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The effectiveness of physical and organisational ergonomic interventions on low back pain and neck pain: a systematic review

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ABSTRACT

Ergonomic interventions (physical and organisational) are used to prevent or reduce low back pain (LBP) and neck pain among workers. We conducted a systematic review of randomised controlled trials (RCTs) on the effectiveness of ergonomic interventions. A total of 10 RCTs met the inclusion criteria. There was low to moderate quality evidence that physical and organisational ergonomic interventions were not more effective than no ergonomic intervention on short and long term LBP and neck pain incidence/prevalence, and short and long term LBP intensity. There was low quality evidence that a physical ergonomic intervention was significantly more effective for reducing neck pain intensity in the short term (ie, curved or flat seat pan chair) and the long term (ie, arm board) than no ergonomic intervention. The limited number of RCTs included make it difficult to answer our broad research question and the results should be interpreted with care. This review, however, provides a solid overview of the high quality epidemiological evidence on the (usually lack of) effectiveness of ergonomic interventions on LBP and neck pain.

INTRODUCTION

Low back pain (LBP) and neck pain are major health problems in the working population and have considerable consequences for workers, employers and society.^{1 2} Prevention of these symptoms is very important and can be categorised into primary, secondary and tertiary prevention. The aim of primary prevention is to prevent the onset of symptoms in a healthy working population, while secondary prevention seeks to aid recovery from early symptoms and reduce the risk of symptom recurrence.³ However, due to the high lifetime prevalences of LBP and neck pain, it is difficult to discriminate between primary and secondary prevention.⁴ Tertiary prevention is targeted at reducing symptoms and/or preventing (further) symptoms and assisting the patient to cope with consequent disabilities.⁵

Because the development of LBP and neck pain is assumed to be multifactorial (ie, individual, psychosocial and physical risk factors play a role),^{5 6} preventive strategies vary widely.

The common strategy of ergonomic intervention is targeted at occupational risk factors such as lifting, physically heavy work, a static posture, frequent bending and twisting, repetitive work and exposure to vibration,⁴ and can be divided into

What this paper adds

- ▶ Ergonomic interventions are usually not effective for preventing or reducing low back pain and neck pain among non-sick listed workers.
- ▶ Ergonomists should pay more attention to compliance and researchers should improve reporting on compliance.
- ▶ The effectiveness of ergonomic intervention should be confirmed by future randomised controlled trials.

individual worker interventions, physical ergonomic interventions and organisational ergonomic interventions.³

Prevention through individual worker interventions mostly consists of (1) physical exercise programs to improve strength/work capacity, (2) education, instruction or advice on working methods or lifting techniques, or (3) lumbar supports or back belts.⁶ Systematic reviews have shown that with the exception of exercise programs,^{7–9} none of these strategies are effective in preventing LBP.^{8–12} Evidence on the effectiveness of training to prevent neck pain is inconclusive.^{13 14}

Prevention through physical ergonomic interventions consists of redesigning the workplace (ie, providing lifting aids and new equipment, and modifying workstations), while prevention through organisational ergonomic interventions encompasses more changes at the system level (ie, job rotation, modifications to the production system, and job enlargement).⁶ Previous reviews have shown that there is insufficient evidence of the effectiveness on LBP prevention of the application of physical or organisational ergonomics.^{5 15 16} Regarding the effectiveness of physical and organisational ergonomics to prevent neck pain, Brewer *et al* found mixed evidence for the effectiveness of arm supports, alternative keyboards and rest breaks.¹⁴ Boocock *et al* concluded that there was moderate evidence that workstation equipment (mouse and keyboard design) and workstation adjustments were effective (ie, modified lighting, new workplaces, changed office lay out and new software application led to positive health benefits among video display unit workers with neck pain). Despite the promising results on video display unit workers, insufficient evidence was found to support the use of

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ergonomic equipment among manufacturing workers with neck pain.¹³

In recent years, several randomised controlled trials (RCTs) on the effectiveness of physical and organisational ergonomics on LBP and neck pain have been conducted and so an up-to-date systematic review seems warranted.

The objective of this systematic review is to investigate the effectiveness of ergonomic interventions (physical and organisational) in reducing the incidence/prevalence and intensity of LBP and neck pain among non-sick listed workers.

METHODS

Search strategy

With the help of an experienced librarian, the medical electronic databases Pubmed, EMBASE, PsychINFO and the Cochrane Central Register of Controlled Trials, and the database of the Cochrane Occupational Health Field between September 1988 and September 2008 were searched. The sensitive search for RCTs and the search for LBP and neck pain used terms recommended by the Cochrane Back Review Group for searching Medline and EMBASE.¹⁷ Search strategies in other databases were as close to the sensitive strategy as possible. Verbeek *et al* found that no single search term was available to adequately locate occupational health intervention studies.¹⁷ Because the terms of ergonomic interventions also vary largely, no search term for ergonomic interventions was added to the search. 'Musculoskeletal disorders' was included as a search term as this term may incorporate LBP and neck pain. Because 'intensity of discomfort' is frequently used to assess the prevalence of LBP and neck pain, the term was also added to the search. Two reviewers (MTD and KIP) independently screened the obtained titles and abstracts for eligibility. Studies were eligible when all four inclusion criteria (see below) were met.

Inclusion criteria

Inclusion criteria were as follows:

- ▶ The study was an RCT.
- ▶ The cohort studied was a non-sick listed working population.
- ▶ The intervention met the definition of a physical or organisational ergonomic intervention, that is, the intervention is targeted at changing biomechanical exposure at the workplace or at changing the organisation of work.
- ▶ The outcome measure included non-specific LBP or neck pain incidence/prevalence or intensity of pain. Studies on neck/shoulder pain were considered as neck pain studies.

Exclusion criterion

The exclusion criterion was as follows:

- ▶ Individual worker interventions.

When inclusion or exclusion of a study could not be decided on reading the title and abstract, the full article was retrieved and checked for inclusion. A consensus meeting with a third reviewer (AJvdB) was arranged to sort out disagreements between the first two reviewers. Finally, the reference lists of eligible RCTs and relevant review studies were checked for relevant citations.

Risk of bias assessment

Using the 12 criteria of the Cochrane Back Review Group, two reviewers (MTD and KIP) independently assessed the risk of bias of the included RCTs. The list and the operationalisation of the criteria are described elsewhere. The criteria were scored as 'yes/no/don't know'. If necessary, a consensus meeting with a third

reviewer (AJvdB) was arranged to sort out disagreements between the first two reviewers. Subsequently, results of the risk of bias assessment were sent to all first authors and they were asked to provide additional information on the criteria scored as 'don't know'. The first authors were also asked to provide additional information on any positive or negative scores they disagreed with. RCTs were considered as having a 'low risk of bias' when at least 50% (six) of the 12 criteria were met, otherwise they were considered as having a 'high risk of bias'.

Data extraction

One reviewer (MTD) extracted the data by using a standardised data extraction form. Information on study design, randomisation level, population, follow-up period, measurement tools, statistical analyses, outcomes and effect sizes was extracted. The second reviewer (KIP) checked all data extracted. In case of disagreements, a third reviewer (AJvdB) was consulted. If data were missing, first authors of the studies were contacted and additional information was requested.

Data analysis and the GRADE approach

A meta-analysis was performed among studies that reported on the same outcome and had a similar duration of follow-up, that is, short term (closest to 6 months) or long term (closest to 12 months). For studies with a follow-up period of more than 12 months, the final measurement was used in the meta-analysis. If studies compared more than one ergonomic intervention with a control, each ergonomic intervention was analysed separately. To avoid double counting of studies, only the effects of the ergonomic intervention with the largest effect size were included in the meta-analysis. For comparisons of dichotomous data (eg, incidence/prevalence), if not provided, risk ratios (RR) with a 95% CI were calculated. For comparisons of continuous data (eg, pain intensity) standardised mean differences with a 95% CI were calculated. The random effects model was used. All analyses were conducted using RevMan 5 software.

The GRADE approach was used to classify the overall quality of the evidence.^{18 19} For each specific outcome the quality of the evidence was based on five factors: (1) limitations of the study referring to the risk of bias for the results across all studies that measure that specific outcome, (2) consistency of results, (3) directness (generalisability), (4) precision (sufficient data) and (5) the potential for publication bias. The overall quality of evidence was considered to be high if multiple RCTs with a low risk of bias provided consistent, generalisable results for the outcome. The overall quality of evidence was downgraded by one level if one of the factors described above was not met. Likewise, if two or three factors were not met, then it was downgraded by two or three levels, respectively. Thus, the GRADE approach resulted in four levels of quality of evidence: high, moderate, low and very low. In case of only one study measuring an outcome, data were considered to be sparse and inconsistent and the evidence was labelled as 'low quality evidence'.

RESULTS

Study selection

The computer generated search resulted in 2654 references in Pubmed, 404 in EMBASE, 62 in PsychINFO, 206 in the Cochrane Central Register of Controlled Trials and 23 in the Cochrane Occupational Health Field. After exclusion of the duplicated references, both reviewers (MTD and KIP) read 3067 titles and abstracts. Disagreements were resolved in a consensus meeting. The most important reasons for exclusion were: the study was

not an RCT, the study population consisted of sick listed workers, and the outcome measure was not LBP or neck pain incidence or intensity. Hand searching of the reference lists of relevant review articles did not result in any new articles. Finally, 10 studies were included in this systematic review (figure 1).

Risk of bias assessment

Before contacting the authors, 52 risk of bias criteria were scored 'don't know'. After authors had provided additional information, 16 risk of bias criteria were still scored 'don't know'. Table 1 shows the risk of bias assessment scores for the included studies. Seven studies were classified as 'low risk of bias' and three as 'high risk of bias'. Few studies were able to keep the participants blinded for the intervention (criterion C), and only one study was able to successfully blind the care provider (criterion D). Some studies did not report at all or reported insufficiently on these criteria. Blinding in workplace settings is not really possible,³⁰ so there is always a potential risk of bias in this field. No study blinded the outcome assessor (criterion E) seeing that self-reported subjective experience of pain was the outcome. Further, most studies did not report on the use of co-interventions or compliance with the intervention.

Study characteristics

Table 2 shows the characteristics of the studies included. The number of participants varied from 59 to 627.^{22 28} All studies, except two, were conducted in an office environment.^{20 26}

Nine interventions were classified as physical ergonomic interventions, and one as an organisational ergonomic intervention.²³ The study of Haukka *et al* was classified as a physical ergonomic intervention because the participatory ergonomic programme predominantly resulted in adjustments to the workplace or new equipment.²⁰ Five studies were conducted on workers with and without symptoms,^{20 22 26–28} three on workers with symptoms,^{21 23 29} and two on workers without symptoms.^{24 25} The duration of follow-up among studies varied from 6 weeks²⁸ to 2 years.^{20 21 23 26 27} One study reported on LBP only,²¹ five on neck pain only,^{23–27} and four reported on both LBP and neck pain.^{20 22 28 29} Measurements used to determine incidence/prevalence among studies varied, and included using a manikin to identify the body region,²⁰ the use of medication for symptoms, cut-off points on self-reported discomfort or pain

intensity scales, and/or subsequent diagnosis by a healthcare provider.^{22 24 25 27} Measurements for pain intensity also varied, and some studies used a visual analogue scale (VAS),^{21 23 25} a 5-point Likert scale²⁶ or a 10-point discomfort scale.²⁹ One high risk of bias study (N=85) showed that a physical ergonomic intervention (ie, workstation intervention) was not effective in reducing LBP and neck pain intensity in the short term.²⁹ However, the study only performed within-group comparisons and did not perform any between-group comparisons. As the authors did not respond to our request to provide additional information on between-group comparisons, this study was excluded from the analyses of this review.

LBP incidence/prevalence

Short term

Two studies with low risk of bias (total N=1131)^{20 22} and one study with high risk of bias (N=59)²⁸ evaluated the effectiveness of an ergonomic intervention on LBP prevalence. The participants included in these studies consisted of workers with or without LBP at baseline. The physical ergonomic interventions studied included ergonomic training incorporating workplace adjustments for university employees,²² a participatory ergonomic programme instituting workplace changes for kitchen workers,²⁰ and computer workplace adjustments for call centre workers.²⁸

The quality of evidence on LBP prevalence was downgraded with two levels. The results were inconsistent because in one study LBP prevalence decreased,²⁸ while in the two other studies LBP prevalence remained the same.^{20 22} The results of the pooled data were indirect, because the effect was largely determined by the high weight (87.7%) in the meta-analysis of one study conducted on kitchen workers.²⁰ Therefore, there is low quality evidence from three studies (N=1190) that there is no statistically significant difference in the reduction in LBP prevalence in the short term (RR 1.03; 95% CI 0.86 to 1.22) between groups that received a physical ergonomic intervention compared to groups receiving no such intervention (figure 2a).

Long term

One low risk of bias study (N=504) evaluated the effectiveness of a physical ergonomic intervention on LBP prevalence in the long term among kitchen workers with and without LBP at baseline. A participatory ergonomic programme was no more effective than no intervention on 2-year prevalence of LBP.²⁰ There is low quality evidence that a physical ergonomic intervention is no more effective than no such intervention at reducing LBP prevalence in the long term.

Neck pain incidence/prevalence

Short term

Three low risk of bias studies (total N=1487)^{20 22 24} and one high risk of bias study (N=59)²⁸ compared the effectiveness of a physical ergonomic intervention to no intervention on neck pain incidence/prevalence. The study of Gerr *et al* was evaluated as regards neck pain free workers,²⁴ while the three other studies included workers with and without neck pain.^{20 22 28} Ergonomic interventions included ergonomic training incorporating workplace adjustments for university employees,²² an alternate or conventional postural intervention with workstation changes for computer workers,²⁴ computer workplace adjustments for call centre workers,²⁸ and a participatory ergonomic programme consisting of workplace changes for kitchen workers.²⁰

Figure 1 Flow chart of selection process.

Table 1 Risk of bias assessment scores

Criterion	A Randomisation	B Concealment	C Patient blinded	D Care provider blinded	E Outcome blinded	F Drop-out	G Intention to treat	H Selective report	I Baseline	J Co-interventions	K Compliance	L Timing	Total score
Haukka <i>et al</i> (2008) ²⁰	1	1	0*	0*	0	1	1	1	1	1*	1	1	9
Lengsfeld <i>et al</i> (2007) ²¹	1*	1*	1	1	0	1	1	1	1	0*	0*	1	9
Brisson <i>et al</i> (1999) ²²	1*	?	0*	0*	0	1	1*	1	1	1*	0*	1	7
van den Heuvel <i>et al</i> (2003) ²³	1	1*	0*	0*	0	1	1*	0	0	1*	1*	1	7
Gerr <i>et al</i> (2005) ²⁴	1	?	?	?	0	1	1	1	1	?	0	1	6
Rempel <i>et al</i> (2006) ²⁵	1	1*	0*	0*	0	0	1	1	1	?	0*	1	6
Rempel <i>et al</i> (2007) ²⁶	1*	1*	0*	0*	0	0	1	1	1	?	0*	1	6
Conlon <i>et al</i> (2008) ²⁷	1	1*	0*	0*	0	0	1	1	0	?	?	1	5
Cook <i>et al</i> (2006) ²⁸	1	0*	0*	0*	0	1	1	1	0	0*	0*	1	5
Mekhora <i>et al</i> (2000) ²⁹	?	?	0	?	0	1	?	1	?	?	?	1	3

*Before the first authors were contacted, items were scored 'don't know'.

The quality of evidence on this outcome was downgraded with one level. The results were indirect, because the pooled effect was largely determined by the high weight (84.7%) in the meta-analysis of one study that was conducted on kitchen workers.²⁰ Therefore, there is moderate quality evidence from four studies (N=1546) that there is no statistically significant difference in the reduction in neck pain incidence/prevalence in the short term (RR 0.93; 95% CI 0.84 to 1.03) between groups that received a physical ergonomic intervention compared to groups receiving no such intervention (figure 2b).

Long term

Two RCTs with low risk of bias (N=686)^{20 25} and one high risk of bias RCT (N=206)²⁷ were identified. All the interventions under study were classified as physical ergonomic interventions and were conducted on workers with and without neck pain at baseline. Rempel *et al* compared the effectiveness of three ergonomic interventions among customer service operators (ergonomic training and trackball, ergonomic training plus arm board and ergonomic training plus trackball plus arm board) to ergonomic training,²⁵ and found that ergonomic training plus an arm board, even when combined with a trackball, was significantly more effective than the ergonomic training only. Among engineering staff, Conlon *et al*, however, did not find any significant differences when an alternative mouse, an arm board combined with an alternative mouse or an arm board with a conventional mouse were compared to a conventional mouse.²⁷ Haukka *et al* showed that a participatory ergonomic programme was no more effective than no intervention among kitchen workers regarding 2-year prevalence of neck pain.²⁰

The quality of evidence on this outcome was downgraded with two levels. Results were inconsistent and pooled data were imprecise, meaning that the width of the confidence interval of the pooled data made it impossible to support or refute the effectiveness of physical ergonomic interventions.

Therefore, there is low quality evidence from three studies (N=892) that there is no statistically significant difference in the reduction in neck pain incidence/prevalence in the long term (RR 0.79; 95% CI 0.41 to 1.53) between groups that received a physical ergonomic intervention compared to groups that received no such intervention (figure 2c).

LBP intensity

Short and long term

One low risk of bias study (N=157) investigated the effects of a physical ergonomic intervention on the reduction in LBP intensity in the short and long term. Using a 2-year follow-up period, Lengsfeld *et al* showed that a new office chair with an electric motor underneath the seat to prevent prolonged sitting, was no more effective than the same chair without an electric motor.²¹ There is low quality evidence that a physical ergonomic intervention is no more effective than no such intervention in reducing LBP intensity in both the short and long term.

Neck pain intensity

Short term

Two low risk of bias studies (total N=748) evaluated an ergonomic intervention.^{23 26} One study investigated the effectiveness of an organisational ergonomic intervention among office workers, but found that rest breaks were no more effective than an informative brochure to reduce neck pain intensity.²³ A study of garment workers evaluated two physical ergonomic interventions: a chair with a curved seat and miscellaneous items,

Table 2 Characteristics of included studies

Study	Participants randomised	Intervention(s)	Control intervention	Duration of follow-up	Outcome	Results intervention versus control	Risk of bias score
Cook <i>et al</i> (2004), Australia ²³	59 call centre workers with and without LBP and NP at baseline	Adjustments to the desk surface to support the forearm, and adjustments to keyboard and mouse position	Workplace adjustments according to Australian standards	6 weeks	Prevalence of LBP and NP (Nordic questionnaire)	LBP: 4/30 vs 8/29¶; NS NP: 5/30 vs 8/29¶; NS	5
Brisson <i>et al</i> (1999), Canada ²²	627 university workers with and without LBP and NP at baseline	Ergonomic training: two 3 h sessions on workplace adjustments (postural and visual components) and work organisation	No ergonomic training	6 months	Prevalence of LBP and NP. Those having pain on 3 days or more in past 7 days greater than >5 on a VAS (0–10) were referred to an occupational therapist for diagnosis. Prevalence determined by a positive diagnosis	LBP: 22/283 vs 24/339*; NS NP: 36/282 vs 46/341*; NS	7
Haukka <i>et al</i> (2008), Finland ²⁰	504 kitchen workers with and without LBP and NP at baseline	Participatory ergonomic programme: on the basis of active group work, workers identified problems, evaluated changes and implemented them in collaboration with management and technical staff	No participatory ergonomic programme	24 months	Prevalence of LBP and NP (manikin illustration)	NP: 176/263 vs 174/241‡; ¶ NS NP: 184/263 vs 159/241§; ¶ NS LBP: 126/263 vs 111/241‡; ¶ NS LBP: 145/241 vs 135/241§; ¶ NS	9
Rempel <i>et al</i> (2007), USA ²⁶	480 garment workers with and without neck/shoulder pain at baseline	1. Curved seat pan chair plus miscellaneous items 2. Flat seat pan chair plus miscellaneous items	Miscellaneous items: foot rest, storage box, side table, task lamp, and reading glasses	4 months	Neck/shoulder pain intensity. Pain intensity in the past month (5 point scale: 1 'little painful' to 5 'very painful')	Difference in slope (intervention—control) of NP score for change over time = −0.34 (95% CI −0.41 to −0.28)‡; p value not reported 2. Difference in slope (intervention—control) of NP score for change over time: −0.14 (95% CI −0.22 to −0.07)‡; p value not reported NP: 3.00 (SD 2.33)* vs 3.14 (SD 2.52); NS	6
van den Heuvel <i>et al</i> (2003), the Netherlands ²³	268 office employees with neck/shoulder pain at baseline	Computer software encouraging 5 min computer breaks after using the computer for 35 min, and a micro break of 7 s after using the computer for 5 min, a booklet and a neck and upper limb disorder risk test	Booklet with information on neck and upper limb disorders and a neck and upper limb disorder risk test	8 weeks	Neck/shoulder pain severity (VAS 1–10)		7
Conlon <i>et al</i> (2008), USA ²⁷	206 (supportive) engineering staff with and without neck/shoulder pain at baseline	1. Alternative mouse: vertical handle for holding, flat base to support ulnar side of the hand and a roller ball for tracking 2. Forearm board plus conventional mouse 3. Forearm board plus alternative mouse	Conventional mouse: hand in almost fully pronated posture and an optical LED for tracking	12 months	Incidence of neck/shoulder pain Workers with discomfort rates of >5 (0–10 scale) in the past 7 days or who had used medication for upper body discomfort were referred to an occupational physician for diagnosis. Presence of NP is a positive diagnosis	1. NP: 4/52 vs 3/52; NS 2. NP: 8/51 vs 3/52; NS 3. NP: 3/51 vs 3/52; NS	5

Continued

Review

Table 2 Continued

Study	Participants randomised	Intervention(s)	Control intervention	Duration of follow-up	Outcome	Results intervention versus control	Risk of bias score
Lengsfeld <i>et al</i> (2007), Germany ²¹	280 office workers with chronic recurrent LBP at baseline	Office chair with micro-rotation function underneath the seat to prevent long term sitting	Office chair without micro-rotation function	24 months	Lumbar pain score (VAS 0–100 mm)	LBP: 39.75 (SD 17.79) vs 38.53 (SD 17.46); NS† LBP: 34.56 (SD 18.41) vs 33.32 (SD 19.39); NS‡	9
Mekhora <i>et al</i> (2000), Thailand ²³	85 office workers with tension neck symptoms at baseline	Workstation intervention: using a software program, advice on computer workstation adjustments was given on monitor and keyboard height and the use of foot stools and document holders	Use of unadjusted workstation	Cross-over design after 14 weeks, intervention becomes own control	Discomfort of LBP and NP (VAS 0–10, 'no pain' to 'extreme pain')	LBP: change score from baseline: –1.436; NS (within group comparison) NP: change score from baseline: –1.197; NS (within group comparison)	3
Gerr <i>et al</i> (2005), USA ²⁴	356 computer workers without neck/shoulder pain at baseline	1. Alternate intervention: postural intervention with workplace changes based on results from a prospective study on musculoskeletal disorders 2. Conventional intervention: postural intervention with workplace change based on OSHA, NIOSH and private industry recommendations	No intervention: continue keying in usual posture and no workstation changes	6 months	Incidence of neck/shoulder pain. Discomfort score of ≥ 6 (0–10 discomfort scale) or medication use for musculoskeletal discomfort on any day of the week	1. NP: 38/114 vs 33/109; NS 2. NP: 36/116 vs 33/109; NS	6
Rempel <i>et al</i> (2006), USA ²⁵	182 customer service operators without neck/shoulder pain at baseline	1. Ergonomic training and trackball 2. Ergonomic training plus arm board 3. Ergonomic training plus trackball plus arm board	Ergonomic training: erect sitting posture, adjustments to the height of the chair, arm supports, work surface, monitor, and mouse and keyboard location	12 months	Incidence of neck/shoulder pain. Pain intensity scores >5 (VAS 0–10) OR pain medication for 2 days or more per week due to neck/shoulder/upper extremity complaints were referred to an occupational physician for diagnosis. Presence of NP is a positive diagnosis Neck/shoulder pain intensity (VAS 0–10)	1. NP: 6/35 vs 19/43 2. NP: 6/40 vs 19/43 3. NP: 8/40 vs 19/43 1. NP: 2.2 (SD 2.2)* vs 1.8 (SD 1.9)* 2. NP: 2.6 (SD 2.8)* vs 1.8 (SD 1.9)* 3. NP: 2.0 (SD 2.4)* vs 1.8 (SD 1.9)*	6

LBP, low back pain; NP, neck pain; NS, not significant; SD, standard deviation; VAS, visual analogue scale.

*Information not reported in study and provided by first authors on request;

†unadjusted estimates;

‡results at short-term follow-up;

§Results at final follow-up measurement;

¶frequencies derived from percentages.

Figure 2 (a) Meta-analysis of three studies on physical and organisational ergonomic interventions compared to a control intervention in reducing short term low back pain prevalence. (b) Meta-analysis of four studies on physical and organisational ergonomic interventions compared to a control intervention in reducing short term neck pain incidence/prevalence. (c) Meta-analysis of three studies on physical and organisational ergonomic interventions compared to a control intervention in reducing long term neck pain incidence/prevalence.

and a chair with a flat seat and miscellaneous items. Compared to a group with miscellaneous items (eg, a foot rest, storage box, side table, task lamp and reading glasses), both chairs were significantly more effective in reducing neck pain intensity.²⁶ The garment study showed, on a 5-point Likert scale, that the curved seat pan chair reduced neck pain intensity by 0.34 points, while the flat seat pan chair reduced neck pain intensity by 0.14 points. It should be noted that these significant results were found in a subgroup of 277 workers with neck pain at baseline, while a total of 480 workers were randomised to one of the three groups. The garment study did not describe the intervention effects among the excluded subgroup ($N=203$, without neck pain at baseline) or among the entire study population ($N=480$).

The use of two different pain scales (continuous and categorical) and the use of different types of ergonomic interventions among the studies made a meta-analysis on this outcome impossible. In summary, there is low quality evidence from one study ($N=268$)²³ that an organisational ergonomic intervention is no more effective than no such intervention in reducing neck pain intensity in the short term. Based on the significant reduction in neck pain intensity found in the garment study ($N=277$),²⁶ there is low quality evidence that a physical ergonomic intervention (ie, a chair with a curved or flat seat pan) is significantly more effective for reducing neck pain intensity in the short term than no ergonomic intervention.

Long term

One study with a low risk of bias ($N=182$) evaluated the effectiveness of three physical ergonomic interventions among customer service operators (ergonomic training and trackball, ergonomic training plus arm board and ergonomic training plus

trackball plus arm board) to no ergonomic training.²⁵ Ergonomic interventions that combined the use of an arm board support and ergonomic training were significantly more effective in reducing neck pain intensity than ergonomic training only. As regards the use of a trackball, no significant effects were reported on neck pain intensity.

Based on the significant reduction in neck pain intensity found in this single study, there is low quality evidence that a physical ergonomic intervention (ie, arm board support) is significantly more effective in reducing neck pain intensity in the long term than no ergonomic intervention.

DISCUSSION

This review investigated the effectiveness of physical and organisational ergonomic interventions on the prevention of and reduction in LBP and neck pain among non-sick listed workers. The findings of this review showed that there is low to moderate evidence that ergonomic interventions were no more effective than control interventions on short and long term LBP and neck pain incidence/prevalence, LBP intensity and short term neck pain intensity. However, we found low quality evidence that in the short term a physical ergonomic intervention (ie, curved or flat seat pan chair) was significantly more effective in reducing neck pain intensity than no ergonomic intervention. There was also low quality evidence that in the long term a physical ergonomic intervention (ie, arm board) was significantly more effective in reducing neck pain intensity than no ergonomic intervention. However, these findings were obtained from two studies only.^{25 26}

The results of the current review have to be interpreted with caution because of the limited number of studies per outcome,

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and the heterogeneity in populations (symptomatic and non-symptomatic), interventions, controls and outcomes. The generalisability of the results to the entire working population is low, because the populations studied only consisted of office workers, garment workers and kitchen workers. Further, the results of the pooled data on short-term prevention of LBP and neck pain were dominated by a large study that was conducted among kitchen workers.²⁰ Moreover, almost all other studies were on neck pain and were conducted in an office setting evaluating physical ergonomic interventions (ie, work station adjustments). At present, RCTs on organisational ergonomic interventions to prevent and reduce LBP and neck pain are lacking. Despite the limited number of included RCTs, this review provides solid epidemiological evidence of the effectiveness of ergonomic interventions on LBP and neck pain.

Findings compared to other reviews

The conclusions of the current review differ somewhat from those of other reviews.^{4 13–15} Compared to previous reviews, this one specifically focussed on LBP or neck pain, while others included a larger variety of symptoms (ie, neck/upper extremity pain, upper extremity musculoskeletal disorders or visual symptoms). Further, this review excluded study designs other than RCTs and excluded individual worker interventions. Moreover, none of the other reviews performed a meta-analysis and none used the GRADE classification system for levels of evidence.

Explanation of the findings

A number of factors may explain the results found in most studies. Due to the small sample sizes, there is a lack of power to detect positive effects. A meta-analysis was conducted that increases the power, but the results of the meta-analysis showed no statistically significant differences in effect. Six studies used relatively short follow-up periods that varied from 6 weeks to 6 months and found no effect. This might indicate that follow-up periods shorter than 6 months are too short to measure an effect. Furthermore, longer follow-up periods make it possible to measure intervention sustainability¹⁶ and enable identification of delayed intervention effects. More measurements during follow-up may also be needed as LBP and neck pain are both marked by periods of remission and exacerbation.^{31 32} By using one or two follow-up points only, the incidence/prevalence of LBP and neck pain may be over- or underestimated. Therefore, more advanced study designs and statistical methods are recommended, for example studies with repeated measurements.³³ Furthermore, a considerable number of studies in this review included workers with and without symptoms at baseline, and as a consequence may suffer from prevalence-incidence bias. Symptomatic workers at baseline may recover during follow-up, while workers without symptoms at baseline may in time develop LBP and neck pain. Further, because baseline pain intensity scores were low, little room was left for improvement on pain intensity scores.^{34 35}

Another reason that no effect was found may be related to exposure to occupational risk factors for LBP and neck pain. In their conceptual model, Westgaard and Winkel hypothesised that the implementation of an ergonomic intervention may change workers' mechanical exposure and/or may affect the physical or psychosocial risk factors for musculoskeletal health, which in turn would lead to improved outcomes on musculoskeletal health.¹⁶ In the current review, eight of 10 studies were conducted among office workers. All but two^{21 23} ergonomic interventions were aimed at optimising workers' mechanical workload, which in turn would reduce the physical risk factors

for neck pain. The most important physical risk factor for neck pain and upper limb symptoms is repetitiveness combined with forceful exertions.^{36–38} However, exposure to such a physical load among office workers is very small. Psychosocial factors may also play a role in the onset of neck pain among office workers,⁵ but none of the ergonomic interventions were targeted at the psychosocial workload.

Another possibility is that the ergonomic interventions did not target the most important risk factors. However, the issue of risk factors for LBP and neck pain is still poorly understood, particularly which risk factors are most likely to change through ergonomic interventions. In addition, risk factors outside the workplace may not be affected by ergonomic interventions.³⁹ Despite the fact that an RCT should control for unforeseen factors, according to some researchers, the work life environment may be too complex for such control. Although we agree that other study designs can add to our knowledge of the mechanisms of ergonomic interventions, in our opinion the RCT design is the gold standard to evaluate the effectiveness of ergonomic interventions. The view that RCTs are only applicable in occupational health settings and to ergonomic interventions is debatable because cross-contamination between workers in intervention and control groups can easily occur. To avoid contamination, randomisation at the workplace level (department or firm) is recommended.⁴⁰ In our review, only two studies performed a so-called cluster randomisation procedure.^{20 23}

Finally, it may be that workers were not compliant with the ergonomic intervention. An intervention may be perfectly designed, but high compliance is still very important for its effectiveness.⁴¹ From the scoring of the methodological quality criteria, it appeared that most studies had either insufficient levels of compliance or did not report on compliance at all. Reporting on this criterion is, therefore, strongly recommended. To increase worker's compliance, the use of an appropriate implementation strategy may be beneficial.⁴² For instance, among floor layers an adequate implementation strategy was effective in reducing severe knee problems.⁴³ Furthermore, to improve interventions, authors mentioned that the combination of quantitative studies with qualitative studies would be worthwhile in order to examine participant's experiences with the intervention and the intervention effects on different subgroups and settings.³⁰ Subsequently, the new insights into the working mechanism of an intervention could be used for the development of new ergonomic interventions.

Strengths and limitations of the review

One of the main strengths of this review is that we only included RCTs, which are the studies least susceptible to bias. Furthermore, this review performed a meta-analysis on the results of the ergonomic interventions.

The present review has some limitations. The aim of this review was to summarise the existing knowledge and evidence concerning the effectiveness of ergonomic interventions on LBP and neck pain. A systematic review is a form of observational research and, therefore, selection bias may have occurred. Even though a highly sensitive literature search was conducted, it is still possible that studies were missed in this review. Three studies evaluated more than one ergonomic intervention. To avoid double counting of these studies, we chose to include the most effective intervention from these studies in the meta-analyses. This may have influenced the results, leading to an overestimation of the intervention effect. If studies did not report risk ratios, we calculated them using uncorrected study data. This also may have led to an overestimation of the effect

size. However, because we did not find a statistically significant difference in effectiveness, these biases can be excluded.

CONCLUSION

This review showed low to moderate quality evidence that physical and organisational ergonomic interventions were not more effective on short and long term LBP and neck pain incidence/prevalence, on short and long term LBP intensity, and on short term neck pain intensity than no ergonomic intervention. In the short term, a physical ergonomic intervention (ie, curved or flat seat pan chair) was significantly more effective in reducing neck pain intensity than no ergonomic intervention. There was also low quality evidence that in the long term a physical ergonomic intervention (ie, arm board) was significantly more effective in reducing neck pain intensity than no ergonomic intervention. However, these findings were obtained from two studies only. In conclusion, ergonomic interventions were usually not effective in preventing or reducing LBP and neck pain among non-sick listed workers.

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