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Occupational interventions for the prevention of back pain: Overview of systematic reviews

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ABSTRACT

Introduction: We conducted an overview of systematic reviews of interventions for the prevention of low back pain (LBP) that can be conducted in a workplace setting. *Methods:* An electronic literature search was performed in Medline, EMBASE, and the Cochrane Library. Published peer-reviewed systematic reviews and meta-analyses, which described interventions for the primary or secondary prevention of LBP applicable to a workplace setting, were eligible for inclusion. The methodological quality of the included systematic reviews was assessed with the AMSTAR tool. The primary outcome of interest was the incidence of LBP; secondary outcomes were LBP-associated absenteeism, activity interference, and costs related to LBP. *Results:* Twenty-eight eligible articles published between 1994 and 2016 were included in a qualitative synthesis following our screening of abstracts and full-text articles. The AMSTAR rating revealed 14 reviews of high, 10 of moderate, and 4 of low methodological quality. The identified interventions included workplace modifications (6 reviews, 10 studies, 6,751 subjects); shoe insoles (4 reviews, 6 studies, 2,356 subjects); and lumbar supports and other assistive devices (15 reviews, 18 studies, 60,678 subjects). Educational interventions investigated were back schools (10 reviews, 30 studies, 9,973 subjects); manual material handling techniques/advice (6 reviews, 24 studies, 10,505 subjects); and other forms of instruction including pamphlets, booklets, and other media (four reviews, 14 studies, 11,991 subjects). Exercise interventions, investigated in 12 reviews (35 studies, 19,330 subjects), showed moderate quality evidence of effectiveness for exercise interventions alone or in conjunction with educational interventions; no other type of intervention was consistently effective in the prevention of LBP or LBP-associated outcomes of interest. *Conclusions:* Our overview provides evidence of effectiveness for exercise with or without educational interventions in the prevention of LBP. *Practical applications:* Exercise interventions with or without educational interventions that can be applied in the workplace have the potential to prevent LBP.

1. Introduction

Non-specific low back pain (LBP) is a major public health concern, with a significant impact on productivity, work ability, and quality of life (Fan, 2016). The lifetime prevalence of non-specific LBP is 60–70% in industrialized countries with an annual adult incidence of 5% (Duthey, 2013). Work-related LBP was estimated to account for 37% of LBP globally, with a two-fold variation across different geographical regions (Punnett, 2005).

Non-specific LBP is the most important cause for the limitation of individual activities with subsequent work absenteeism globally, imposing a significant financial burden on healthcare systems and economies (Duthey, 2013). It has also been reported that 35% of all disability adjusted life years (DALYs) worldwide were linked to different occupational factors, and about 21.8 million DALYs globally were attributed to work-related LBP in 2010 (Driscoll, Jacklyn, Orchard, et al., 2014).

Low back pain is associated with a considerable socioeconomic burden. For instance, LBP was reported to be the most common cause of disability in young adults in the United Kingdom in a study carried out in 1996, causing more than 100 million workdays lost annually (Croft, Rigby, Boswell, Schollum, & Silman, 1993; Duthey, 2013). A survey in 1996 showed that the population of the United Kingdom was estimated at 58.2 million (Jefferies, 2005). At an estimated population size of 244.5 million (Population Estimates Program, Population Division, U.S. Census Bureau, n.d.), a 1988 study conducted in the United States demonstrated that LBP was responsible for about 149 million workdays lost per year (Guo, Tanaka, Halperin, & Cameron, 1999), with overall annual costs ranging from 100 to 200 billion US dollars (Katz, 2006; Rubin, 2007).

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Several factors including anthropometric characteristics, the nature and severity of physical work, working postures, and methods of manual lifting/handling have been linked to the development of LBP. In addition, other aspects such as lifestyle conditions and psychological factors (Duthey, 2013) may also be considered as independent risk factors for the development of LBP. Due to the multifaceted etiological nature of LBP, it can be a challenge to diagnose and treat (Duthey, 2013). Understanding the mechanism of LBP development may enable advancement of interventions to either prevent or treat this condition.

As non-specific LBP has a high global prevalence resulting in considerable health and socioeconomic consequences, together with the fact that currently available treatment options are not always satisfactory, preventive efforts therefore merit special attention (Luhmann, 2006). Interventions aimed at the prevention of LBP are desirable for the workplace setting - in principle, as prevention of pain is generally preferable to its treatment - and also because of the specific difficulty in treating already established LBP and the adverse effects of some analgesics that may impact alertness or cognition, and therefore safety at work. Many interventions such as education (e.g., back schools), exercise, lumbar supports (e.g., back belts), lifting techniques, insoles/foot orthoses, chair backrests and dynamic sitting, training of employees, and organizational interventions (Luhmann, 2006) have been suggested to prevent work-related LBP. Moreover, a number of systematic reviews have been carried out to evaluate the effectiveness of these interventions, either individually or in combination. Nevertheless, these systematic reviews may come to no definitive conclusion and sometimes offer contradictory conclusions on the same or similar interventions.

Therefore, we have conducted an overview of systematic reviews evaluating the effectiveness of various interventions carried out in the workplace or which could be carried out in such a setting to prevent work-related LBP. Based on the PRISMA statement (Liberati, Altman, Tetzlaff, et al., 2009) and the Cochrane Collaboration (Green et al., 2011) definitions, a systematic review seeks to address a clearly preformulated question that employs systematic and explicit methods to collate relevant research, and to collect and analyze data from the studies that satisfy a pre-defined set of eligibility criteria. A systematic review may or may not include meta-analysis, which refers to the use of statistical techniques to combine the results of included studies. The summaries and conclusions of systematic reviews are intended to inform, for example, on the effectiveness or lack thereof of an intervention. An overview of systematic reviews, as employed in the present study, seeks to compile and summarize data from various systematic reviews regarding an intervention. For the purposes of this study, the term workplace interventions may include changes made at the workplace to modify body function (physical or mental), activity, participation, environmental factors (physical, social or attitudinal), personal factors, or a combination of these. This is in keeping with previous work that defined intervention approaches based on the International Classification of Functioning, Disability and Health (ICF, under the WHO, 2001) (Aas, Tuntland, Holte, et al., 2011).

The present overview of systematic reviews, thus, aims to assess the evidence for the various workplace interventions employed to prevent the development of back pain, as reviewed in the published medical literature and aims to provide recommendations for occupational health practice.

2. Methods

2.1. Searching

An electronic literature search was conducted in Medline (Ovid), EMBASE (Ovid), and the Cochrane Library. The last search date was April 20th 2017. The search strategies and study selection are outlined in the Appendix. We considered reviews published in English or German.

2.2. Inclusion criteria

To be included in the analysis, articles had to be published peer-reviewed systematic reviews or meta-analyses (i.e., numerical evidence syntheses). Additionally, the reviews had to describe interventions, which pertained to primary or secondary prevention of LBP and were performed in, or applicable to, an occupational setting (i.e., the workplace). Articles in the gray literature were excluded. Also considered ineligible were pharmacological interventions to treat LBP. Guidelines on low back pain prevention per se were excluded, however guidelines based on systematic reviews were screened further to assess if the systematic reviews satisfied our inclusion criteria. Two reviewers (DS, RB) independently selected articles in accordance with the above-mentioned criteria that had been determined a priori. Discrepancies were resolved with the help of another reviewer (SS).

2.3. Quality assessment of the systematic reviews and data extraction

The methodological quality of included reviews was evaluated using the Assessment of Methodological Quality of Systematic Reviews (AMSTAR) guideline (Shea, Hamel, Wells, et al., 2009), which consisted of 11 criteria, each given a rating of 'yes' (1), 'no' (0), 'can't answer' (0) or 'not applicable' (0). A review was considered high quality when the total score was 8–11; a total score of 4–7 was considered moderate quality, while a score of 0–3 was low quality. Data on the authors, date of publication, number of studies and subjects, subjects' baseline characteristics, preventive modality, as well as the reviewer authors' main results and conclusions were extracted from the included reviews. Data extracted by one reviewer (DS) were independently verified by a second reviewer (MZ). A third reviewer (SS) arbitrated discrepancies.

2.4. Data synthesis

Due to the heterogeneity in the study subjects' baseline characteristics, types of intervention, and outcome measures, quantitative meta-analysis was not deemed suitable. Therefore, a descriptive, qualitative knowledge synthesis was conducted. Reviews were categorized based on intervention type, outcome measure, and baseline characteristics. Additionally, to facilitate data synthesis, interventions were considered as primary or secondary prevention in accordance with subjects' baseline characteristics and outcome measures reported. Interventions aimed at subjects with no history of back pain were categorized as primary prevention; when subjects had previous back pain, but did not demonstrate current back pain at study baseline, interventions were considered secondary prevention. We assigned to a third category of mixed primary and secondary prevention those reviews where review authors did not explicitly describe subjects' baseline characteristics in that regard. Furthermore, when a review described interventions for both LBP prevention and treatment, we only extracted data related to prevention.

3. Results

The electronic searches yielded 925 hits and 13 additional records were obtained from the references lists of the included reviews; 838 records were screened after deduplication. Following abstract screening, 66 full-text review articles were selected for further evaluation; examining these full-text articles resulted in the exclusion of 38 articles, thus leaving 28 systematic reviews that were included in our overview (Fig. 1). The publication dates of the included reviews ranged from 1994 to 2016.

All review articles were systematic reviews with or without meta-analyses with 27 articles in English and one in German. The main reasons for exclusion were that articles were narrative reviews, not systematic reviews, that interventions were therapeutic rather than preventive or that some of the articles were previous versions of

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updated reviews and, in such cases, only the most recent review was included. A list of excluded articles and reasons for exclusion are presented in Appendix Table 1 (provided in the Appendix).

3.1. Methodological quality assessment

The assessment of the methodological quality of the 28 included reviews was performed based on the AMSTAR tool in the form adapted by Moore, Derry, Aldington, & Wiffen (2015) This showed that 14 reviews were of high, 10 of moderate and 4 of low quality (Appendix Table 2, again provided in the Appendix). Of the 11 criteria, all included reviews performed poorly on the question "*Was the likelihood of publication bias assessed?*". Except for seven reviews, which listed all included and excluded studies, all the other 21 reviews reported details only on the included studies.

3.2. Categorization of interventions

Reviews were classified as primary prevention, secondary prevention, or mixed primary and secondary prevention based on study subjects' baseline characteristics (Tables 1 and 2). Six reviews reported on primary prevention, 19 reviews reported on secondary prevention, and three reviews reported on mixed primary and secondary prevention.

For primary prevention, the main outcome measure considered was the incidence of new LBP. The primary outcome of interest for secondary prevention interventions was the recurrence (or absence thereof) of LBP. Secondary outcome measures such as cost and absenteeism due to LBP (sick leave) were also assessed.

Furthermore, to enable effective comparison between different interventions, all reported interventions were categorized under three broad groups: (1) devices, technologies or workplace modifications; (2) educational and behavioral interventions; and (3) exercise.

As shown in Appendix Table 3, there was a high degree of heterogeneity regarding the baseline characteristics of subjects, the intervention type, its duration, frequency, and intensity. In addition, the outcome measures assessed for a given intervention and the follow-up periods differed significantly between the individual studies contained in the systematic reviews we investigated. Thus, we deemed it appropriate to perform a descriptive and qualitative data synthesis.

3.3. Devices, technologies and workplace modifications

This category comprised all interventions that employ the use of appliances, devices, or equipment for the prevention of LBP in the workplace. These devices aim to limit biomechanical strain on the back in occupational settings where workers are predisposed to LBP. As shown in Table 1 and Appendix Table 3, the interventions identified in this category include lumbar supports and other assistive devices (back belts, braces, corsets) (15 reviews), shoe insoles (4 reviews), and workplace/risk factor modifications (6 reviews). The 15 reviews that reported on lumbar supports and other assistive devices comprised a total of 18 primary studies and more than 60,678 study subjects (three of the studies did not report the number of subjects). Six primary studies with 2,356 subjects were included in the four reviews that reported on shoe insoles or orthoses. Reviews that described workplace modification interventions also included risk factor modifications, which were reported in three of six reviews (10 studies, 6,751 subjects). In the other three reviews (Lahad et al., 1994; Linton & van Tulder, 2001; Verbeek & Ivanov, 2013) workplace modification was classified as an intervention for the prevention of LBP, but none of these three identified any studies reporting this intervention strategy.

Two high quality reviews and one review of moderate quality reported on the effectiveness of lumbar support and other assistive devices for the primary prevention of LBP (Bigos et al., 2009; Curran et al., 2015; Verbeek et al., 2011). The type of lumbar supports considered included back belts and chair backrests. In two reviews (Bigos et al., 2009; Verbeek et al., 2011) (5 studies, 9,156 subjects), back belts did not demonstrate efficacy for the prevention of LBP when compared with no intervention (4,635 subjects) or other interventions such as education alone (8,471 subjects). In one review that investigated the use of chair backrests and reducing seated hip flexion, there was limited evidence that chair backrests were preventive against low back discomfort (seven studies, number of subjects was not provided) and no evidence that chairs that promoted hip flexion reduced LBP or low back discomfort (21 studies, 675 subjects). Also, O'Sullivan et al. (2012) (7 studies, 471 subjects) demonstrated that dynamic sitting using dynamic chairs was not effective for the prevention of LBP.

Four high quality (Dawson et al., 2007; Steffens et al., 2016; van Duijvenbode et al., 2008; van Poppel et al., 2004), five moderate quality (Ammendolia et al., 2005; Lahad et al., 1994; Linton & van Tulder, 2001; Maher, 2000; Tveito et al., 2004) and one low quality (Karas & Conrad, 1996) reviews investigated the efficacy of lumbar supports and assistive devices in subjects with mixed baseline characteristics (mixed primary and secondary prevention). Specific lumbar support devices included back belts (Ammendolia et al., 2005), lumbar braces (Maher, 2000) and corsets (Lahad et al., 1994). There was consistent evidence among all reviews in this category (10 studies, 15,521 subjects) that lumbar supports were not effective in reducing episodes, prevalence, or severity of LBP, nor sick leave due to LBP. In both short term (up to 12 months) and long term (>12 months) studies, back belts had no significant impact on the incidence or episode of LBP, sick leave or costs associated with LBP, compared to no intervention or other interventions. When employed as a supplement to back schools, one review (1 study, 82 subjects) reported that there was limited evidence that lumbar supports reduced the number of days lost from work due to back injury compared to back schools alone (van Duijvenbode et al., 2008) but no effect on the incidence of LBP was found. When combined with usual care in that same review (van Duijvenbode et al., 2008), lumbar supports reduced the number of days with LBP and improved functional status in the long term better than usual care alone, but did not reduce long term sick leave (1 study, 360 subjects). One review (Gatty et al., 2003) of moderate quality (4 studies, 45,479 subjects), which did not describe the baseline characteristics of subjects, showed that the evidence on the effectiveness of back belts in the prevention of LBP was inconclusive.

Of the four reviews that reported on the impart of shoe insoles in the prevention of LBP, three were of high quality (Chuter et al., 2014; Sahar et al., 2007; Steffens et al., 2016) while one was of moderate quality (Bigos et al., 2009). Two of the high quality reviews (Chuter et al., 2014; Sahar et al., 2007) and the moderate quality (Bigos et al., 2009) review reported on subjects without LBP (6 studies, 2,356 subjects). Findings from Bigos et al. (2009) revealed no difference in the prevention of LBP between shoe orthoses (semi-rigid), shoe orthoses (soft) or simple shoe inserts. The review by Chuter et al. (2014) also demonstrated no statistically significant difference between shoe orthoses and a control group in the risk of developing LBP.

In a mixed (primary and secondary prevention) population of subjects, Sahar et al. (2007) demonstrated strong evidence that non-customized insoles are no more effective than no intervention in the prevention of LBP. Also, one high quality review by Steffens et al. (2016) found low quality evidence of no protective effect of shoe insoles on episodes of LBP in the short term. Thus, the overall findings from these four reviews present no convincing evidence that shoe insoles or foot orthoses are effective in preventing LBP in either pain-free subjects or subjects of a mixed primary and secondary prevention population.

The last group in this category of interventions is workplace modifications. In the present context of preventing LBP, these interventions described strategies at the workplace intended to minimize risk factors, which may predispose employees to the development of LBP. Overall, four reviews, (Gatty et al., 2003; Lahad et al., 1994; Linton & van Tulder, 2001; Maher, 2000) all of moderate quality (Table 2), were identified which reported on these preventive interventions. Two of

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Table 1
Characteristics and categorization of the included reviews.

Author (year)	Number of studies and subjects	Study and subject baseline characteristics	Inclusion and exclusion criteria	Types and frequencies of interventions
Bell and Burnett (2009)	15 studies (n = 6,593). 7 studies (n = 2,152) on incidence of LBP. 4 studies (n = 4,441) on LBP impact and disability (sick leave, activity interference, and cost)	Subjects without history of LBP and subjects with recurrent LBP.	IC: 1) Peer-reviewed controlled trials published in English involving exercise as an intervention to prevent the first episode of LBP, or to prevent the recurrence of LBP, during work time or within the workplace were identified 2) Studies had to assess LBP and/or injury outcomes; functional status and time lost from work EC: 1) Studies were excluded if the worker cohort was not analyzed and reported separately 2) Conference abstracts and unpublished materials	Exercise (various exercise programs including general strength, stretching and/or cardiovascular exercises) for the primary, secondary and tertiary prevention of LBP in the workplace Duration: High heterogeneity with regard to duration (5–60 min), frequency (6 times per month to every workday) and intensity (light to moderate) of exercises
Bigos et al. (2009)	i) 9 studies on exercises (n = 865) ii) 4 studies on education including back school (n = 4,168) iii) Stress management (n = 49) iv) Lumbar support (n = 9,112) v) Shoe inserts (n = 527) vi) Programs for reducing lifting using combinations of workplace policies, training and mechanical lifting devices (n = 1,788)	i) 651 subjects had history of back problems at baseline; 214 subjects were a mixed with or without back problems ii) Mix of subjects with and without history of back problems at baseline iii) Mix of subjects with and without back problems at baseline. iv) Mix of subjects with and without back problems at baseline v) 146 subjects were mix of subjects with and without back problems at baseline; 381 subjects did not have history of back problems at baseline vi) Mix of subjects with and without back problems at baseline	IC: 1) Peer-reviewed article in English 2) Prospective study either RCT or another non-randomized controlled trial where intervention assignment was nonrandom but unbiased, and where assignment of intervention was either to individual subjects or to preexisting groups 3) Baseline subject characteristics were similar in intervention and control groups for factors that may influence back problems 4) Interventions evaluated were adequately described 5) Assessment methods were adequately described and identical protocols were used for all subjects for measuring baseline factors and outcomes 6) Acceptable clinical or functional outcomes were evaluated. 7) Follow-up rates for all groups were at least 80% for the first 6 months after study onset, and at least 70% for longer-term follow-up 8) Results were adequately presented and statistical analysis was appropriate EC: Studies that evaluated subjects with serious underlying spinal pathology (spinal fracture, dislocation, tumor or infection, or cauda equina syndrome), inflammatory arthropathies, systemic disease, pregnancy or other non-spinal causes of referred back pain	i) Exercises (types and amount varied, most focusing on abdominal and back extensor muscle strength and endurance, and flexibility). Duration from 45 to 60 min, twice a week for 3–12 months ii) Ergonomic/back education (back school, training in ergonomic lifting methods) iii) Stress management iv) Lumbar-support v) Shoe inserts vi) Programs for reducing lifting using combinations of workplace policies, training and mechanical lifting devices
Chuter, Spink, Searle, and Ho (2014)	6 trials examined the prevention of LBP (n = 2,379) with foot orthoses or insoles	People with LBP or at risk of developing LBP	IC: 1) Published reports of RCTs or crossover trials that compared orthoses or insoles with no treatment or placebo EC: 1) Subjects with LBP caused by specific pathologies or conditions 2) Treatment trials of limb length discrepancy and pelvic obliquity. Non-randomized or quasi-random clinical trials	Foot orthoses or insoles Duration: Only 1 study reported duration of intervention where subjects wore shoe inserts for average of 870 min for 5 days
Curran, O'Sullivan, O'Sullivan, Dankaerts, and O'Sullivan (2015)	i) Part 1: 26 studies (512 subjects) compared the effect of sitting with at least two different hip angles ii) Part 2: 7 studies (131 subjects) compared the effect of sitting with and without a chair backrest	People with LBP or pain free	IC: 1) Peer-reviewed articles published in English 2) Studies that compared at least two sitting conditions with different seated hip flexion angles or compared sitting with a backrest to at least one other condition without a backrest; measured LBP, LBD or activation of at least one trunk muscle 3) Studies must either report quantitative values for muscle activation, LBD, or LBP, or perform statistical comparisons between sitting conditions EC: Conference proceedings	i) Chair backrest ii) Chairs that reduce hip flexion Duration: 10 min to 1 h sitting for 3 days to 6 months.

Table 1 (*continued*)

Author (year)	Number of studies and subjects	Study and subject baseline characteristics	Inclusion and exclusion criteria	Types and frequencies of interventions
Sahar, Cohen, Ne'eman, et al. (2007)	6 RCTs: i) 3 examined primary prevention of back pain (2,061 subjects) ii) 3 examined mixed populations (256 subjects)	i) Subjects in military settings with no back pain ii) It is unclear whether studies were primary prevention or secondary prevention	IC: Trials that examined adults, aged 18 years and over, with nonspecific LBP for secondary prevention trials, or without LBP for primary prevention EC: 1) Retrospective reports, cohort studies or studies with no control group 2) Studies of special types of insoles that were designed to treat limb-length inequality	1) Customized insoles (semi-rigid insoles or viscoelastic polymer material) 2) Non-customized insoles (viscoelastic polyurethane insoles or Neoprene filled with nitrogen bubbles) Duration: Shoe inserts worn for 5–14 weeks
Verbeek et al. (2011)	18 studies in total; 9 RCTs (20,101 subjects) and 9 cohort studies with a concurrent control group (1,280 subjects)	Subjects without LBP and subjects who were not actively seeking treatment	IC: All interventions aimed at changing human behavior in MMH or using assistive devices EC: 1) Studies focusing on treatment of LBP 2) Interventions aimed at workplace adaptations	1) MMH training 2) Simple advice on lifting 3) Back belt use 4) MMH training and lifting aids Duration of sessions ranged from 30 min to 4 h and lasted from 1 week to 24 months
Ainpradub, Sitthipornvorakul, Janwantanakul, and Van Der Beek (2015)	36 studies for methodological quality assessment 15 RCTs (n = 9,676) included for analysis	Patients with back pain and healthy subjects	IC: 1) RCT study design that used education as an intervention and had follow-up 2) Full-text article published in English; neck pain and/or LBP was assessed in the study 3) Only studies, which compared education programs to no education program, were included in the analysis EC: 1) Letters, abstracts, books, conference proceedings, and posters were excluded 2) Also excluded were studies on neck and low back pain due to specific underlying pathology, such as tumors, fractures, infection, dislocation, whiplash-associated disorder, and osteoporosis	Education: Short term (<3 months); intermediate term (between 3 and 12 months); long term (12 months or more)
Ammendolia, Kerr, and Bombardier (2005)	10 studies (5 RCTs of 14,133 subjects; 2 non-RCTs that did not report number of subjects; 2 cohort studies of ~36,000 subjects with one study not reporting on number of subjects, and 1 survey of 13,873 subjects)	Workers with or without history of LBP	IC: 1) Subjects were material handlers exposed to lifting 2) Outcome measures included the incidence and/or duration of lost time of reported LBP in the back belt group compared with the no back belt group 3) Studies that included workers with a previous history of LBP were included 4) Restriction was not made on the style of back belts used EC: Not reported	1) Back belt 2) Training session in lifting techniques and back pain prevention 3) Back belt and training 4) Education 5) Education and lumbar support Intervention was for 1 h and follow-up ranged from 3 months to 6 months. In one study, follow-up period was 6 years
Choi, Verbeek, Tam, and Jiang (2010)	13 RCTs (1,820 subjects)	Subjects who currently have, or previously had at least one episode of non-specific LBP. Adults male and female 18 years and older.	IC: 1) Studies with exercise intervention aimed at prevention of recurrences of LBP 2) Studies with male and female adults, aged 18 or older, who currently had, or had ever had at least one episode of non-specific LBP EC: 1) Studies on back pain due to infections, metastatic diseases, neoplasm, osteoarthritis, or fractures 2) Studies using an exercise intervention that was combined with other interventions such as psychotherapy, specific medication, back school, electro-physical therapies, or lumbar traction	Exercise interventions (strengthening, endurance training and aerobic exercises) with varying frequencies and follow-up time (short term <6 months; medium term, 6 months to 2 years; long term, 2 to 5 years)
Dawson et al. (2007)	8 RCTs (1,055 subjects) 8 non-randomized controlled trials (2,244 subjects)	Subjects with or without back pain at baseline	IC: 1) RCT and non-randomized controlled trials in English or German 2) Prospective study on nurses designed with comparison intervention and control groups recruited from same setting 3) Interventions aimed at the prevention of LBP, back pain and/or back injury	1) Exercise: strength, endurance and coordination exercises for 20–30 min per session. Duration ranged from 8 weeks to 13 months 2) MMH: training and lifting devices for 30 min–2 h ranging from 8 weeks to 2.5 years 3) Lumbar supports: Training in back belts, wearing back belts when lifting,

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Table 1 (*continued*)

	Author (year)	Number of studies and subjects	Study and subject baseline characteristics	Inclusion and exclusion criteria	Types and frequencies of interventions
				4) Singular and multidimensional strategies were eligible EC: 1) Studies that did not analyze and report the nursing cohort separately 2) Laboratory testing of patient handling techniques or equipment was excluded	3 h MMH training 4) Stress management: home exercise; stress reduction training of 7 × 1.5 h. 3 month and 6 month follow-up 5) Multidimensional interventions: Strength and flexibility exercise, relaxation and MMH education for 1 h; 5 × 40 h/week residential program, which entails 4 h exercise per day; post-injury program
t1.24	Demoulin et al. (2012)	9 RCTs (11,849 subjects in intervention groups and 8,040 subjects in control groups)	Asymptomatic subjects with or without history of back pain	IC: 1) Only RCTs published in peer-review journals. 2) Subjects not seeking treatment 3) Preventive intervention programs designed for the purpose of primary or secondary prevention of LBP 4) Reported outcomes related directly to LBP EC: 1) Non-randomized controlled trials 2) Studies on neck pain 3) Programs including a combination of education and another major component (e.g., physical training, coping intervention and/or ergonomics intervention at the workplace)	Educational interventions: Number and duration of sessions ranged from 1 h session to about 8 h (i.e. five 90 min sessions or two 4 h sessions). Included courses about anatomy, body mechanics, safe lifting, handling and transfer techniques. Courses were given by experts in the field and sometimes included videos
t1.25	Driessen et al. (2010)	10 studies; 1,555 subjects	Mostly office workers with and without back pain	IC: 1) RCT of working population with no LBP 2) The intervention was a physical or organizational workplace intervention aimed at changing biomechanical exposure or at changing the organization of work 3) Outcome measure was non-specific incidence/prevalence or intensity of pain EC: Individual worker interventions	Physical workplace interventions and organizational interventions
t1.26	Gebhardt (1994)	6 studies; 890 subjects	Workers from various occupations with or without back pain	IC: 1) Study on effectiveness of training on the occurrence of back pain or LBP-associated sick leave 2) A (quasi-) experimental design that involves employees as subjects EC: Articles not based on a (quasi-) experimental design	1) Physical activity (muscle training) at worksite 2) Education plus muscle training (fitness) Duration: 8 weeks to 2 years Follow-up: immediately after intervention to 2 years
t1.27 t1.28 t1.29	Henrotin, Cedraschi, Duplan, Bazin, and Information (2006)	11 RCTs (n = 3,378, 205 were healthy); 1 parallel group controlled survey (4,730 subjects in general population and 2,556 general practitioners); 1 longitudinal study (266 employees with LBP and 184 without LBP)	Subjects with acute or recurrent non-specific LBP; healthy subjects with no history of LBP	IC: 1) A review of RCTs or controlled prospective studies. 2) Experimental regimen must include an information-based intervention (booklet, video program, multimedia campaign, Internet-based information) 3) At least one of the following primary outcome variables: pain, disability, return to work, use of health resources or patient's knowledge, beliefs, or attitudes about back pain 4) Include patients suffering from nonspecific LBP, whether acute or chronic, or subjects drawn from the general population 5) Published in English or French EC: 1) Abstracts and unpublished studies 2) Uncontrolled, non-randomized observational studies	1) Booklet (biopsychosocial model-based booklet; biomedical booklet, educational booklet) 2) Video program 3) Media campaigns 4) Internet-based information Follow-up period ranged from 1 week to 2 years
t1.30	Karas and Conrad (1996)	15 studies (7,523 subjects). 2 studies did not report the number of subjects	Subjects with or without back pain at study baseline	IC: 1) Work/site study. Experimental or quasi-experimental intervention study 2) Published between 1966 and 1995 EC: Non-experimental studies, non-published studies, studies conducted in laboratory settings	1) Back belts 2) Back schools 3) Exercise/flexibility training 4) Educational classes Duration: 1 month to 6 years

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Table 1 (*continued*)

Author (year)	Number of studies and subjects	Study and subject baseline characteristics	Inclusion and exclusion criteria	Types and frequencies of interventions
Lahad, Malter, Berg, and Deyo (1994))	64 studies	All the studies reviewed included asymptomatic subjects with and without prior back pain	IC: 1) Prevention studies of subjects with or without prior acute LBP 2) Studies published between 1966 and 1993 in English EC: 1) Studies of patients with a history of chronic back pain 2) Studies aimed at preventing the emergence of chronic back pain in symptomatic patients	1) Exercises: Strength, flexibility, and general aerobic exercises for 6 h per month at work; a 5 week program combining 4 h of aerobic exercise and 4 h of back education daily; aerobic training twice weekly for 8 weeks 2) Education on back pain and prevention: Pamphlet describing back pain prevention or back school program (consists of a 4 h to 8 h course in which information is presented on back biomechanics, preferred lifting strategies, optimal posture, exercise to prevent back pain, stress and pain management) 3) Mechanical back supports (corsets): 1 h training session included information on back mechanics, proper lifting techniques, and warm up exercises. Belts worn at work for 8 months 4) Risk factor modification
Linton and van Tulder (2001)	27 studies (19 RCTs: 7,391 subjects; 7 non-randomized controlled trials, 2,006 subjects; 1 study was on neck pain subjects and was excluded)	Subjects not seeking treatment	IC: 1) RCT or non-randomized controlled trial published in English, German, Dutch, or Swedish, that reported on subjects not seeking treatment 2) Preventive intervention specific to some form of back problem, or prevent development of long term back problems EC: No interventions were excluded	1) Back schools and education: discussions on anatomy, biomechanics, lifting, and postural changes related to work. One to 4 sessions, 20 min to 4 h per session. Follow-up ranged from immediately following intervention to 6 months 2) Lumbar supports: back belts at work for 3 to 6 months 3) Exercises: muscle strengthening, warming up, and stretching for 20 min and average of 6 sessions per month; or 1 h sessions per week for 3 to 12 months 4) Ergonomics 5) Risk factor modification
Maher (2000)	13 RCTs; 6,007 subjects (both intervention and control groups)	Subjects with or without LBP at baseline	IC: 1) RCTs and studies in which method of allocation was not truly random but randomization was intended 2) The subjects were workers and interventions were industrial based 3) The study provided outcomes for LBP or, where trials reported injuries to other areas of the body, the outcomes were reported separately for LBP 4) Peer-reviewed and published full-text article in English. EC: 1) Trials where the outcomes were restricted to risk factors for LBP, e.g. poor lifting technique. These were not considered because reversal of risk factors may not necessarily prevent LBP	1) Exercise: group calisthenics (45 min, biweekly for 3 months); endurance, strength exercises for trunk extensors, plus functional exercises to simulate pulling and pushing; 20 min six times a month for 13 months; 5-week residential vigorous exercise program 4 h per day. Follow-up was between 6 to 18 months 2) Back braces: brace with adjustable strap and Velcro fastener; training on spine anatomy and body mechanics; braces with adjustable elastic side pulls, Velcro fasteners and flexible stays; brace with custom molded lumbar insert; lifting instruction. Follow-up was between 3 to 8 months 3) Education: educational programs for 1.5 h in a group of 10–15 workers during work time; 120-minute lecture on back care. Follow up was 3 to 10 months 4) Education and workplace modification: Two session back school, with 3–4 reinforcement sessions plus physical and procedural modifications to workplace; education, training, physical fitness and ergonomic improvement to workplaces. Follow-up was between 12 months to 5 years 5 months
Maier-Riehle and Harter (2001)	18 studies, not all relevant to prevention. 1,682 subjects included in meta-analysis	Mean age 38.4 years 57% women subjects	IC: 1) Studies had to have a treatment group that was largely or exclusively back schools 2) There had to be a control group 3) Measurements must have occurred at the same times in the treatment groups, no retrospective design 4) Study must contain information needed to calculate effect sizes; sample size must be reported EC: Not reported	Back schools; mean number of sessions: 6.2

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Table 1 (*continued*)

Author (year)	Number of studies and subjects	Study and subject baseline characteristics	Inclusion and exclusion criteria	Types and frequencies of interventions
O'Sullivan, O'Keeffe, O'Sullivan, O'Sullivan, and Dankaerts (2012)	7 studies; 3 studies on 396 LBP subjects (not included in our qualitative analysis) and 4 studies examined development of LBD among pain-free subjects (75 subjects).	1) Subjects with established LBP 2) Pain-free subjects (for development of low back disorder)	IC: 1) Prospective studies involving humans, published in English after 1990 comparing dynamic sitting to at least one other sitting condition, and measured LBP and/or low back disorder 2) Studies that examined the effect of dynamic sitting on the onset of low back disorder among pain-free subjects EC: 1) Conference proceedings 2) Studies that solely examined the effects of dynamic sitting on other parameters such as posture, postural sway, muscle activation or spinal shrinkage, or if they only examined overall body discomfort rather than specifically low back disorder 3) Studies that involved seats or chairs that were not used in typical daily environments such as the office, car and home	Dynamic sitting (chair with lumbar support, stability ball, office chair with back rest and motor-driven seat, static office chair with backrest and motor-driven seat). Pain-free subjects sat for 2 h each day similar to their control group; subjects with LBP sat for an average of just over 5 h each day
Steffens, Maher, Pereira, et al. (2016)	23 published reports (21 different RCTs including 30,850 subjects)	Most of the trials focused on working age populations with or without LBP	IC: 1) Subjects without LBP at study entry or at least 1 outcome was not present at baseline (e.g., some subjects had mild LBP, but all were working and the study outcome was an episode of work absence due to LBP) 2) Aimed to prevent future episodes of LBP 3) Compared intervention group with no intervention group, placebo, or minimal intervention and reported a measure of a new episode of LBP (e.g., episode of LBP or episode of sick leave due to LBP) EC: 1) Studies that used a quasi-randomized design or reported the comparison of 2 prevention strategies	1) Exercise 2) Exercise and education 3) Education 4) Back belt 5) Shoe insoles 6) Other prevention strategies. Follow up: short term (up to 12 months) and long term (>12 months) Outcome: LBP episode and sick leave
Tveito, Hysing, and Eriksen (2004)	24 studies (~8,976 subjects) 4 treatment interventions studies were not included	Workers from various settings with or without back pain	IC: 1) Controlled workplace interventions with employees as subjects, aiming to prevent LBP 2) Studies that used one of the following outcome measures: lost workdays or sick leave due to LBP, cost or cost-effectiveness, new episodes of LBP, level of pain EC: 1) Studies without a control group 2) Studies that did not involve workplace interventions 3) Studies that did not use any of the outcome measures of interest	1) Education: back schools (included instructions in proper lifting techniques and body mechanics). 30 min to 2 h sessions per day. Follow-up ranged from 2 weeks to 2 years 2) Exercise: specific exercises that strengthen back muscles or for flexibility, or exercises to increase strength and fitness generally. Could be high to low intensity, performed during or outside of working hours. 20 min to 1 h exercise program once or twice a week. Follow-up from 6 weeks to 1.5 years 3) Back belts: back belts worn at work for 3 months to 8 months 4) Multidisciplinary interventions (education, exercise, ergonomics): 8 h per day lasting 5 weeks to 1 year 5) Pamphlet: duration not reported
van Duijvenbode, Jellema, van Poppel, and van Tulder (2008)	7 preventive studies (14,435 subjects). 8 treatment studies were not included in our overview.	Subjects with or without LBP at baseline	IC: 1) RCTs with study population consisting of workers aged 18 to 65 years 2) Trials studying any type of lumbar support, flexible or rigid, used for the prevention of LBP were included EC: 1) Non-randomized trials were excluded 2) RCTs where LBP was caused by specific pathological entities such as infection, neoplasm, metastasis, osteoporosis, rheumatoid arthritis, or fractures were excluded 3) Special types of lumbar supports for severe scoliosis and kyphosis and for back surgery were excluded	Lumbar supports: short term follow-up (up to 3 months); intermediate (>3 up to 6 months) long term follow-up (>6 months)

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Table 1 (*continued*)

Author (year)	Number of studies and subjects	Study and subject baseline characteristics	Inclusion and exclusion criteria	Types and frequencies of interventions
van Poppel, Hooftman, and Koes (2004)	i) Lumbar supports: 4 RCTs (676 intervention subjects and 375 control subjects), 3 controlled clinical trials (6,637 subjects) ii) Education or back school program: 6 RCTs (2,556 intervention subjects and 2,414 control subjects); 2 controlled clinical trials (230 intervention subjects and 325 control subjects) iii) Exercise: 4 RCTs (361 intervention subjects and 234 control subjects)	Workers from various settings with or without back pain	IC: 1) A prospective controlled clinical trial design comparing intervention group with a concurrent control group derived from the same setting and with randomized or nonrandomized allocation of subjects to the study groups 2) Workplace initiated intervention aimed at the prevention of back pain 3) No restriction to subjects with back pain at the start of the study EC: Abstracts and unpublished material were excluded	i) Lumbar supports: back belts worn for 3 to 8 months ii) Education and back school programs: 1-hour training consisting of five sessions. The first four 90 min sessions were given during a 2-week period and the fifth session after 2 months. Instructions included body mechanics, exercises for back and abdominal muscles. Subjects were encouraged to exercise at home iii) Exercise: back muscle exercises during 13 months, with an average of six sessions of 20 min per month Calisthenics exercises for back and abdominal muscles for 40 min twice a week for 3 months; weekly sessions of 35 min at work plus 30 min at home with general stretching, strengthening and cardiovascular exercises for 18 months; or an individually designed exercise program performed at least twice a week at home
Verbeek and Ivanov (2013)	23 systematic reviews	Not specified by the authors	IC: Occupational safety and health intervention studies as well as systematic reviews EC: Not reported	1) Environmental 2) Behavioral 3) Clinical (pre-employment examinations)
Clemes, Haslam, and Haslam (2010)	7 studies (n = 759; 389 intervention subjects and 370 control subjects) on MMH training in nurses. Subject numbers not given in 1 study 1 study (1,703 intervention subjects and 1,894 control subjects) of MMH training in postal workers 1 study (28 intervention subjects and 32 control subjects) of exercise training on workers with MMH tasks	Not specified by the authors	IC: 1) Studies conducted both in the workplace and in a laboratory environment on MMH training intervention with and without control groups 2) Articles must be peer-reviewed, described empirical research, impact of exercise 3) Studies on all occupations were included 4) Also included were reports from health and safety agencies and published conference proceedings EC: Not reported	MMH training including patient handling techniques, safe lifting, and advice on lifting. The effectiveness of the intervention was assessed after 2 weeks, 3 weeks, 2 months and up to 2 years. Some sessions were administered for 45 min or 1 h per week
Gatty, Turner, Buitendorp, and Batman (2003)	9 studies (50,325 subjects; one study did not report number of subjects)	Not reported	IC: 1) Articles published in peer-reviewed journals and in English between 1995 and 2000 were included 2) Studies had to be conducted in the workplace in North America or Europe 3) At least one LBP related outcome measure EC: Not reported	1) Back belts: 3 months, 6 months and up to 6-year follow-up 2) Education and task modification: 3-year combined education and training program (patient transfer technique, physical fitness and stress management) 3) Education and task modification with work redesign
van Dieen, Hoozemans, and Toussaint (1999)	27 studies; 581 subjects	Not reported	IC: Studies comparing stoop and squat lifting techniques with respect to mechanical load on the back EC: Not reported	1) Stoop lifting technique 2) Squat lifting technique

IC: inclusion criteria; EC: exclusion criteria; LBP: low back pain; MMH: manual material handling; RCT: randomized controlled trial; LBD: low back disorder; min: minute; h: hour.
Where listed items refer to the same concept in different columns, Roman numerals are used to construct the list.

the reviews (Lahad et al., 1994; Linton & van Tulder, 2001) did not identify any trials evaluating the effectiveness of these strategies in LBP prevention. The other two reviews (Gatty et al., 2003; Maher, 2000) (7 studies, more than 6,484 subjects; number of subjects was not reported by one study) described interventions to modify risk factors at the workplace including task modification. The specific interventions intended to modify such workplace risk factors as lifting, physically heavy work, a static posture, frequent bending and twisting, repetitive work, and exposure to vibration. Driessen et al. (3 studies, 1,100 subjects) showed that workplace interventions, which included training about workplace adjustments, a participatory program instituting workplace changes, and computer workplace adjustments, were no more effective in the prevention of LBP than no interventions in the short term (up to 12 months). In the long term (>12 months), likewise, physical workplace modification intervention was not effective in the prevention of LBP (one study, 504 subjects). Steffens et al. (2016) (two studies, 3,536 subjects) and Verbeek et al. (Verbeek & Ivanov, 2013) (number of subjects was not reported) did not find any effect of workplace modification programs in the reduction of LBP episodes. These findings provide evidence that workplace, risk or task modifications are no more effective than no intervention control groups in the prevention of LBP.

3.4. Educational and behavioral interventions

Interventions in this category involve strategies that influence workers' behavior at the workplace that may lead to a change in performing a task to prevent LBP. Educational approaches aim to provide

Table 2
Main results and conclusions of the included reviews.

Prevention categories and intervention types	Author (year)	Authors' main results	Authors' conclusions	Quality rating of review
Primary prevention Exercise	Bell and Burnett (2009)[a]	1) 7 low quality studies demonstrated a significant effect of exercise on preventing LBP. 2) 2 studies with methodological weaknesses showed significant effects of exercise on reduction of sick leave due to LBP. 3) 2 studies showed significant improvements with exercise on activity interference due to LBP.	1) There was limited evidence for overall effectiveness of exercise for the prevention of LBP. 2) There was limited evidence for a positive effect of exercise on sick leave due to LBP. 3) There was strong evidence that exercise reduces activity interference from LBP.	High
Primary prevention Exercise Education Exercise and education	Bigos et al. (2009)	1) 7 studies demonstrated that exercise alone or combined with education increased strength and flexibility of abdominal muscles and improved symptoms resulting from back problems, reduced number of painful months because of LBP. The number of days absent from work and days with back-pain symptoms, as well as incidence of new back-pain episodes were all reduced. 2) Education alone or combined with workplace programs, stress management, lumbar support, shoe inserts or programs for reducing lifting did not reduce prevalence and duration of episodes of LBP.	Exercise was found to be an effective intervention for prevention of back problems.	Moderate
Primary prevention Foot orthoses or insoles	Chuter et al. (2014)[a]	6 trials showed a non-significant 22% reduction in the risk of developing LBP with the use of foot orthoses or insoles (RR 0.78; 95% CI: 0.50 to 1.23) compared to the control group, with a high level of heterogeneity present ($I^2 = 76.8\%$).	There was insufficient evidence to support the use of foot orthoses or insoles for prevention of LBP.	High
Primary prevention Chair backrests Chairs involving less hip flexion	Curran et al. (2015)	Based on limited evidence chair backrests did not reduce LBD. Chairs involving less hip flexion did not reduce LBP or LBD.	There was limited evidence that chair backrests reduced LBD. Available evidence showed that chairs involving less hip flexion reduced LBP or LBD.	High
Primary prevention Insoles	Sahar et al. (2007)	Rate of LBP was not statistically significantly different between insole users and control group.	There was strong evidence that insoles were not effective in the prevention of LBP.	High
Primary prevention Training Simple advice on lifting Back belt use Training and lifting aids	Verbeek et al. (2011)	There was moderate quality evidence in 7 RCTs that training resulted in similar LBP incidence as no intervention (OR 1.17; 95% CI: 0.68 to 2.02). Simple advice did not prevent against LBP (OR 0.93; 95% CI: 0.69 to 1.25). None of the other comparisons showed evidence of a preventive effect of training or provision of assistive devices on LBP.	No evidence that training and provision of assistive devices prevented LBP when compared to no intervention or another intervention.	High
Secondary prevention Education	Ainpradub et al. (2015)[b]	3 studies showed no long term effect of education program on the prevalence of LBP (RR 1.02; 95% CI: 0.78 to 1.33). 3 RCTs showed low quality evidence of a positive effect of education on incidence of LBP in long term follow-up. 3 studies showed no long term effect of education program on fear avoidance belief score (SMD −0.02; 95% CI: −0.17 to 0.12).	Education programs were not effective in preventing low back pain.	High
Secondary prevention Back belt	Ammendolia et al. (2005)	Of 5 RCTs, 3 did not show positive results with back belt use; 1 showed decreased time loss in a training and back belt group. Subgroup analysis suggested that this effect was seen only among workers with a previous history of LBP. Another RCT reported a marginally significant decrease in low back injury rates among employees receiving a back belt compared with control group. 1 high quality cohort study did not show any effectiveness of back belt use to prevent or reduce lost time due to LBP. An observational study with analytical and methodological weaknesses found positive results with back belt use on LBP. Those with a previous history of LBP may experience some potential benefit from back belt use.	There was no conclusive evidence to support back belt use to prevent or reduce lost time from LBP. Individual workers presenting with no prior history of LBP are unlikely to benefit from the use of a back belt.	Moderate
Secondary prevention Exercise	Choi et al. (2010)	Post-treatment exercises (exercise interventions aimed to prevent LBP recurrence of subjects previously treated for LBP) versus no intervention: The 3 studies that evaluated this comparison showed that the number of subjects with recurrences was significantly lower (RR 0.5; 95% CI: 0.34 to 0.73) at medium term follow-up in 2 studies but not at long term follow-up (RR 0.75; 95% CI: 0.53 to 1.07). The time to recurrence measured in one study yielded a hazard ratio of 0.43 (95% CI: 0.21 to 0.87) at medium term follow-up. Number of recurrences measured in two studies with mean difference of −0.35 (95% CI: −0.60 to −0.10) at medium-term follow-up, and in one study at long term follow-up with a MD of −1.97 (95% CI: −3.84 to −0.10). Post-treatment exercise did not influence the number of persons on sick leave as a result of recurrences at medium or long term follow-ups, but did decrease the number of days on sick leave due to recurrences in 2 studies at medium-term follow-up with mean difference of −4.37 (95% CI: −7.74 to −0.99). When an additional exercise machine was added to the post-treatment exercise, 1 study showed no effect on the number of days on sick leave compared to general exercises. Exercise treatment versus sham treatment: When compared to ultra-sound sham treatment group, exercise treatment resulted in neither fewer persons with recurrences nor a shorter duration of recurrent back pain. McKenzie exercises versus back pain education: McKenzie exercises compared to back pain education did not significantly differ in the number of subjects who had recurrences in the medium-term; there was no significant difference in the number of days on sick leave between the two groups.	There was moderate quality evidence that post-treatment exercises were more effective compared with no intervention in reducing the number of subjects with recurrences at medium-term follow-up. There was moderate quality evidence that they were more effective at reducing the number of recurrences of back pain at medium-term follow-up. There was low quality evidence that post-treatment exercises decreased the number of days on sick leave at medium-term compared to no intervention. There was low quality evidence that the recurrence rate at medium-term and at long term follow-ups was similar between the exercise and usual care group. There was very low quality evidence that McKenzie exercises are similar to back pain education at reducing recurrences of back pain at medium-term follow-up and very low quality evidence that the number of sick leave days is similar after pain education in the medium and long term follow-ups.	High

Table 2 (*continued*)

	Prevention categories and intervention types	Author (year)	Authors' main results	Authors' conclusions	Quality rating of review
t2.29 t2.30 t2.31 t2.32 t2.33 t2.34 t2.35 t2.36	*Secondary prevention* Exercise MMH training MMH training and equipment Lumbar supports Stress management Multidimensional interventions	Dawson et al. (2007)	*Exercise interventions*: Reported no effect on LBP prevalence, intensity, and interference with activities. 1 trial showed reduction in LBP prevalence, intensity and lost work days with exercise while 1 trial was inconclusive. *MMH techniques* (*training and or equipment*): All trials showed no effect on LBP prevalence, and intensity on back injury except 1 study, which showed reduction in LBP prevalence but no effect on injury or disability. *Lumbar supports*: Limited evidence of positive effectiveness on the prevention of LBP in nurses. *Multidimensional interventions*: Moderate evidence of effectiveness on the prevention of LBP in nurses. *Stress management intervention*: Moderate evidence of no effectiveness on the prevention of LBP. *Exercise intervention combined with MMH training*: Moderate evidence of effectiveness in the reduction of LBP frequency and intensity.	MMH techniques in isolation was not effective in the prevention of LBP. Limited evidence that exercise, lumbar supports, stress management and manual handling equipment and training were not preventive against LBP. Moderate evidence that multidimensional interventions prevents LBP in nurses.	
t2.37 t2.38	*Secondary prevention* Education	Demoulin et al. (2012)	The education interventions differed widely from one study to another. No significant differences between the control and education groups were found at follow-up in 8 out of 9 studies on the incidence of back pain, disability or sick leave.	Educational interventions mainly focused on a biomechanical or biomedical model were not effective in preventing LBP.	Moderate
t2.39 t2.40	*Secondary prevention* Workplace intervention	Driessen et al. (2010)	3 studies of low quality, showed no statistically significant difference regarding LBP prevalence in the short term (RR 1.03; 95% CI: 0.86 to 1.22) between groups that received a physical workplace intervention compared to groups receiving no such intervention. There was low quality evidence that a workplace intervention is no more effective than no intervention at reducing LBP prevalence in the long term ($n = 504$).	There was low to moderate quality evidence that physical and organizational workplace interventions were not effective in reducing short and long term LBP incidence, prevalence as well as short and long term LBP intensity.	High
t2.41 t2.42 t2.43	*Secondary prevention* Training (exercise and physical activity)	Gebhardt (1994)	Training of employees reduced incidence of back pain or the period of sick leave resulting from back pain. Effect sizes ranged from $d = -4.18 \times 10^{-8}$ to 0.67. Overall combined effect size was $d = 0.24$ and correlation coefficient, $r = 0.12$.	Modest relationship between training of employees and a decrease in occurrence of back pain or sick leave associated with back disorder.	Moderate
t2.44 t2.45	*Secondary prevention* Education	Henrotin et al. (2006)	There was strong evidence that a booklet increases knowledge and moderate evidence that physician-related cues increased confidence in a booklet and adherence to exercises. There was limited evidence that a biopsychosocial booklet was more effective than a biomedical booklet to shift subjects' beliefs about physical activity, pain and associated consequences. There was strong evidence that booklets were not efficient on absenteeism, but there was conflicting evidence that they were efficient on healthcare use. There was no evidence that email discussion or video programs alone were effective to reduce LBP, disability, or healthcare costs. Nevertheless, information delivery alone was not sufficient to prevent absenteeism and reduce healthcare costs.	To shift subjects' beliefs on LBP, biopsychosocial-based information was recommended, although it was inadequate to prevent absenteeism and reduce LBP related healthcare costs.	Moderate
t2.46 t2.47 t2.48 t2.49 t2.50	*Secondary prevention* Back belt Back school Exercise/flexibility training Education	Karas and Conrad (1996)	All four programs showed generally positive results. *Back belt*: Of the 4 back belt programs, 1 study reported a decrease in the number of back injuries and 1 reported no change. 2 studies reported a reduction in lost time. 1 study reported no change in abdominal strength. *Back school programs*: 2 studies reported a reduction in back injury rates. 1 study reported a decrease in lost time, and 1 reported no change. 1 study showed no change in costs. 1 study each showed an increase in flexibility and body mechanic usage scores (measure of the positioning of the body while moving, lifting, lowering, pulling or transferring objects or patients), respectively. *Exercise/flexibility*: 2 studies each reported a decrease in back injury and lost time, respectively. 3 studies reported a decrease in cost and 3 reported an increase in muscle flexibility. 2 studies reported an increase in exercise behavior while 1 reported an increase in body mechanic usage. *Education programs*: Of the 3 education programs, 1 study reported a decrease in the back injury rate, utilizing a combination of an education program and administrative program.	All interventions demonstrated positive effects on the prevention of LBP. Exercise/flexibility intervention was more effective in the prevention of LBP compared to the other interventions. There were, however, few studies with limited methodological quality. Therefore, conclusions must be considered with caution.	
t2.51 t2.52 t2.53 t2.54	*Secondary prevention* Exercise Education Mechanical supports	Lahad et al. (1994)	*Exercise*: All 16 RCTs showed a statistically significant short term benefit from an exercise intervention in the number of workdays lost because of back pain or fewer days with back pain than controls. None of the studies followed up subjects beyond 18 months. 7 studies observed significant associations between increased fitness or flexibility and decreased LBP, but 4 found no protective effect. *Education*: Of 5 RCTs 1, which combined education with an exercise, program reported a significant decrease in subsequent LBP. 4 of the trials reported negative overall results, but significant differences in intermediate outcomes were observed in 3 of the 4. *Mechanical supports*: 1 study showed no difference in mean rates of work lost between subjects in belt-only group and controls, nor between subjects in the belt-and-training group and controls. Compliance to wear corsets was 42% in this study. In another study, a corset plus education group had a significantly greater increase in knowledge and decrease in days lost from work compared to education alone or no intervention group. There were no differences in changes in abdominal strength, productivity, and rates of injuries between the groups.	Exercise interventions may be mildly protective against back pain. Aerobic exercise appeared to be as effective as exercises aimed at trunk muscles. There was limited evidence to recommend exercise to prevent LBP in asymptomatic individuals, and there was insufficient evidence to recommend other prevention strategies. There was minimal support for use of educational strategies to prevent LBP. There was insufficient evidence to recommend use of mechanical supports for back pain.	Moderate

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Table 2 (*continued*)

Prevention categories and intervention types	Author (year)	Authors' main results	Authors' conclusions	Quality rating of review
Secondary prevention Back schools and education Lumbar supports Exercises	Linton and van Tulder (2001)	*Back schools and education*: 6 of 8 RCTs did not find any significance differences on any of the outcome variables compared between back school intervention and usual care or no intervention or between different types of back schools. Only 1 RCT reported a significant positive effect on initial sick leave and duration of symptoms. 3 of 5 non-randomized controlled trials reported positive results on at least one variable. *Lumbar supports*: 4 RCTs and 2 non-randomized controlled trials. Results of 3 RCTs showed no significant differences on any of the outcome measures when lumbar supports were compared with no intervention. No effect was shown when compared with training or education on anatomy and body mechanics, and lifting instructions. The remaining RCT did not find any differences between lumbar supports and training on LBP prevention versus training only, but the supports reduced the number of days lost from work when compared with no intervention. The non-randomized controlled trials showed positive results for lumbar supports on the incidence of back pain and injury. Most of the subjects did not comply with wearing the lumbar supports. *Exercises*: 4 of the 5 studies comparing exercises with no intervention showed that exercises significantly reduced LBP and reduced work absenteeism. Findings from 1 study were inconsistent, but the between-group analysis by authors may not have been sufficient. 1 study showed that exercises were more effective than back school. Another study found little support for a preventive effect of exercise on pain when compared with advice and a free membership in a health club.	There was consistent evidence from RCTs that neither back schools nor lumbar supports were effective in preventing back pain or injury. There was consistent evidence that exercises were effective in the prevention of back pain.	
Secondary prevention Exercises Lumbar braces Education Workplace modification and education	Maher (2000)	*Exercise*: 4 of the 5 RCTs were low quality and 1 was high quality. 3 of the 4 low quality trials showed exercise reduced LBP prevalence. 1 high quality and 1 low quality trial found that exercise reduced the severity of LBP. 3 of 4 trials (including the high quality trial) showed exercise reduced sick leave. 1 RCT (of low methodological quality) that compared exercise with back school provided no dependable evidence on the effectiveness of either intervention. *Lumbar braces*: 4 trials evaluated efficacy of lumbar braces, 3 of 4 comparing a brace with a no brace control, and 3 of 4 evaluating the brace as a supplement to an education program. The use of braces alone or as a supplement to an education program was not effective in the prevention of LBP, LBP severity, sick leave due to LBP or costs of LBP compared to a no brace control. 1 low quality trial found that while the brace did not reduce the prevalence of LBP, it did reduce sick leave due to LBP. *Education*: 6 RCTs (4 of the trials also considered other preventive interventions already accounted for above). 2 trials evaluated efficacy of education as a supplement to lumbar brace and found no effect for LBP prevalence, severity, sick leave or costs due to LBP. Negative results were also found. In the trials that compared education with no intervention group, 10 of the 12 outcome comparisons demonstrated no effect for education. *Workplace modification and education*: 2 RCTs (1 reported more than 4,000 subjects for both groups and the other reported 205 for both groups). Both trials were of low quality and one trial did not provide any statistical analysis of results. Thus, there was no evidence for or against an effect of workplace modification and education on LBP prevalence.	Exercise was the only workplace intervention, which was effective to prevent LBP. Other interventions were either not effective or analysis were not adequately conducted. There was limited evidence that exercise reduces the prevalence of LBP. There was moderate evidence that exercise reduces sick leave due to LBP. There was limited evidence that braces were not effective in reducing the costs of LBP. There was moderate evidence that education was not effective in reducing the prevalence of LBP, sick leave or severity of LBP. There was limited evidence that education was not effective in reducing the costs of work-related LBP.	Moderate
Secondary prevention Back schools	Maier-Riehle and Harter (2001)	Significant effect of back schools on recurrence of back pain was reported for the time period up to 6 months. No documented significant effect for time period greater than 6 months. The number of studies or subjects with no LBP baseline were not provided. Likely, many would have previously had LBP, but the parameter of 'recurrence of back pain' implicitly refers to subjects without LBP at baseline; for such subjects the intervention was considered secondary prevention.	In a time-limited fashion, back schools were effective in preventing recurrence of back pain.	
Primary and secondary prevention Chair with no lumbar support Static office chair with back rest Dynamic office chair with back rest	O'Sullivan et al. (2012)	*Chair with no lumbar support* vs *same chair with static lumbar support*: No significant difference. *Chair without lumbar support continuous passive motion*: No significant difference. *Static office chair with backrest*: Significantly increased LBD with dynamic sitting. *Dynamic office chair with back rest* vs *motor driven seat*: No significant difference. *Car seat with lumbar support continuous passive motion* (*BackCycler*): Significantly decreased LBD with dynamic sitting. *Static office chair with back rest and motor-driven seat*: Decreased LBD with dynamic sitting. *Two dynamic chairs with back rest* (*one had a seat and back rest moveable in a fixed ratio to one another and the other had a freely moveable seat and back rest* vs *static office chair*): No significant difference.	Dynamic sitting did not significantly reduce LBP or LBD.	High

Table 2 (*continued*)

Prevention categories and intervention types	Author (year)	Authors' main results	Authors' conclusions	Quality rating of review
Primary and secondary prevention Exercise Exercise and education Education Back belt Shoe insoles Other LBP prevention strategies	Steffens et al. (2016)	*Exercise* vs *control, minimal intervention, or other intervention*: 4 trials provided low quality evidence of a short term (<12 months) protective efficacy of exercise on incident cases of LBP (RR 0.65; 95% CI: 0.50 to 0.86). 2 trials showed very low quality evidence of no effect of exercise (RR 1.04; 85% CI: 0.73 to 1.49). 2 trials showed very low quality evidence that exercise reduced the risk of sick leave due to LBP in the long term (>12 months) (RR 0.22; 95% CI: 0.06 to 0.76). *Exercise and education* vs *control, minimal intervention, or other intervention*: 4 trials showed moderate quality evidence that exercise and education reduced the risk of LBP episode at short term follow-up (RR 0.55; 95% CI: 0.41–0.74). 2 trials provided low quality evidence of a protective effect (RR 0.73; 95% CI: 0.55 to 0.96). 3 trials at short term follow-up and 2 trials of long-term follow-up reported low quality evidence of no protective effect of exercise on sick leave at short term follow-up (RR 0.74; 95% CI: 0.44 to 1.26) or long term follow-up (RR 0.72; 95% CI: 0.48 to 1.08), respectively. *Education* vs *control, minimal intervention, or other intervention*: 3 trials at short term follow-up and 2 trials at long term follow-up (LBP episode) provided moderate quality evidence of no protective effect of education at either short term follow-up (RR 1.03; 95% CI: 0.83 to 1.27) or long term follow-up (RR 0.86; 95% CI: 0.72 to 1.04). A single trial, not included in the meta-analysis, provided moderate quality evidence of no protective effect of education at long term follow-up (RR 1.11; 95% CI: 0.90 to 1.37). 2 trials provided very low quality evidence of no protective effect of education on sick leave due to LBP at short term follow-up (RR 0.87; 95% CI: 0.47 to 1.60). *Back Belt* vs *control, minimal intervention, or other intervention*: 2 trials showed very low quality evidence of no short term effect of back belts over controls (RR 1.01; 95% CI: 0.71 to 1.44). At long term follow-up, a single trial provided moderate quality evidence that back belts do not reduce the risk of LBP episodes when compared with controls (RR 0.85; 95% CI: 0.64 to 1.14). A single trial provided low quality evidence of no effect of back belts compared with controls at short term follow-up (RR 1.44; 95% CI: 0.73 to 2.86). *Shoe Insole* vs *control, minimal intervention, or other intervention*: 4 trials showed low quality evidence that shoe insoles did not prevent LBP versus control at short term follow-up (RR 1.01; 95% CI: 0.74 to 1.40). *Other LBP prevention strategies*: A workplace program (moderate quality evidence) was not effective in reducing episodes of LBP at short term follow-up compared to controls (OR 1.23; 95% CI: 0.97 to 1.57). Due to very low quality evidence (RR 0.95; 95% CI: 0.51 to 1.76) it was unclear whether LBP-associated sick leave can be prevented by education, training, or ergonomic adjustments.	There was low quality evidence that exercise alone was effective in the prevention of LBP. There was moderate quality evidence that exercise in combination with education was effective in the prevention of LBP. The evidence for other interventions, including education alone, back belts, and shoe insoles, was inconclusive because of low quality studies. The effect of education, training, or workplace adjustments on prevention of sick leave is uncertain, because the quality of evidence is low.	High
Secondary prevention Educational interventions Exercise Back belt Multidisciplinary interventions Pamphlet	Tveito et al. (2004)	*Educational interventions*: 10 studies. Out of 6 studies reporting on sick leave due to LBP, 2 studies reported a non-significant positive effect in the intervention vs the control groups. Regarding costs, 3 of 4 studies reported a significantly positive effect and 1 study did not find any significant effects on costs. 2 out of 6 studies showed educational intervention reduced episodes of LBP. 1 study showed a significant reduction in pain in the intervention group compared to controls while two studies did not find any significant difference in pain between the groups. *Exercise*: 6 studies. 2 studies showed that exercise had a significant effective on sick leave, but with a risk of selection bias and low scores on internal validity. 2 studies showed that exercise had a significant cost savings. 3 studies reported a significant effect of exercise on new episodes of LBP. 3 studies showed no significant differences between exercise and control group on pain due to LBP. *Back belt*: 5 studies with low compliance. 1 study demonstrated a significantly positive effect of back belt on sick leave compared to the control group while 2 studies did not find any significant differences. 1 study found no significant effect of back belt on costs. 2 studies found no effect of back belts on new episodes of LBP; one study showed a significant effect but had a low methodological score. *Multidisciplinary interventions*: Of 2 studies, 1 study found no significant difference between the 2 groups on sick leave, but demonstrated a clinically important positive effect on the level of pain. The other study showed positive effects on costs and new episodes of LBP. *Pamphlet*: 1 methodologically weak study showed no significant difference between a pamphlet and control group on LBP-associated sick leave.	There was a non-significantly positive effect of education on sick leave. Educational interventions did not reduce costs due to LBP. There was limited evidence for no effect of educational interventions on new episodes of LBP. There was no evidence for an effect of educational interventions on pain levels. There was limited evidence for a positive effect from exercise on sick leave, costs, and new episodes of LBP. There was no evidence of effect of exercise on level of pain. There was limited evidence that multidisciplinary interventions have no effect on sick leave, no evidence for effect on costs or new episodes of LBP, and limited evidence of effect on level of pain. In addition, there was no evidence of the effect of an information pamphlet on sick leave due to LBP.	

(*continued on next page*)

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Table 2 (*continued*)

Prevention categories and intervention types	Author (year)	Authors' main results	Authors' conclusions	Quality rating of review
Secondary prevention Lumbar supports	van Duijvenbode et al. (2008)	3 of 5 studies, one of high quality, comparing lumbar supports with a no intervention group, reported no significant differences in long term back injury or incidence of LBP. 1 study used 2 control groups: 1 group had a safety meeting with information about low-back health and the other group was passively followed and not informed about the study. The study reported a difference in long term back injury between those who wore lumbar supports and the control informed group, and no significant differences between those who wore lumbar supports and the advice group. Concerning short term (<12 months) sick leave, 1 study did not find any significant difference between the group that wore lumbar supports and the advice group. 3 RCTs did not find any significant difference in long term (>12 months) sick leave between those who wore lumbar supports and those who had no intervention. When compared to other prevention interventions, lumbar supports did not lead to significant differences between intervention and control groups assessing LBP incidence and sick leave due to LBP for long term period. When lumbar support plus back school was compared to back school alone, 1 study found significant differences in the number of days lost from work due to back injury in the long term but no significant differences in the incidence of LBP. A study on lumbar support plus usual care versus usual care alone found significant differences of the former group versus the latter group in the number of days with LBP and functional status in the long term, but no significant effect in long term sick leave.	There was moderate evidence that lumbar supports did not prevent short and long term incidence of LBP or sick leave when comparing lumbar support groups and no intervention groups. There was moderate evidence that lumbar supports were not more effective than training in lifting techniques to prevent long term LBP and sick leave. There was limited evidence that lumbar supports plus back school reduced the number of days lost from work due to back injury in the long term more than back school alone, but not affecting the incidence of LBP. There was limited evidence that lumbar supports plus usual care reduced the number of days with LBP and improve functional status in the long term better than usual care alone, but were not better at reducing long term sick leave.	High
Secondary prevention Lumbar supports Education Exercise	van Poppel et al. (2004)	*Lumbar supports*: 1 of 4 RCTs reported that in combination with education, lumbar support had a positive effect on the number of days lost from work but not on the incidence of LBP. The other 3 RCTs and non-randomized controlled trials reported no significant effect of lumbar supports on incidence of LBP or sick leave. 2 RCTs reported that subjects at high risk for LBP due to a history of back pain benefited from lumbar supports compared to control intervention. Compliance to wear lumbar supports was very low. *Education*: None of 6 RCTs showed any significant effect of education on reduction of back pain incidence or absenteeism. *Exercise*: All 4 RCTs reported that exercise reduces incidence of LBP, although the effect was not always statistically significant.	There was no evidence for the effect of lumbar supports in the prevention of LBP. There was no evidence of effectiveness of education for prevention of back pain. There was limited evidence for the effectiveness of exercise for the prevention of LBP.	
Secondary prevention Environmental interventions Behavioral interventions	Verbeek and Ivanov (2013)	*Environmental interventions*: A review on the effectiveness of participatory ergonomic interventions included 7 studies with mixed results, but the authors concluded that participatory interventions were effective. A more recent review of ergonomic interventions to prevent back pain in workers included 10 RCTs and concluded that these interventions were no more effective than no intervention. *Behavioral interventions*: 6 RCTs of education for correct lifting showed no evidence of a preventive effect on back pain. Training in manual handling of patients or materials does not lead to a reduction of back pain or back injury.	This is a review of reviews. The available reviews did not provide evidence that back pain can be prevented by the investigated.	Low
Mixed prevention Educational training MMH training Exercise training	Clemes et al. (2010)	Educational training was not effective in reducing LBP. Workplace and laboratory intervention showed MMH training did not prevent the development of LBP. Exercise training at the workplace showed promise to prevent back injuries.	There was very little evidence for the effectiveness of educational- and technique-based manual handling training in all industries. MMH training was largely ineffective in reducing back pain and back injury. Exercise interventions showed promise in the prevention of LBP.	High
Baseline characteristics not reported Back belt Education and task modification Education and task modification with workplace with workstation redesign	Gatty et al. (2003)	*Back belt*: 4 studies. No significant difference in number of self-reported back injuries or LBP was identified between the groups. Another study reported a 34% decrease in back injury rates between years with no back support use (30.6 units of incidence/million working hours) and years with back support use (20.2 units of incidence/million working hours). One study showed that back belt use reduced the number of days per month of reported back pain compared to the no back belt group, 1.2 vs. 6.5 days per month; 62% indicated that back belts provided support for the back. Another study found no significant differences in back pain (OR 0.99; 95% CI: 0.85 to 1.14) and back injury claims (RR 1.20; 95% CI: 0.87 to 1.65) between a 'high compliance level' and a 'low compliance level' groups. No significant differences were reported in back pain (OR 0.81; 95% CI: 0.82 to 2.84) and back injury claims (RR 1.53; 95% CI: 0.58 to 1.14) between the two compliance level groups for the subgroup of heavy material handlers.	The effectiveness of back belt to prevent back pain and injury remained inconclusive. Positive outcomes were associated with studies reporting high compliance that used job-specific and individualized/small group education and training approaches.	

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Table 2 (*continued*)

Prevention categories and intervention types	Author (year)	Authors' main results	Authors' conclusions	Quality rating of review
		Education and task modification: 3 studies (702 subjects; 1 study did not report the number of subjects). One study on nurses showed that 1 year post a 3-year combined education training program led to a significant increase in the frequency of registered nurses' (~48%–~60%) reporting back pain (p = 0.007). There was no significant change in frequency of state enrolled nurses compared to auxiliary nurses reporting pain. Another study where lift teams were implemented to reduce lifts by nurses led to a 69% decrease in the number of lift-related back injuries, a 90% decrease in lost workdays, a decrease in LBP incidence by 62.5%, a decrease in compensation costs due to LBP by 31%–100%. In another study, back injuries decreased from 5 to 6 to 1–2 per year within the Offshore Business Unit Wellness Program (OBUWP) group of a subset of Amoco Corporation. However, there was no statistically significant difference between OBUWP and Amoco Corporation's back injury rates. *Education and task modification with workstation redesign*: Two studies. There was a statistically significant increase in the knowledge of safe work behaviors in experimental vs. control workers at midpoint of intervention. No statistically significant difference in rate of task-specific back injuries between intervention and control groups (RR 0.97; 95% CI: 0.79 to 1.3) was reported. The proportion of back injuries resulting in lost workdays was 61% for the intervention group and 56% for the control group. In another study, there was a statistically significant (p = 0.01) gain in knowledge of occupational risk factors related to back injury. Trainees in the low patient transfer departments who received the intervention reported significantly fewer back pain days (p = 0.024) than controls in same departments. There was a 30% reduction in the number of lost time back injuries for all employees, pre to post-training, and a 73% decrease in the number of lost workdays per back injury for all employees pre to post-training. No significant difference was found in the number of back pain days (p = 0.69) between trainees and controls in the high patient transfer departments.		
Mixed prevention	van Dieen et al. (1999)	There was no statistically significant difference between the stoop or squat technique in the prevalence of LBP. Squat lifting may be advantageous for a limited range of lifting tasks in which the load can be lifted from between the feet (up to 34% reduction in net moment).	Available evidence did not provide support for advocating the squat technique as a means of preventing LBP compared to the stoop technique.	Low

Abbreviation: CI: confidence interval; EC: exclusion criteria; HR: hazard ratio; IC: inclusion criteria; LBD: low back disorder; LBP: low back pain; MMH: manual material handling; OR: odds ratio; RCT: randomized control trial; RR: risk ratio (relative risk); SMD: standardized mean difference.

[a] Data on treatment interventions were not extracted.

[b] Data on neck pain, children and treatment (rather than preventive) interventions were not extracted.

knowledge to subjects on the anatomy of the back, instructions on effective lifting and handling of materials, and information on potential causes of LBP. This primarily enables workers to develop abilities to adapt to the work environment, which may ultimately lead to prevention of occupationally induced LBP (Deyo & Diehl, 1988). The different forms of educational interventions were described by 18 of the included systematic reviews which comprised 6 high quality (Ainpradub et al., 2015; Clemes et al., 2010; Dawson et al., 2007; Steffens et al., 2016; van Poppel et al., 2004; Verbeek et al., 2011), 9 moderate quality (Bigos et al., 2009; Demoulin et al., 2012; Gatty et al., 2003; Gebhardt, 1994; Henrotin et al., 2006; Lahad et al., 1994; Linton & van Tulder, 2001; Maher, 2000), and 3 low quality reviews (Karas & Conrad, 1996; van Dieen et al., 1999; Verbeek & Ivanov, 2013). The specific interventions reported include educational programs such as back schools (30 studies, more than 9,973 subjects; number of subjects not described in one study), manual material handling (MMH) techniques or advice (24 studies, 10,505 subjects), and other types of instruction (14 studies with 11,991 subjects) including pamphlets, booklets, videos, and e-mail discussions aimed at providing knowledge on how to prevent LBP at the workplace (Table 1).

Of the included reviews in this category, two (one of high quality (Verbeek et al., 2011) and the other of moderate quality (Bigos et al., 2009)) reported on educational interventions in subjects with no history of LBP. Findings from Verbeek et al. (2011) demonstrated that MMH advice in the intermediate term (3 to 12 months) or long term (>12 months) did not change the incidence of back pain and the back injury rate compared to no intervention (5 studies, 13,926 subjects). Additionally, these authors showed that MMH advice was not effective in preventing back-related disability at intermediate term follow-up (3 to 12 months). There were no statistically significant differences in the incidence of back pain and back pain-related disability between an extensive MMH training group and a group that received minor advice. In addition, for subjects who received MMH advice, there was no statistically significant difference compared to a back belt group in the incidence of back pain (2 studies, 658 subjects). When MMH advice was combined with MMH devices, there was again no statistically significant difference in the incidence of back pain or back-related disability compared to MMH advice alone or a no intervention group (1 study, 346 subjects). In support of these findings, Bigos et al. (2009) also showed that back education as well as MMH training were not effective in the prevention of LBP (4 studies, 1,982 subjects). Altogether, these findings demonstrate that MMH training and advice are not effective in the prevention of LBP incidence and LBP associated disability.

Thirteen reviews also investigated the effect of education and behavioral interventions in the prevention of LBP in a mixed primary prevention and secondary prevention population of subjects. Four of the reviews were of high quality (Ainpradub et al., 2015; Dawson et al., 2007; Steffens et al., 2016; van Poppel et al., 2004), seven were moderate quality (Demoulin et al., 2012; Gebhardt, 1994; Henrotin et al., 2006; Lahad et al., 1994; Linton & van Tulder, 2001; Maher, 2000; Tveito et al., 2004), while two were low quality (Karas & Conrad, 1996; Verbeek & Ivanov, 2013). Specific education interventions included back schools where workers were taught anatomy and function of the back, advised on how to perform work with minimal mechanical constraints, especially proper lifting techniques, as well as promoting specific back exercises (Ainpradub et al., 2015). Other forms of information include booklets, leaflets, books, and videos, aimed at increasing subjects' knowledge about LBP (Henrotin et al., 2006). All the 13 reviews in this category demonstrated that educational programs were not effective in reducing the incidence and prevalence of LBP. However, there was limited evidence that educational interventions were effective in reducing costs and absenteeism compared to no intervention or other interventions. The reviews consistently showed that the educational intervention groups were more knowledgeable about LBP and back dynamics following the study period compared to the no intervention group. However, this knowledge did not seem to translate into the prevention of LBP and related disability.

Three reviews (one each of high (Clemes et al., 2010), medium (Gatty et al., 2003), and low methodological quality (van Dieen et al., 1999)) also reported on the effect of educational intervention in the prevention of back pain in a mixed primary prevention and secondary prevention population of subjects. Interventions consisted of both manual handling training techniques and instructions or advice on lifting strategy. All three reviews did not find that training and instructions on lifting were effective interventions for the prevention of LBP and back-related injuries. Van Dieen et al. (1999) (24 studies, more than 513 subjects, three studies did not report the number of subjects) compared two types of lifting techniques, the stoop versus squat lifting techniques, and provided no evidence to support either technique as an effective lifting strategy to prevent LBP over the other (Table 2).

3.5. Exercise

Of the 28 reviews included in this overview, 12 described exercise interventions (35 studies with 19,330 subjects); 5 of the reviews were of high quality (Bell & Burnett, 2009; Choi et al., 2010; Dawson et al., 2007; Steffens et al., 2016; van Poppel et al., 2004), 6 were of moderate quality (Bigos et al., 2009; Gebhardt, 1994; Lahad et al., 1994; Linton & van Tulder, 2001; Maher, 2000; Tveito et al., 2004), and 1 was of low quality (Karas & Conrad, 1996). Although the type of exercise interventions and duration varied between studies, they were all aimed at preventing LBP and related disability. The specific exercise regimen reported in the reviews included strengthening and endurance (abdominal and back extensor muscles), stability and flexibility, calisthenics (exercises without the use of equipment), stretching, and cardiovascular fitness exercises. The duration and frequency of the exercise programs varied considerably from 3 months follow–up to 18 months follow–up, and 5 min to 60 min per session.

One high quality (Bell & Burnett, 2009) and one medium quality (Bigos et al., 2009) review (15 studies, 7,002 subjects) provided evidence of the effect of exercise on LBP in subjects with no LBP at baseline. Both reviews demonstrated moderate quality evidence of exercise to prevent episodes of LBP in the workplace.

Ten reviews described the effectiveness of exercise in the prevention of LBP in subjects with mixed characteristics at baseline (i.e., with or without a history of LBP). Three reviews were of high quality (Dawson et al., 2007; Steffens et al., 2016; van Poppel et al., 2004), six were of moderate quality (Choi et al., 2010; Gebhardt, 1994; Lahad et al., 1994; Linton & van Tulder, 2001; Maher, 2000; Tveito et al., 2004) while one was of low quality (Karas & Conrad, 1996) (16 studies, 8,905 subjects). All the reviews with the exception of one (Dawson et al., 2007) provided moderate quality evidence of a protective effect of exercise for the prevention of LBP. Exercise interventions were shown to be effective in the reduction of sick leave, incidence of LBP, and LBP recurrence (Choi et al., 2010). The one exception (Dawson et al., 2007), which showed that exercise programs were not effective in the prevention of LBP, was of moderate quality. Choi et al. (2010) demonstrated that exercise interventions following an episode of LBP, were effective in the reduction of the rate of recurrences at one year compared to no intervention (4 studies with 407 subjects). Regarding the follow-up period, the protective effect of exercise interventions in reducing incident cases of LBP was demonstrated in the short term (up to 12 months) when compared with no intervention (Steffens et al., 2016). There was low quality evidence of no long-term effect of exercise on LBP incidence, although the risk of sick leave due to LBP was reduced by exercise in the long term (>12 months) (Steffens et al., 2016). Although the overall methodological quality of the exercise programs in LBP prevention was moderate based on AMSTAR, the primary studies from which the conclusion was drawn were of low quality, as assessed by the review authors employing the method recommended by the Cochrane Back Review Group (Furlan, Malmivaara, Chou, et al., 2015; van Tulder et al., 2003).

When an exercise program was combined with education, there was moderate quality evidence that exercise and education reduced the risk of LBP episode during short term follow-up compared to control or minimal interventions (Bell & Burnett, 2009; Bigos et al., 2009; Steffens et al., 2016). During long-term follow-up, the evidence for efficacy of exercise in the prevention of LBP and accompanying disabilities of exercise was of low quality (Bell & Burnett, 2009; Bigos et al., 2009; Steffens et al., 2016).

4. Discussion

Low back pain is a multifactorial and debilitating disorder with high prevalence, exerting a huge socioeconomic burden on individuals and health care systems. In the present overview, various interventions aimed at the prevention of LBP that can be conducted at the workplace were assessed. The respective interventions were categorized into either primary or secondary prevention approaches based on the baseline characteristics of the study subjects. For primary prevention, the outcome measures assessed included incidence and prevalence of LBP while secondary prevention outcome measures included recurrence of LBP. In both cases, the impact of LBP, disability (such as work absenteeism and activity interference), and cost were also considered as outcomes. Our overview demonstrates that exercise alone or in combination with education was the only approach that could consistently be shown to be effective in the prevention of LBP.

Significant heterogeneity exists between the individual studies that were included in the systematic reviews, which we included in our overview. Specifically, heterogeneity exists regarding the baseline characteristics, the specific prevention intervention, comparison group, outcome measures, and outcome assessment time points (short-term and long-term). The heterogeneity between studies may be attributable partly to the systematic review methods employed by the review authors and, in particular, their eligibility criteria for study inclusion. One can speculate that permissive inclusion criteria may have been informed by the relative dearth of (high-quality) studies. After thorough consideration of the available data, quantitative meta-analysis did not appear meaningful and was therefore not undertaken. We acknowledge that this is a limitation to our information synthesis.

Regarding the use of assistive devices and other technologies, the findings in the overview overall showed no evidence of a preventive effect. Lumbar support as an approach to prevent LBP in the workplace has recently gained popularity but the evidence to support its application is, at best, conflicting (Ammendolia et al., 2005; Jellema, Van Tulder, Van Poppel, Nachemson, & Bouter, 2001; Linton & van Tulder, 2001). In keeping with our findings, both the U.S. National Institute for Occupational Safety and Health (NIOSH) and the Canadian Centre for Occupational Health and Safety recommend against the use of back belts as a preventive measure at the workplace (Canadian Task Force on Preventive Health Care, 2003; Wassell, Gardner, Landsittel,

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Johnston, & Johnston, 2000). Furthermore, European guidelines do not recommend lumbar supports for the prevention of LBP (Burton et al., 2005). Methodological issues may be important in this context; low compliance by study subjects to wear back belts may play a role (Reddell, Congleton, Dale Huchingson, & Montgomery, 1992; van Poppel, Koes, van der Ploeg, Smid, & Bouter, 1998). In addition, trials that assess the effectiveness of lumbar supports on LBP have a high dropout rate (Ammendolia et al., 2005). The specific lumbar supports employed varied between the primary studies of the included systematic reviews. The lumbar support devices worn by study subjects included braces, back belts, and corsets, worn for various time periods and with different follow-up periods. The occupations of the subjects ranged from hospital workers, warehouse workers, postal workers, to baggage handlers. These occupational groups would all engage in some form of manual handling. The findings from these studies may therefore be generalizable to manual material handlers. In view of the between-study heterogeneity we identified, future trials of the effectiveness of lumbar supports should clearly define the baseline characteristics of the study participants.

The rationale for the use of shoe insoles or foot orthoses stems from the hypothesis that the function of the foot is linked to the etiology of LBP development (Botte, 1981). It has been suggested that the degree of pronation of the foot may induce a strain on the spine, which may lead to LBP. Our observation demonstrated that, the four reviews that evaluated the effectiveness of shoe insoles, inserts or orthoses found no evidence to support their application in the workplace (Bigos et al., 2009; Chuter et al., 2014; Sahar et al., 2007; Steffens et al., 2016). Our overview revealed that the four systematic reviews that evaluated the use of insoles and foot orthoses to prevent the risk of LBP development (incidence) used the same trials to arrive at the conclusion that insoles are not effective to reduce the incidence of LBP. The conclusion was, however, limited by the small number of included studies in the reviews, the heterogeneity that existed in the design of the shoe insoles, and the variability in time period of using the insoles. Moreover, the subjects in the primary studies for all these reviews were mainly (presumably healthy) male military personnel, which may limit the generalizability of the findings to the general population. Thus, the available evidence cannot definitely answer the question of whether shoe insoles are effective as prevention modality against LBP in other occupational settings. Future studies in other occupational settings employing identical or at least substantially similar shoe inserts, outcome measures, and follow-up periods may be helpful to assess the overall effectiveness of insoles in the prevention of LBP.

Workplace modification generally involves the redesign of the work environment to provide a suitable space to prevent or minimize potential risk factors for LBP. The reduction of risk factors may occur at the level of the individual or the organization (workplace setting). Individual risk factors that could in theory be modified include smoking (Shiri, Karppinen, Leino-Arjas, Solovieva, & Viikari-Juntura, 2010), obesity, and psychological factor (Driessen et al., 2010; Lahad et al., 1994). Modifiable organizational risk factors vary from the concept of matching the individual to the occupational task, behavioral, and psychological changes, to providing ergonomic interventions (Driessen et al., 2010). None of the included reviews provided dependable evidence to support an effect of workplace modification or task modification intervention in the prevention of LBP. Here, it must be noted that very few high quality primary studies exist to assess the effectiveness of workplace modification and task modification (Driessen et al., 2010; Gatty et al., 2003). Furthermore, the number of study subjects in the available trials is comparatively small. This may be due to challenges in conducting high quality studies on this research question; for example, there may be issues with conducting randomization and blinding of the individual subjects. According to Driessen et al. (2010), a number of factors could be attributed to the lack of effect of workplace interventions for the prevention of LBP. These factors included the level of exposure to the occupational risk factors, the inadequacy of the intervention to target the important risk factors, the proper experimental design, and the compliance of the experimental subjects. One may also speculate that the paucity of primary studies could be due to the result of lack of funding or academic interest in the field. Therefore, the evidence regarding redesigning the workplace as a preventive approach can be regarded, at this time, as insufficient to draw definitive conclusions.

Educational interventions were also not effective in the prevention of LBP based on moderate quality evidence. The particular education interventions identified in the present overview included back schools, dissemination of information in the form of videos and pamphlets, instruction, and training on proper lifting technique. Back schools were originally established to offer lessons on back anatomy and dynamics as well as education on 'proper' exercise and lifting modalities (Heymans, van Tulder, Esmail, Bombardier, & Koes, 2005). Back school education has been employed as a therapeutic approach in the treatment of LBP. However, none of the available reviews demonstrated dependable evidence of efficacy for back schools in the treatment of LBP (Heymans et al., 2005; Poquet, Lin, Heymans, et al., 2016; Straube, Harden, Schroder, et al., 2016). In the present overview, we evaluated the effectiveness of back school as a preventive strategy and similarly found no dependable evidence for the prevention of LBP. An explanation for the lack of evidence to support back schools as a preventive approach may be that provision of knowledge does not necessarily mean application of knowledge (St-Vincent, Tellier, & Lortie, 1989). This was evidenced by studies that showed that the knowledge acquired during back education was not necessarily applied at the workplace (Ainpradub et al., 2015; Demoulin et al., 2012; Steffens et al., 2016). Furthermore, the knowledge acquired through back schools may not apply to the specific workplaces or exposures involved. Although there was evidence that subjects receiving such education had increased knowledge about back anatomy and occupationally-induced LBP development, there was no effect on LBP prevention (Henrotin et al., 2006). Similarly, instructions and training offered on proper lifting techniques to manual material handlers were not effective in the prevention of LBP.

Moderate quality findings from our overview indicated that exercise interventions were effective in the prevention of LBP occurrence and recurrence, leading to a reduction in lost time and disability associated with back pain. The reasons for the effectiveness of exercise in the prevention of LBP may relate to strengthening the back and increasing trunk flexibility; increasing blood supply to the spine muscles, joints and intervertebral disks; and improving mood while altering the perception of pain (Lahad et al., 1994; Linton & van Tulder, 2001). In addition, exercise interventions could be effective because identifiable risk factors for LBP include low levels of physical fitness (Cady, Bischoff, O'Connell, Thomas, & Allan, 1979) and reduced static back muscle endurance (Luoto, Heliövaara, Hurri, & Alaranta, 1995). Other evidence suggests that 'stretch and flex' workplace exercise programs lead to improved safety culture and communication (Goldenhar & Stafford, 2015), which may lower back injury risk.

In general, exercise interventions tend to strengthen and precondition the muscles of the back, which may lead to a reduction of the factors that may predispose a subject to develop LBP. The evidence further demonstrated that the effectiveness of exercise interventions is apparent in the short term (up to 12 months) (Steffens et al., 2016). Whether the beneficial effect of exercise in the prevention of LBP can be sustained over the long term remains to be answered. In addition, the type, frequency, and duration of the particular exercise intervention that proved effective in the prevention of LBP and its associated disability are yet to be established. Generally, aerobic exercises (Lahad et al., 1994) and resistance training (Sjögren et al., 2006) were reported to be effective (Bigos et al., 2009; Steffens et al., 2016). In relation to duration, Bigos et al. (2009) reported that 5–17 min of exercise doses daily as well as 6 min of training per working day were effective

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in the reduction of LBP incidence. Our findings are consistent with European guidelines for prevention of LBP that recommended that physical activity and exercise be prescribed to workers (Burton, Balague, Cardon, et al., 2006).

As seen for other preventive interventions considered above, it is worth noting that the baseline characteristics of the study subjects of the primary studies of the systematic reviews, which we included in our overview, varied considerably. The workplace setting, the exercise regime and frequency, as well as the outcome measures were also heterogeneous across the various studies. This therefore limits the conclusion that could be drawn in the present overview regarding exercise interventions. Furthermore, not all exercise intervention may be applicable to all participants and different occupational settings. High quality randomized control trials that consider different exercise regimes incorporating varying duration, frequency, and intensity are therefore recommended for future studies.

Multidimensional strategies that involve more than one intervention have been proposed to be effective in the prevention of LBP. The rationale for this approach lies in the multifactorial nature of the etiology of LBP. However, our findings showed that exercise in combination with education was the only multidimensional approach for which there was dependable evidence that it was effective in the prevention of LBP. Bell et al. (Bell & Burnett, 2009) reported that exercise in conjunction with education was more effective in preventing episodes of LBP compared with education alone in agreement with findings by Steffens et al. (2016). None of the reviews that reported on this interventional strategy compared the difference between the effectiveness of exercise and education relative to exercise alone. Therefore, whether exercise combined with education is more effective than exercise alone remains to be determined by future research.

5. Conclusion

The main conclusions of the present overview are summarized in Table 3 below.

6. General comments and limitations

In the present overview, an attempt was made to draw a clear distinction between primary and secondary prevention interventions. However, this distinction was not always clear. For example, it is possible that reviews categorized as primary prevention in the present overview may have included participants with a history of LBP. This limitation could be overcome by a more detailed description of the subjects' characteristics in systematic reviews in LBP prevention.

As LBP prevalence increases with age, age should in future studies be accounted for in an assessment of the effectiveness of a given intervention (Hoy, Brooks, Blyth, & Buchbinder, 2010; Kent & Keating, 2005).

Lack of study subject adherence, as indicated in some studies (Robison & Rogers, 1994), may be due to lack of motivation or incentive of seemingly healthy and asymptomatic subjects to engage in preventive interventions. Researchers, and employers, may therefore consider providing additional incentives at the workplace to enhance participation in workplace interventions to prevent LBP.

Table 3
Summary of interventions for the prevention of LBP and their effectiveness.

Intervention	Conclusion
Exercise (stretching, flexibility, endurance)	Evidence of effectiveness
Exercise and education	Evidence of effectiveness
Education (booklets, back schools, videos)	Evidence of no effectiveness
Foot orthoses or shoe insoles	Evidence of no effectiveness
Lumbar support (back belts, braces, chair back rests)	Evidence of no effectiveness
Workplace modification	Evidence available but no clear conclusions can be drawn

Due to a high level of heterogeneity between studies regarding intervention type, duration and frequency together with differences in the baseline characteristics of subjects and in the workplace settings, our synthesis of the research findings made use of a qualitative and descriptive approach, meta-analysis across reviews was not deemed feasible.

Since most of the included reviews reported on trials with short-term follow-up, further, long-term studies are needed in the future.

Confounding factors among study subjects may have contributed to the heterogeneity in the findings. For instance, lifestyle factors, genetic make-up, and the load that may provoke back pain may vary considerably among individual participants undergoing the same intervention. These confounders may be difficult to control under experimental conditions, but may still affect the conclusions of the systematic reviews and ultimately our overview.

7. Practical application

The present overview provides moderate quality evidence that exercise interventions are effective in the prevention of LBP and its associated disability and workplace impact, at least in the short term. Exercise programs in combination with education are more effective in the prevention of LBP compared to education alone, lending support to this multidimensional approach for the occupational prevention of LBP.

No precise conclusions can be drawn on the particular exercise program that would be most effective in preventing LBP in workers in different occupational settings. Based on data from Bell and Burnett (2009), exercise programs conducted for shorter durations (5 to 10 min) were found to be beneficial.

Following the proven effectiveness of the exercise regimen in question (this would require further research), employers could then provide incentives to employees to facilitate implementation and adherence to that exercise regimen. There is, however, the need for high quality research on best-practice implementation approaches for workplace programs and related exercise interventions that will fit the context of a given workplace.

Researchers conducting primary research in the field should be encouraged to specify clearly defined and detailed criteria for including participants in their studies. The interventions and the outcome measures should also be described in sufficient detail to enable comparison between them. The studies conducted should include both short term and long-term follow-up.

Systematic reviewers should explicitly state eligibility criteria and ensure that the quality of each included study is assessed with validated tools.

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Declaration of interest Q8

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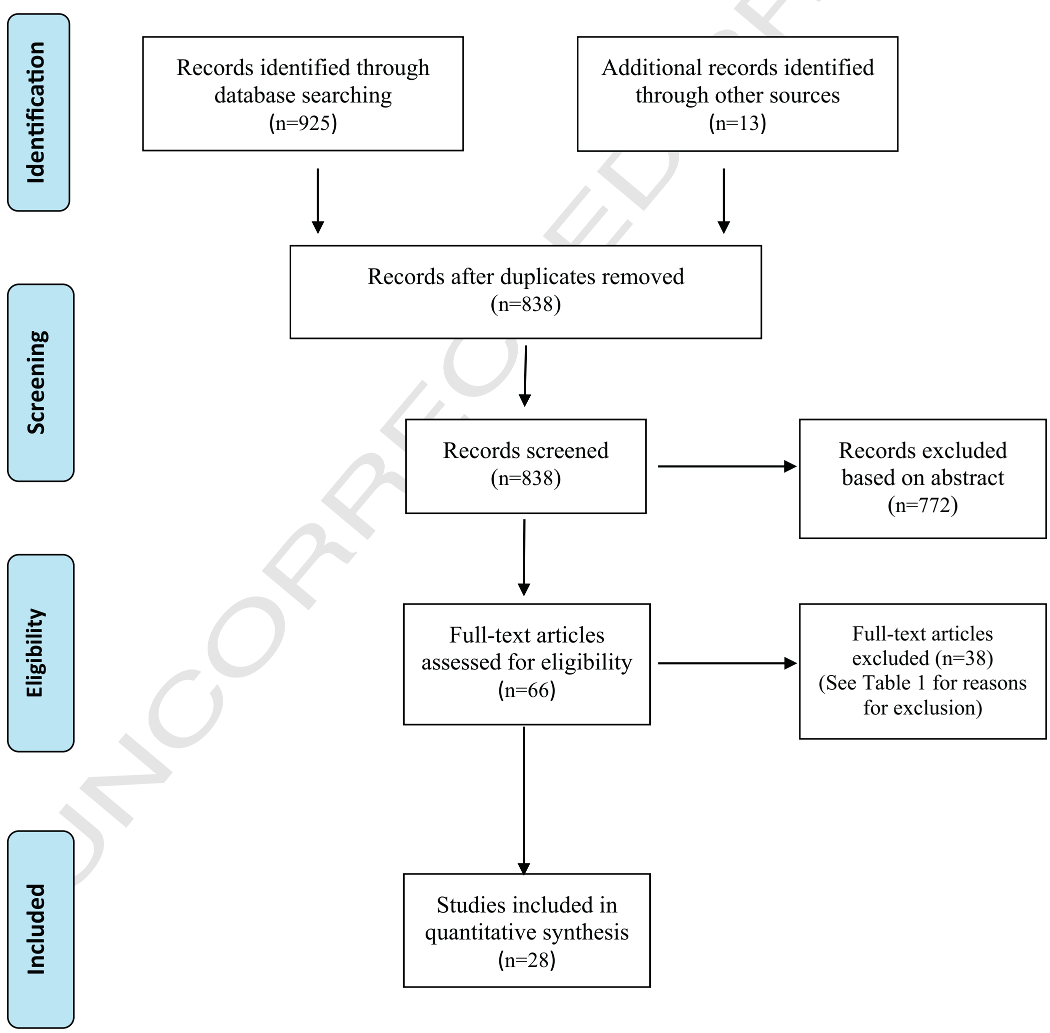
Appendix A



From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). *P*referred *R*eporting *I*tems for *S*ystematic Reviews and *M*eta-*A*nalyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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Fig. 1. Study selection.

Appendix B. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsr.2018.05.007.

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David Antle (PhD, MSc, BSc) holds a PhD in Kinesiology from McGill University and a Master's of Science in Kinesiology from Memorial University, specializing in occupational biomechanics and ergonomics. David's research interests relate to prevention of work-related musculoskeletal disorders, identification of biological markers that relate to work-related injury, and review of knowledge translation and exchange systems to improve workplace injury prevention. David is an associate researcher with EWI Works International Inc. in Edmonton, Alberta, Canada, and has worked as a certified professional ergonomist in many industrial settings. Currently, David is enrolled in the Doctor of Medicine program at the University of Alberta.

Linda Miller (OTD, OT(c), MSc) is a certified Ergonomist and Occupational Therapist at EWI Works International Inc. for the past 25 years. She works extensively in injury prevention in the workplace. Industry experience ranges from mining to manufacturing environments focusing on ergonomic program development and education and training. She received her undergraduate degree in Occupational Therapy from the University of Alberta, Masters in Environmental Design from the University of Calgary and a Doctor of Occupational Therapy from Boston University. She is an Adjunct Professor in the Faculty of Rehabilitation Medicine at the University of Alberta. She is also a member of the Editorial Board of WORK: A Journal of Prevention, Assessment, and Rehabilitation.

Michael Zakhary (MD, MPH) graduated from the Faculty of Medicine, University of Alexandria, Egypt with distinction, and earned a Master's degree in Public Health from the High Institute of Public Health at the same University. He worked as a general practitioner and a Public Health specialist until he moved to Canada. He then joined the Public Health and Preventive Medicine residency program at the University of Alberta in 2015. Dr. Zakhary is currently in his second year of residency training, and is doing a Master's degree in Public Health focusing on Health Policy and Management at the School of Public Health, University of Alberta.

Sebastian Straube (BM BCh, MA (Oxon), DPhil) holds degrees in Medicine and Physiological Sciences from the University of Oxford (England) where he also did his DPhil (PhD). After clinical work and research at the Oxford Radcliffe Hospitals, Dr. Straube joined the Institute of Occupational, Social and Environmental Medicine at the University Medical Center Göttingen, Germany. Here he completed his Habilitation (German postdoctoral qualification) and his postgraduate medical training in the specialties of Occupational Medicine and Social Medicine. Dr. Straube was an Extraordinary Professor at the University of Göttingen until he took up his current post as Associate Professor in the Division of Preventive Medicine of the University of Alberta, Canada, in 2014. He was appointed as Division Director for Preventive Medicine in 2016. Dr. Straube's primary research interest is in evidence-based medicine (systematic reviews and meta-analyses).