evidence to suggest that ergonomic interventions have the potential to cause more precise local segment changes in sitting posture, as assessed by specific joint angles. Further research employing detailed biomechanical assessment of sitting posture is warranted.

Implications for research

This review searched for studies employing a range of intervention types including: 1) Exercise; 2) Ergonomic behaviour training; 3) Biofeedback training; 4) Workstation adjustment combined with familiarisation; and 5) Cognitive behavioural training. Research investigating each intervention type was identified, however, only interventions featuring ergonomic behaviour training were included after applying the review criteria. Studies were frequently excluded on the basis of follow-up durations judged to be too short (less than one month) to provide a valid assessment of the intervention. A number of workstation adjustment studies were excluded, where multiple studies demonstrated that chair design had the potential to significantly alter and improve acute sitting posture measured under laboratory conditions (Gadge and Innes 2007; Bush and Hubbard 2008; O'Sullivan et al. 2012). In contrast, mixed findings were obtained for acute comparisons of sitting posture with office chairs and stability balls (Gregory et al. 2006; McGill et al. 2006; Kingma and van Dieën 2009; Jackson et al. 2013). It is recommended that future studies avoid acute comparisons and assess the effectiveness of combined instruction and various sitting surfaces over the long-term. In addition, it is recommended that sitting posture is measured during a range of tasks as previous research has identified interactions between chair design and the actions performed at a VDT (Ellegast et al. 2012; Groenesteijn et al. 2012).

The review also excluded multiple studies that demonstrated bio-feedback devices have the potential to create large positive effects on acute sitting posture (Breen et al. 2009; Epstein et al. 2012; Park and Yoo 2012; Yoo and Park 2015), sitting posture measured over short intervention periods (2 weeks to 1 month; Moon and Oah 2013; Yu et al. 2013) and sitting posture measured after very short follow-up periods (less than 1 month; Taieb-Maimon et al. 2012; Golebowicz et al. 2015). A range of bio-feedback devices were identified that assessed posture using accelerometers (Breen et al. 2009), ultrasonic sensors (Yoo and Park 2015), pressure sensors (Epstein et al. 2012; Moon and Oah 2013; Yu et al. 2013), photographs (Taieb-Maimon et al. 2012) and electrical activity of surface muscles (Park and Yoo 2012; Golebowicz et al. 2015). In addition, feedback of posture related information to VDT users was provided across a range of modalities including graphical interfaces (Breen et al. 2009; Yu et al. 2013), simple visual indicators (Taieb-Maimon et al. 2012; Park 2012; Moon and Oah 2013; Golebowicz et al. 2015) vibration alarms (Epstein et al. 2012), auditory cues (Yoo and Park 2015) and novel methods including cartoon animation clips (Wang et al 2014) and moving portraits on photo frames (Obermair et al. 2008). It is recommended that future studies in this area include longer duration interventions and follow-up periods, whilst investigating the feedback types and density that are most effective in creating behaviour change.

The majority of studies (9 of 12) included in this review featured simple observational methods to assess sitting posture. These methods have the advantage of being inexpensive and easy to use (David 2005). In addition, five of the included studies (Culig 2008; Robertson 2009; Zeidi 2011; Tavafian 2012; Mahmud 2015) reported reliability statistics with Cronbach α = 0.79-0.84, ICC = 0.32-0.99 and interobserver agreement = 97-99%, demonstrating that the methods provided satisfactory to high interrater reliability. However, multiple authors from the studies acknowledged that the methods used were limited due to posture being assessed at a single moment in time and therefore unreflective of the range of postures adopted during a workday (Pillatrini 2010; Zeidi 2011). Additionally, for all studies included in this review participants were aware of the measurement procedure when it occurred. It is likely that this awareness influenced participants to adapt their behaviour thus providing a source of bias. Therefore, it is recommended that measurement strategies employed in future studies should seek to increase the potential window over which measurements are made to avoid anticipatory responses by participants. Examples of possible strategies include well positioned recording equipment that can capture images over an entire workday and recent technologies including chairs with inbuilt sensors (Fernandez and Carbonell 2012) and wearable technologies (Dunne et al. 2007) that can quantify gross posture or angles of body segments over extended time periods. These recommended strategies would enable posture to be assessed efficiently on multiple occasions to quantify reliability and better understand the dynamics of sitting posture and its response to intervention over the long-term.

Finally, evidence quality for the review outcomes evaluated were categorised as low or very low. It is recommended that future research avoid single-group intervention designs due to their limited ability to contribute to a high quality evidence base. When including control groups it is recommended that participants are randomly allocated. However, at workplaces where it is difficult to randomise individual participants, cluster-randomised designs with suitable numbers of intervention and control clusters should be included to minimise site-specific confounding. To ensure that the quality of evidence is not downgraded future studies should avoid selective reporting of important issues such as randomisation, allocation concealment procedures, withdrawals and statistical methods implemented to account for withdrawals.

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Figure Headings

Figure 1: PRISMA Study flow diagram

Figure 2: Risk of bias graph

Figure 2 legend below: * indicates review of randomised controlled trials, † indicates review of non-randomised controlled trials, # indicates review of single-group intervention trials.

Figure 1

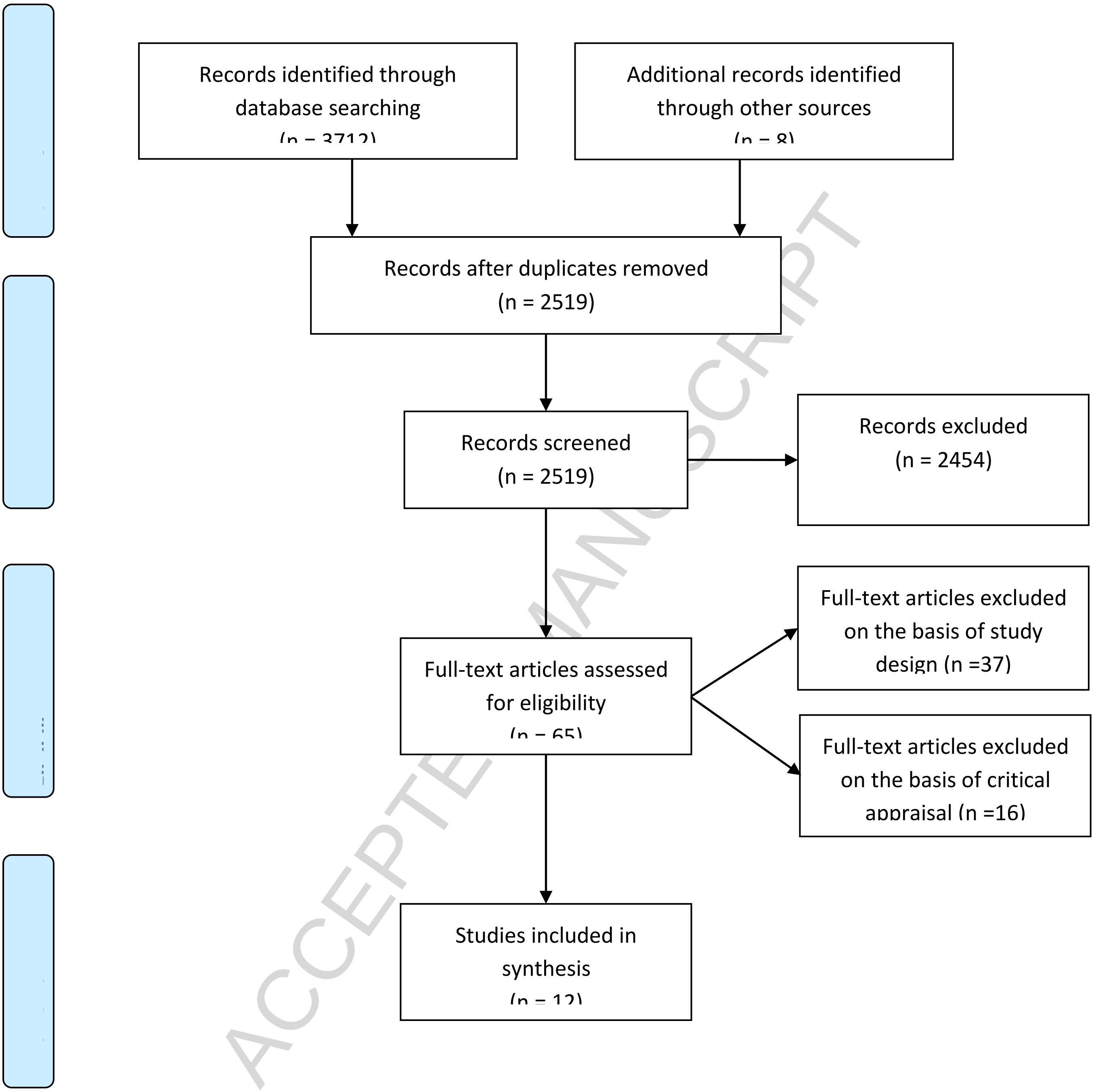
Records identified through database searching (n = 3712)
Additional records identified through other sources (n = 8)
Records after duplicates removed (n = 2519)
Records screened (n = 2519)
Records excluded (n = 2454)
Full-text articles excluded on the basis of study design (n =37)
Full-text articles assessed for eligibility (n = 65)
Full-text articles excluded on the basis of critical appraisal (n =16)
Studies included in synthesis (n = 12)

Figure 2

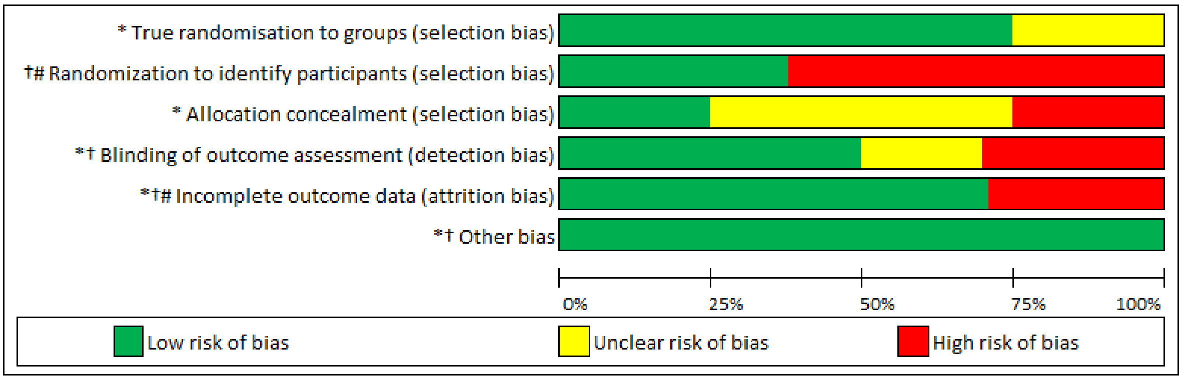
* True randomisation to groups (selection bias)
†# Randomization to identify participants (selection bias)
* Allocation concealment (selection bias)
*† Blinding of outcome assessment (detection bias)
*†# Incomplete outcome data (attrition bias)
*† Other bias
0%
25%
50%
75%
100%
Low risk of bias
Unclear risk of bias
High risk of bias

Table 1: Risk of bias criteria evaluated for all study designs

*1. Was assignment to groups (†# or participant selection) random?	*†# 2. Were criteria for inclusion clearly defined?	*†# 3. Were confounding factors identified and strategies to deal with them stated?	*†# 4. Were outcomes assessed using objective criteria?	*†# 5. Was follow-up carried out over a sufficient time period?	*†# 6. Were outcomes of withdrawals described	*†# 7. Were outcomes of withdrawals included in analyses
*†# 8. Were outcomes measured in a reliable way?	*†# 9. Was appropriate statistical analysis used?	* 10. Was allocation to groups concealed?	*† 11. Were outcome assessors blind to treatment assignment	*† 12. Were groups similar at baseline?	*† 13. Were outcomes measured the same across groups?	

* indicates appraisal for randomised controlled trials, † indicates appraisal for non-randomised controlled trials, # indicates appraisal for single group intervention trials.

Table 2: Characteristics of studies included in the systematic review

Author (Year)	Country (Research design)	Sample	Intervention	Outcome measure	Longest follow-up duration
Zeidi (2011)	Iran (RCT)	Intervention: (n=67) Control: (n=67)	Eight 2h ergonomic sessions followed by encouragement and motivation according to TTM	RULA	6 months
Tavafian (2012)	Iran (RCT)	Intervention: (n=75) Control: (n=75)	Eight 2h ergonomic sessions followed by encouragement and motivation according to TTM	RULA	3 months
Dropkin (2014)	USA (RCT)	Intervention: (n=56) Control: (n=53)	Two training ergonomic training sessions of approximately 1h and provision of keyboard tray and touch pad.	RULA	3 months
Mahmud (2015)	Malaysia (RCT)	Intervention: (n=27) Control: (n=30)	One day ergonomic training session	Posture checklist	1 year
Robertson (2009)	USA (n-RCT)	Intervention1: (n=48) Intervention2: (n=79) Control: (n=43)	Intervention 1: 1.5h ergonomic training session. Intervention 2: 1.5h ergonomic training session plus adjustable chair.	RULA	1 month
Pillastrini (2010)	Italy (n-RCT)	Intervention: (n=90) Control: (n=86)	Ergonomic adjustment of workstation, assessment of posture by physical therapist and follow up consultations	REBA	30 months
Horgen (2005)	Poland/ Norway/ USA (SGIT)	Intervention (n=102)	Poland: Ergonomic workstation adjustment. Norway: Ergonomic training and adjustment of workstations. USA: Ergonomic training, workstation adjustment and onsite coaching	Flex/ext angle of neck	1 month
Kornarska (2005)	Poland (SGIT)	Intervention (n=33)	Ergonomic workstation adjustment	Flex/ext angle of neck and back	1 year
Culig (2008)	USA (SGIT)	Intervention (n=7)	Ergonomic training session. Individual ergonomic evaluation and subsequent tailored performance management intervention comprising feedback and praise.	Posture checklist	10 months
Mirmohammadi (2012)	Iran (SGIT)	Intervention (n=70)	Four hour ergonomic training session	RULA	1 month

Meinert (2013)	Germany (SGIT)	Intervention (n=23)	Access to web-based ergonomic information	Flex/ext angle of neck	1 month
Dalkilinc (2014)	Turkey (SGIT)	Intervention (n=102)	Access to web-based ergonomic information	RULA	1.5 months

RCT: Randomised controlled trial; n-RCT: Non-randomised controlled trial; SGIT: Single group intervention trial; TTM: Transtheoretical model; RULA: Rapid Upper Limb Assessment; REBA: Rapid Entire Body Assessment.

Table 3: Summary of results from studies included in the systematic review

Author (Year)	Sample	Result Summary	Effect Size (95% CI)
Zeidi (2011)	Intervention: (n=67) Control: (n=67)	Similar baseline RULA score with significant group differences 6 months post intervention (better posture in intervention group)	INT: 1.58 (1.26-1.91) INT/C: 1.44 (1.13-1.76)
Tavafian (2012)	Intervention: (n=75) Control: (n=75)	Similar baseline RULA score with significant group differences 3 months post intervention (better posture in intervention group)	INT: 0.66 (0.46-0.87) INT/C: 0.49 (0.24-0.75)
Dropkin (2014)	Intervention: (n=56) Control: (n=53)	No significant change in RULA score assessed at spine and lower extremities 3 months post intervention	INT: 0.03 (-0.17-0.23) INT/C: 0.03 (-0.26-0.32)
Mahmud (2015)	Intervention: (n=27) Control: (n=30)	Significant improvement in posture checklist for intervention group only 12 months post intervention	INT: 1.30 (0.87-1.74) INT/C: 1.12 (0.68-1.57)
Robertson (2009)	Intervention1: (n=48) Intervention2: (n=79) Control: (n=43)	Improvement in RULA score significantly greater for both intervention groups 1 month post intervention	Data not available
Pillastrini (2010)	Intervention: (n=90) Control: (n=86)	Improvement in REBA score significantly greater for intervention group 30 months post intervention	INT: 0.75 (0.57-0.93) INT/C: 0.91 (0.68-1.15)
Horgen (2005)	Intervention: (n=102)	Mixed findings with neck flexion exhibiting : 1) no significant change (Norway); 2) significant increase (Poland); 3) significant decrease (USA)	Data not available
Kornarska (2005)	Intervention: (n=33)	Descriptive statistics showed large changes in median flexion/extension angles of neck and back, with large inter-individual differences 1 year post intervention.	Neck angle INT: 0.83 (0.50-1.17) Back angle INT: 0.61 (0.31-0.92)
Culig (2008)	Intervention: (n=7)	Improved scores on posture checklist were obtained post intervention with a trend towards baseline over subsequent 4 to 10 months	Data not available
Mirmohammadi (2012)	Intervention: (n=70)	Significant improvement in RULA scores 1 month post intervention	INT: 0.77 (0.55-0.99)
Meinert (2013)	Intervention: (n=23)	No significant change in head inclination angle 5 weeks post intervention	INT: 0.09 (-0.22-0.40)
Dalkilinc (2014)	Intervention: (n=102)	Significant improvement in RULA scores 6 weeks post intervention	INT: 0.51 (0.35-0.68)

INT: Effect size for intervention group only; INT/C: Effect size relative to control group; NA: Data not available to calculate effect size; RULA: Rapid Upper Limb Assessment; REBA: Rapid Entire Body Assessment.

Table 3: Summary of findings table

Outcomes	Impact	No of Participants (studies)	Quality of the evidence (GRADE)
Ergonomic assessment of posture Follow-up: short term (approximate 1 month)	Those exposed to intervention experienced improvements in posture.	388 (3 studies: 1 Non-randomised control trial; 2 Single-group intervention)	⊕◯◯◯ Very Low [1]
Ergonomic assessment of posture Follow-up: medium to long term (median 6 months)	Those exposed to intervention experienced improvements in posture.	664 (6 studies: 4 Randomised controlled trial; 1 Non-randomised control trial; 1 Single-group intervention)	⊕⊕◯◯ Low [2,3]
Biomechanical assessment of posture Follow-up: short term (approximate 1 month)	Mixed findings between studies	32 (2 Single-group intervention)	⊕◯◯◯ Very Low [4]
Biomechanical assessment of posture Follow-up: long term (1 year)	Changes in joint angles were not consistent across those exposed to the intervention.	116 (1 study: Single-group intervention)	⊕◯◯◯ Very Low [5]

1 Risk of bias high due to selective reporting, failure to include data from withdrawals and unblinded assessors, downgraded with one level.
2 Risk of bias high due to unblinded assessors and failure to conceal allocation, downgraded with one level.
3 Risk of bias high due to due to selective reporting and allocation not concealed, downgraded with one level.
4 Inconsistent findings with and between studies, downgraded with one level.
5 Risk of bias and imprecision due to selective reporting and failure to include inferential statistics, downgraded with one level

Highlights:

- First systematic review to investigate workplace interventions and sitting posture
- Low quality evidence for medium to large improvements in gross sitting posture
- More research required with longer follow-up and less biased assessment of posture