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Review

Risk Factors for Work-Related Musculoskeletal Disorders: A Systematic Review of Recent Longitudinal Studies

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Objective *This systematic review was designed and conducted in an effort to evaluate the evidence currently available for the many suggested risk factors for work-related musculoskeletal disorders.*

Methods *To identify pertinent literature we searched four electronic databases (Cinahl, Embase, Medline, and The Cochrane Library). The search strategies combined terms for musculoskeletal disorders, work, and risk factors. Only case–control or cohort studies were included.*

Results *A total of 1,761 non-duplicated articles were identified and screened, and 63 studies were reviewed and integrated in this article. The risk factors identified for the development of work-related musculoskeletal disorders were divided and organized according to the affected body part, type of risk factor (biomechanical, psychosocial, or individual) and level of evidence (strong, reasonable, or insufficient evidence).*

Conclusions *Risk factors with at least reasonable evidence of a causal relationship for the development of work-related musculoskeletal disorders include: heavy physical work, smoking, high body mass index, high psychosocial work demands, and the presence of co-morbidities. The most commonly reported biomechanical risk factors with at least reasonable evidence for causing WMSD include excessive repetition, awkward postures, and heavy lifting. Additional high methodological quality studies are needed to further understand and provide stronger evidence of the causal relationship between risk factors and work-related musculoskeletal disorders. The information provided in this article may be useful to healthcare providers, researchers, and ergonomists interested on risk identification and design of interventions to reduce the rates of work-related musculoskeletal disorders.* Am. J. Ind. Med. 53:285–323, 2010. *© 2009 Wiley-Liss, Inc.*

KEY WORDS: musculoskeletal disorders; risk factors; longitudinal; work

INTRODUCTION

Musculoskeletal disorders are injuries or dysfunctions affecting muscles, bones, nerves, tendons, ligaments, joints, cartilages, and spinal discs. Musculoskeletal disorders include sprains, strains, tears, soreness, pain, carpal tunnel syndrome, hernias, and connective tissue injuries of the structures previously mentioned. According to the National Institute for Occupational Safety and Health (NIOSH), several epidemiological studies have demonstrated evidence of a causal relationship between physical exertion at work and

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work-related musculoskeletal disorders (WMSD) [Bernard et al., 1997]. Several factors have been associated with WMSD such as repetitive motion, excessive force, awkward and/or sustained postures, prolonged sitting and standing.

In the US alone, more than 600,000 workers have WMSD resulting in days away from work each year [United Electrical Radio and Machine Workers of America, 1999]. Moreover, WMSD is the most expensive form of work disability [Thiehoff, 2002; Picavet and Schouten, 2003; Guo et al., 2004]. It was estimated that the cost of WMSD was approximately 215 billion dollars in 1995 in the US; 26 billion Canadian dollars in 1998 in Canada, and 38 billion Euros in 2002 in Germany [Coyte et al., 1998; Praemer et al., 1999; Thiehoff, 2002].

Each type of WMSD (e.g., low back WMSD, carpal tunnel syndrome, tendinitis, epycondilitis, etc.) has different risk factors. It is difficult for a single study to satisfy all criteria to determine a causal relationship between risk factors and WMSD. Thus, it is important to integrate information derived from different studies of factors contributing to different types of WMSD. This way, risk factors and the level of evidence of their relationship with each WMSD can be evaluated.

A previous thorough review published by NIOSH in 1997 included studies of risk factors for WMSD affecting the neck, the upper limbs, and the low back [Bernard et al., 1997]. The NIOSH report provides pivotal information on WMSD risk factors thanks to its extensive search of the literature and in-depth discussion regarding potential causal relationships between exposure to risk factors and WMSD. However, a substantive amount of epidemiological studies have been published since the release of the NIOSH report. Other reviews have also investigated a potential causal relationship between risk factors and WMSD affecting specific body parts such as the low back and the upper limbs [Hoogendoorn et al., 1999, 2000a; National Research Council and Institute of Medicine (NRC/IOM), 2001]. But no reviews of high methodological quality studies of risk factors for multiple body parts were found in the published literature after the NIOSH review.

Given the gap identified, our systematic review was designed and conducted in an effort to evaluate the evidence currently available in high methodological quality studies published after the NIOSH review (Bernard et al., 1997) of the numerous suggested risk factors for WMSD affecting different body parts. As it was done in the NIOSH report, we investigated and reported potential causal relationships between exposure to risk factors and development of WMSD. We also integrated the results of the previous body part-specific reviews by comparing those findings with our findings.

METHODS

Literature Search and Data Management

We searched four electronic databases (Cinahl, Embase, Medline, and The Cochrane Library) from January 1997 to March 2008 in order to identify studies evaluating risk factors for WMSD. Our strategy was to combine terms for musculoskeletal disorders, work, and risk factors. The terms included free text-words and subject headings specific to each database (Appendix 1). We based our procedure on guidelines for effective searching [Gallagher et al., 2002; Gillespie and Gillespie, 2003]. We also used information from the ''help'' section of each examined database, and consulted one medical librarian. All the titles identified were merged into RefWorks Web Based Bibliography Management Software (http://www.refworks.com/).

Inclusion and Exclusion Criteria

In this review, injuries due to slips, trips, falls, or similar accidents were not included. To be eligible the articles had to:

(1) be a case–control or cohort study of risk factors for WMSD precipitation in the adult population;
(2) be published in or after 1997, the year the NIOSH report was released [Bernard et al., 1997];
(3) report statistically significant association (i.e., odds ratio with confidence interval that does not include ''1.0'') between risk factor and WMSD;
(4) be peer reviewed;
(5) be published in English;
(6) be published in full text.

We did not include case series and cross-sectional studies as these designs are not ideal to identify determinants of a health condition [Walker-Bone and Cooper, 2005; Carroll et al., 2008]. Case–control and cohort studies are more appropriate to evaluate causality. They were defined according to Domholdt [2005].

Screening Process

Both authors screened independently and in duplicate the titles and abstracts of all identified citations and retrieved the full texts of all potentially eligible studies when available. The reference lists of all retrieved studies were screened for additional relevant articles. Both authors applied independently and in duplicate the eligibility criteria to all potentially eligible studies identified.

Both authors were blinded to each other's search process and results prior to the agreement analyses. Kappa statistics was used to calculate the chance-adjusted between-reviewer agreement on the selection of articles by applying the inclusion/exclusion criteria defined for screening titles and abstracts. Disagreements regarding study eligibility were resolved afterwards through discussions until consensus was reached regarding the inclusion or exclusion of each article.

Evaluation Process

The methodological quality of the eligible studies was evaluated in relation to whether they fulfilled the criteria for inference of causality or not, and to how likely misleading factors (chance, bias, and confounding factors) affected the results.

The criteria we used to evaluate a potential causal relationship included: strength of association, consistency between studies, temporality, dose–response relationship, and coherence [Bernard et al., 1997]. These criteria were established in accordance with the work of Hill [1965], the work of Lilienfeld and Lilienfeld [1980], and the NIOSH report [1997]. To fulfill the criterion ''strength of association,'' relative risks or odds ratio defining the association between exposure and outcome had to present a ratio of at least ''3.0'' and a confidence interval that did not cross ''1.0'' in at least one study. Risk factors were considered ''consistent'' if more than one study reported their association with the outcome of interest. Only risk factors identified in prospective cohorts were considered to have fulfilled the criterion ''temporality.'' To satisfy the ''dose–response relationship'' criterion, at least one study had to show evidence of a dose–response curve of the observed association (evidence that disorder is dose-dependent and aggravates as exposure increases or vice-versa). ''Coherence'' means that an association is consistent with the natural history and biology of the investigated disorder.

The five major misleading factors that we detected were: poorly defined case population, use of conventional stepwise regression, no assessment of variables' co-linearity, insufficient sample sizes (e.g., <15 subjects/variable), and insufficient response rates (e.g., $<70\%$ of eligible population enrollment or follow-up) [Greenland, 1989; Bernard et al., 1997; Field, 2005; Carroll et al., 2008].

We used a stringent classification of ''level of evidence'' in the present study in order to avoid ceiling effects. Risk factors identified in the included studies were classified as currently presenting either strong evidence, reasonable evidence, or insufficient evidence of their causal relationship with different types of WMSD.

- *Strong evidence risk factors*—satisfied at least four of the five criteria for causality and bias and confounding factors were controlled for or were not present (most of the studies presented no misleading factors).
- *Reasonable evidence risk factors*—satisfied at least one of the criteria for causality, but bias or confounding factors could not be completely ruled out (most of the studies presented 1–3 potentially misleading factors).
- *Insufficient evidence risk factors*—satisfied none of the criteria for causality or presented clear bias or confounding factors (most of the studies presented 4 or 5 potentially misleading factors).

RESULTS

Literature Search and Evaluation

Our search yielded 1990 references. The title and abstract screening resulted in 102 potentially eligible studies. In addition, we identified 36 additional potentially eligible studies from the reference lists of the 102 initially selected articles. Sixty-three studies were included, 51 (81%) had a prospective cohort design, 1 (2%) had a historical cohort design, and 11 (17%) had a case–control design.

The chance-adjusted between-reviewer agreement on the application of study inclusion criteria to the titles and abstract screening was substantial (kappa $= 0.70$) [Landis and Koch, 1977]. Figure 1 schematically presents the search and selection results.

Risk Factors for WMSD and Their Evidence by Body Part

We included 22 (35%) studies of upper limb WMSD; 12 (19%) studies of low back WMSD; 9 (14%) studies of WMSD in multiple body parts; 7 (11%) studies of neck WMSD; 6 (10%) studies of lower limb WMSD; 5 (8%) studies of non-specified WMSD, and 2 (3%) studies of work-related fibromyalgia. Our search did not yield any studies investigating ankle/feet WMSD that fulfilled criteria for inclusion in this review, thus lower limb studies refer only to hip and knee WMSD.

The risk factors identified were divided and organized according to (1) the affected body part (low back, neck, upper limbs, lower limbs, fibromyalgia, and non-specified WMSD); (2) the type of risk factor (biomechanical, psychosocial, or individual), and (3) the level of evidence supporting their causal relationship with a WMSD (strong, reasonable, or insufficient).

Tables I–IV present an overview of the selected studies per body part, including their design, population, outcomes measured, methods of risk factor assessment, and limitations. The risk factors that were commonly identified throughout all of the included studies were heavy physical work, repetitive work, awkward postures, smoking, high BMI, presenting co-morbidities, and high psychosocial demands. The next sections present our findings for each body part.

Spine

Table I presents an overview of the studies investigating risk factors for spine WMSD.

Neck. The biomechanical risk factors identified for the development of neck WMSD were heavy physical work, awkward posture, and frequent lifting. The psychosocial risk factors identified were low level of work satisfaction and

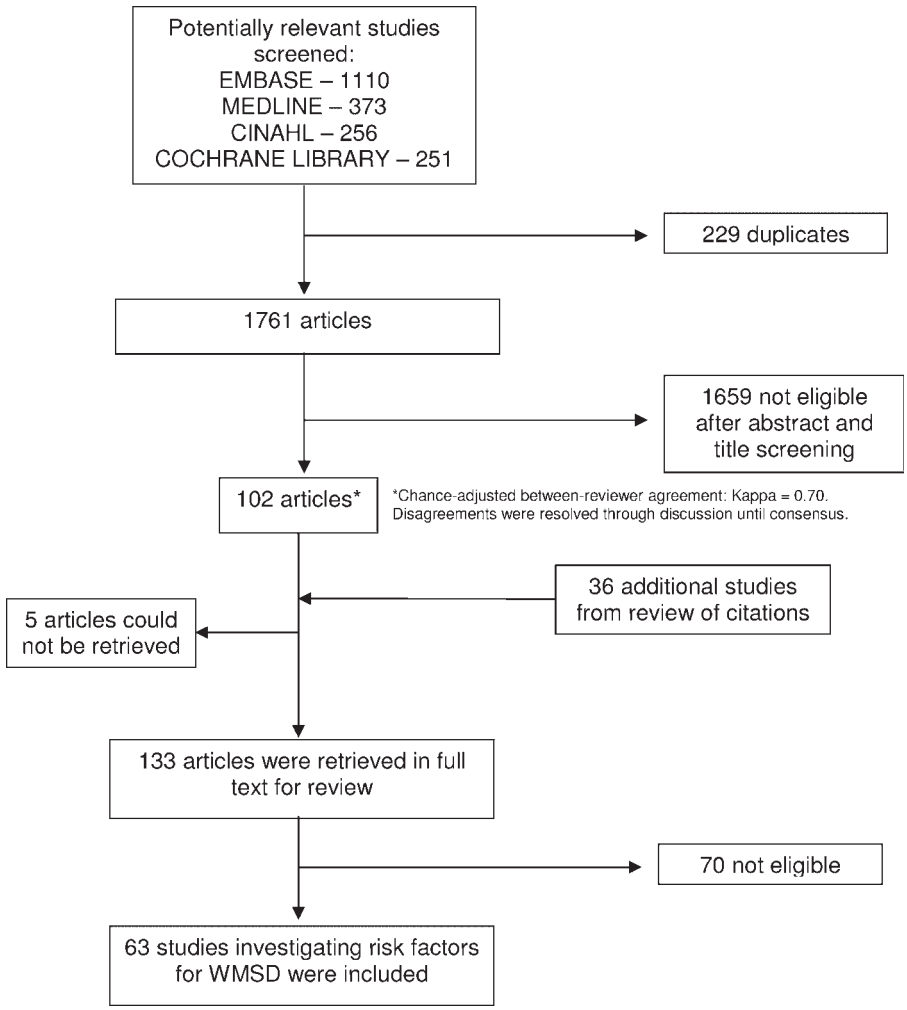

FIGURE 1. Stages of systematic review of studies investigating risk factors for WMSD.

support, and high level of distress. Individual risk factors identified were older age, female gender, sedentary lifestyle, high BMI, co-morbidity, and smoking.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Psychosocial factors	Heavy physical work
	Smoking	Lifting
	Gender	Sedentarism
	Posture	Older age
	Co-morbidity	High BMI

Low back. The main biomechanical risk factors identified for the development of low back WMSD were heavy physical work, awkward static and dynamic working postures, and lifting. The psychosocial risk factors identified were negative affectivity, low level of job control, high psychological demands and high work dissatisfaction. Individual risk factors identified were younger age, female gender, Black or African American race, smoking, high BMI, and co-morbidity.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Awkward posture	Gender
	Heavy physical work	Race
	Lifting	Smoking
	Psychosocial factors	Co-morbidity
	Younger age	
	High BMI	

Upper limbs

Table II presents an overview of the studies investigating risk factors for upper limbs WMSD.

Non-specified upper limb WMSD. The biomechanical risk factor for the development of non-specified upper limb

TABLE I. Overview of Studies Investigating Risk Factors for Spine Work-Related Musculoskeletal Disorders (WMSD)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Korhonen et al. [2003]	Neck WMSD	Gender	Prospective cohort	180 full-time working office employees in three administrative units of a medium sized city in Finland who were working >4 hr/week with VDUs	Ergonomic measurements and questionnaires to investigate physical risk factors in the workplace, psychological and psychosocial factors at work, health-related factors, and other individual factors	Use of stepwise regression
		Male (reference) OR: 1.0				Unclear case definition.
		Female OR: 6.7 (1.4–30.9)				
Viikari-Juntura et al. [2001]	Neck WMSD (radiating neck pain)	Posture	Prospective cohort	3,994 workers from a large forestry company in Finland	Questionnaire, to investigate physical risk factors in the workplace, physical activity, health-related factors, and other individual factors	Use of stepwise
		Working with a hand above shoulder level (hr/day) <0.5 (reference) OR: 1.0 >1 OR: 1.6 (1.3–2.0) Co-morbidities Previous radiating neck pain (days during preceding 12 months) 0–7 (reference) OR: 1.0 8–30 OR: 5.3 (4.5–6.3) >30 OR: 9.5 (7.8–11.6) Other musculoskeletal pain OR: 1.4 (1.3–1.5) Gender Female gender OR: 1.4 (1.2–1.6) Age (years) <35 (reference) OR: 1.0 35–44 OR: 1.4 (1.2–1.6) 45–54 OR: 1.7 (1.4–1.9) 55–64 OR: 1.4 (1.1–1.8) BMI (kg/m^2) <23.0 (reference) OR: 1.0 >29.0 OR: 1.3 (1.1–1.5) Psychological factor Mental stress Not at all (reference) OR: 1.0 Little OR: 1.3 (1.1–1.5) To some extend OR: 1.5 (1.3–1.8) Much OR: 1.7 (1.4–2.0) Self-assessed ability to work during the coming 5 years because of musculoskeletal health No problems OR: 1.0 Problems possible OR: 1.5 (1.4–1.7) Problems likely OR: 2.0 (1.6–2.5)				

(*Continued*)

TABLE I. (*Continued*

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Ariens et al. [2001]	Neck WMSD	Psychosocial factor Quantitative job demands (working under time pressure or working with deadlines) Low (reference) RR: 1.0 High RR: 2.14 (1.28–3.58) Co-worker support High (reference) RR: 1.0 Low RR: 2.43 (1.11–5.29)	Prospective cohort	977 workers from 34 companies located throughout the Netherlands that included various industrial and service branches	Questionnaires and video recording to investigate physical risk factors in the workplace, psychological and psychosocial factors at work, health-related factors, and other individual factors	Unclear case definition
Fredriksson et al. [2000]	Neck/shoulder WMSD	Heavy physical work High physical workload OR: 2.2 (1.1–4.6)	Case–control	Swedish general population Cases: 271 individuals who reported medical consultation or sick leave for more than 7 days consecutively due to symptoms in the neck/shoulder or who reported having symptoms in the neck/shoulder for over 7 days in the past 12 months Controls: 2 controls per case matched by gender and age	Structured interview regarding physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported Response rate of 62%
Kaergaard and Andersen [2000]	Neck/shoulder WMSD	Psychosocial factor High social support (reference) RR: 1.00 Low social support RR: 3.72 (1.22–11.30) Smoking No (reference) RR: 1.00 Yes RR: 3.93 (1.33–11.58)	Prospective cohort	133 women who were sewing machine operators from six departments in three different Danish companies	Questionnaire regarding physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors. Also conducted a standardized clinical examination	Method of regression not reported Co-linearity not assessed Response rate of 55%
Andersen et al. [2003a]	Neck/shoulder WMSD	Repetition, heavy physical work, posture	Prospective cohort	1,546 blue collar or white collar workers from industrial and service sector settings. Most of the participants had mainly repetitive job tasks; a smaller group of participants had more varied jobs and served as a reference group	Questionnaire, video recording, and physical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Enrollment response rate not reported

		Reference category OR: 1.0 High physical exposure OR: 1.5 (1.2–1.9) Psychosocial factor Job demands Reference category OR: 1.0 High job demands OR: 1.5 (1.3–1.8) Level of distress Low (reference) OR: 1.0 Medium OR: 1.4 (1.1–1.7) High OR: 1.8 (1.4–2.5) Physical examination Pain pressure threshold Reference category (high threshold) OR: 1.0 Low pain pressure threshold: 1.3 (1.1–1.5)				Follow-up response rate of 45% Co-linearity not assessed. Unclear case definition.
Smedley et al. [2003]	Neck/shoulder WMSD	Co-morbidities Previous neck/shoulder pain >1 year prior to baseline measurements HR: 1.6 (1.1–2.3) Previous neck/shoulder pain within the past year prior to baseline measurements HR: 2.8 (2.0–3.9) Total duration of previous neck/shoulder pain <1 week HR: 1.7 (1.1–2.5) 1–4 weeks HR: 2.3 (1.5–3.3) >4 weeks HR: 2.6 (1.7–4.0) >4 weeks and pain within past year (compared to never had pain) HR: 3.3 (1.9–5.8) Previous LBP >1 year prior to baseline measurements HR: 1.8 (1.2–2.7) Previous LBP pain within the past year prior to baseline measurements HR: 1.9 (1.4–2.7) Total duration of previous LBP pain 1–4 weeks HR: 1.8 (1.2–2.7) >4 weeks HR: 2.3 (1.6–3.3) >4 weeks and pain within past year (compared to never had pain) HR: 2.6 (1.8–3.9) Repetition, posture	Prospective cohort	587 female nurses from two hospitals in the south of England	Questionnaire to investigate physical risk factors in the workplace, psychosocial factors at work, psychological factors, health-related factors, and other individual factors	Enrollment response rate of 59% Co-linearity not assessed Method of regression not reported

(*Continued*)

TABLE I. (*Continued*

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
		Assist a patient to mobilize using a walking stick, Zimmer frame, or crutches, never (reference) HR: 1.0, ≥5/shift HR: 1.6 (1.1–2.3) Move a patient around in a wheelchair, bed, hoist, trolley, commode, etc., never (reference) HR: 1.0, ≥5/shift HR: 1.6 (1.1–2.4) Wash/dress a patient while they are on a chair/commode, never (reference) HR: 1.0, ≥5/shift HR: 1.7 (1.1–2.8)				
Gheldof et al. [2007]	Low back WMSD	Psychosocial factor Negative affectivity OR: 1.06 (1.01–1.11)	Prospective cohort	Sample of 812 individuals that was predominantly composed of male industrial workers from Belgian and Dutch metallurgical/steel companies	Questionnaire and clinical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Response rate of 63%
Krause et al. [1998]	Low back WMSD	Posture Years of professional driving 0–5 years OR: 6.07 (4.05–9.11) >5–15 years (reference) OR: 1.00 >15 years OR: 0.49 (0.33–0.71) Regular driving hours per week 20–30 hr OR: 0.37 (0.15–0.93) 31–40 hr (reference) OR: 1.00 Overtime driving per week (10 hr) Diesel bus (reference) OR: 1.00 Cable car OR: 3.04 (1.85–5.00) Age (year) 25–44 (reference) OR: 1.00 45–60 OR: 0.63 (0.45–0.88) 61–65 OR: 0.28 (0.08–0.98) Psychosocial factor High psychological demands OR: 1.50 (1.13–1.99) High job dissatisfaction OR: 1.56 (1.09–2.23)	Prospective cohort	1463 transit vehicle operators employed by the San Francisco Municipal Railway	Medical examination and questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported
Eriksen et al. [1999]	Low back WMSD	Heavy physical work	Prospective cohort	562 workers who responded to a questionnaire seeking employed individuals sent to the general population of Ullensaker (Norway)	Questionnaire to investigate physical risk factors in the workplace, psychological factors, health-related factors, and other individual factors	Enrollment response rate of 67%

		Heavy lifting and much standing OR: 2.30 (1.21–4.34) Heavy physical work × smoking Heavy lifting, much standing, and smoking OR: 4.04 (1.15–14.21) Co-morbidities Musculoskeletal pain in the previous year (except for LBP) OR: 1.61 (1.03–2.52) Physical activity Performing physical activity less than once a week OR: 1.55 (1.03–2.33)				Co-linearity not assessed
van Poppel et al. [1998]	Low back WMSD	Co-morbidities Back pain more than twice in the past year OR: 9.8 (2.8–34.4) Psychological factor Job dissatisfaction OR: 1.2 (1.01–1.4) Posture Riding forklift truck OR: 0.7 (0.5–0.99)	Prospective cohort	312 workers involved with manual material handling from the cargo department of a major Dutch airline company at Schiphol Airport	Questionnaire to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Co-linearity not assessed
Kerr et al. [2001]	Low back WMSD	BMI (kg/m^2) Decrement of 4.8 units (cases lower) OR: 2.0 (1.20–3.58) Compensation claim Prior compensation claim for LBP OR: 2.2 (1.07–4.43) Psychosocial factor Lower workplace social environment score (cases lower) OR: 2.6 (1.30–5.42) Higher education relative to others in similar jobs (cases lower) OR: 2.2 (1.05–4.92) Higher job satisfaction (cases higher) OR: 1.7 (1.15–2.48)	Case–control	Assembly and non-assembly workers of a modern automobile production complex that manufactures passenger cars and light trucks Cases: 137 workers reporting a new episode of low back pain to one of the on-site occupational nursing stations Controls: The main control group consisted of 179 workers randomly selected (unmatched) from the same study base as the case subjects. A second control group was also recruited, with 65 controls matched to cases by the actual job performed (not job title)	Questionnaires and work-site assessment to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	"Cases" response rate of 56% "Controls" response rate of 43% Unclear case definition Co-linearity not assessed

(*Continued*)

TABLE I. (*Continued*

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
		Higher coworker support (cases higher) OR: 1.6 (1.07–2.32) Higher perceived exertion at work (cases higher) OR: 3.0 (1.79–5.36) Heavy physical work (biomechanical measures) Higher peak lumbar shear (cases higher) OR: 1.7 (1.02–2.86) Higher cumulative lumbar disc compression (cases higher) OR: 2.0 (1.22–3.59) Higher peak hand force (cases higher) OR: 1.9 (1.21–3.10)				
Miranda et al. [2002a]	Low back WMSD (sciatic pain)	Smoking Non-smoker (reference) OR: 1.0 Ex-smoker OR: 2.3 (1.3–4.3) Physical activity Jogging Not at all or only little (reference) OR: 1.0 Moderately or actively OR: 3.9 (1.4–10.7) Psychosocial factor Job satisfaction Rather or very satisfied OR: 1.0 Rather or very dissatisfied OR: 2.8 (1.2–6.7)	Prospective cohort	2,984 workers from a large forestry company in Finland	Questionnaire, to investigate physical risk factors in the workplace, physical activity, health-related factors, and other individual factors	Enrollment response rate of 47%
Harkness et al. [2003a]	Low back WMSD	Psychosocial factor Never/occasionally performing monotonous work (reference) OR: 1.0 Performing monotonous work at least half of the time OR: 1.8 (1.1–2.8) Co-morbidities Any pain lasting 24 hr or longer in the month prior to baseline OR: 1.5 (1.1–2.1) Temperature in the workplace Working in hot conditions OR: 1.7 (1.1–2.6)	Prospective cohort	520 newly employed workers from 12 diverse occupational groups	Questionnaire to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Follow-up response rate of 55%

Hoogendoorn et al. [2000b]	Low back WMSD	Lifting Number of lifts ≥25 kg per 8-hr working day Never (reference) RR: 1.0, >15 times/working day RR: 1.62 (1.04–2.53)	Prospective cohort	861 workers from 34 companies located throughout the Netherlands. Workers were in blue-collar jobs as well as in white-collar jobs and caring professions and had been employed in their current job for at least 1 year and working 24 hr per week or more	Questionnaire, video recording, and physical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Use of stepwise regression
Myers et al. [1999]	Low back WMSD	Posture Frequent performance of extended reach OR: 2.04 (1.13–3.67) Frequent performance of stooping OR: 1.59 (1.01–2.48) Psychosocial factor Medium job strain OR: 1.73 (1.14–2.63) High job strain OR: 2.12 (1.28–3.52) BMI (kg/m^2) Increased body mass index OR: 1.54 (1.08–2.18)	Case–control	Sample consisted of workers from four different departments from the city of Baltimore (education, public works, recreation and parks, and transportation) Cases: 200 injured workers who had been assigned restricted activity or had lost time beyond the day of back injury Controls: 2 non-injured controls were randomly selected for each case	Questionnaire with questions regarding the following domains: characteristics of current and past work, physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Use of stepwise regression Co-linearity not assessed
Peek-Asa et al. [2004]	Low back WMSD	Age <45 years (reference) RR: 1.00 45–54 years RR: 0.78 (0.66–0.92) Lifting High lifting intensity <45 years (reference) RR: 1.00 45–54 years RR: 0.75 (0.62–0.91) ≥55 years RR: 0.78 (0.62–0.98)	Historical cohort	Cohort of approximately 50,000 full-time equivalents. Workers were material handlers employed in the California stores of the home depot	Investigation of personnel records and computerized injury claim records to collect information on health-related factors and current and past work information. Exposure was measured using incidence density methods	Method of regression not reported Co-linearity not assessed
Eriksen et al. [2004]	Low back WMSD	Heavy physical work, repetition No positioning of patients in bed (reference) OR: 1.0 Positioning patients in bed 5–9 times per shift OR: 1.63 (1.14–2.31)	Prospective cohort	3,651 nurses' aides randomly selected from the member list of the Norwegian Union of Health and Social Workers	Questionnaire to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Enrollment response rate of 62.3% Co-linearity not assessed

(*Continued*)

TABLE I. (*Continued*

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
		Individual factor No preschool children (reference) OR: 1.0 One preschool children OR: 1.64 (1.16–2.31) Special tasks of caring nature in the leisure time (e.g., caring for elderly relatives or handicapped children) Never (reference) OR: 1.0 A little OR: 0.82 (0.62–1.09) Co-morbidities No back injury in the last 3 months OR: 1.0 Prior back injury in the last 3 months OR: 3.39 (2.61–4.40) Individuals diagnosed with fibromyalgia OR: 1.67 (1.30–2.14) Intensity of musculoskeletal pain (any) no (reference) OR: 1.00, a little OR: 2.45 (1.29–4.65), rather intense OR: 3.75 (1.95–7.21), very intense OR: 3.49 (1.72–7.03) Fatigue/fitness, Always or usually fit (reference) OR: 1.0, Varied between fit and fatigued OR: 1.49 (1.14–1.96)				
Engkvist et al. [2000]	Back WMSD	Co-morbidities Prior back injury in the last 12 months RR: 1.8 (1.2–2.9) Heavy physical work, repetition Working hours (≥35 hr/week) RR: 2.4 (1.6–3.6) Patient transfer (≥1/shift) RR: 2.7 (1.6–4.5) Nurses working in orthopedic vs. nurses working in other clinics RR: 5.2 (2.7–10.2)	Case–control	Cases: 240 female nurses who reported on a work injury insurance form, a work-related over-exertion back injury that was coded as an occupational accident Controls: 3 controls were randomly selected for each case from the source population, matching on sex and age (within 5 years)	Questionnaire to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported Co-linearity not assessed Unclear case definition

TABLE II. Overview of Studies Investigating Risk Factors for Upper Limb Work-Related Musculoskeletal Disorders (WMSD)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Descatha et al. [2007]	Upper limb WMSD	Co-morbidities	Prospective cohort	166 blue-collar workers of shoe factories	Questionnaire and clinical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported
		Previous upper limb work-related MSD OR: 3.90 (1.31–11.62)				Co-linearity not assessed Unclear case definition.
Hakkanen et al. [2001]	Upper limb WMSD	Heavy physical work	Prospective cohort	364 assemblers in a trailer production company of Finland	Investigation of health status and sick leaves via medical records; and on-site ergonomics observations and job titles used to assess exposure	Method of regression not reported
		High work load HR: 3.2 (1.1–9.4)				Co-linearity not assessed Unclear case definition
Punnett et al. [2004]	Upper limb WMSD	Job change at follow up RR: 4.8 (1.5–15.4)	Prospective cohort	790 workers from an automotive stamping plant and an automobile engine assembly plant, both in Detroit (USA)	Interview, questionnaire and standardized physical examination of the upper limbs. During interview data was collected on psychosocial strain and current and past medical and work histories	Method of regression not reported
						Co-linearity not assessed Response rate of 67% Unclear case definition
Werner et al. [2005a]	Upper limb WMSD	Age	Prospective cohort	501 workers from 4 industrial and 3 clerical work sites	Questionnaire and physical examination to assess upper limbs physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors. Electro-diagnostic test to assess performance of the median and ulnar sensory nerves. Rating of jobs ergonomic exposure according to the American Congress of Governmental Industrial Hygienists' threshold limit value	Method of regression not reported
		Age >40 RL: 2.51 (1.22–5.14) Co-morbidities History of wrist/hand/finger discomfort RL: 3.14 (1.41–6.99) Hand threshold limit value above the proposed action limit RL: 2.14 (1.01–4.54)				Co-linearity not assessed
Werner et al. [2005b]	Upper limb WMSD (upper limb tendonitis)	Age	Prospective cohort	501 workers from 4 industrial and 3 clerical work sites	Questionnaires and physical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Enrollment response rate not reported

(*Continued*)

TABLE II. (*Continued*)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
		>40 years old OR: 1.76 (1.04–2.98)				Follow-up response rate of 51%
		BMI (kg/m^2)				Method of regression not reported
		>30 1.93 (1.12–3.34)				Co-linearity not assessed
		Physical examination				
		Shoulder discomfort at baseline OR: 1.84 (1.03–3.29)				
		Worst discomfort rating at baseline OR: 1.21 (1.06–1.38)				
Leclerc et al. [2001]	Upper limb WMSD (carpal tunnel syndrome, wrist tendinitis, and lateral epicondylitis)	Epicondylitis	Prospective cohort	598 individuals from18 different companies exposed to repetitive work in one of the following: assembly line work, clothing and shoe industry, food industry, packaging, and supermarket cashiers. The sample also included 326 subjects not exposed to repetitive work	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Use of stepwise regression
		Age				Co-linearity not assessed
		≥40 years of age OR: 3.40 (1.24–9.32)				
		Co-morbidities				
		≥3 diagnoses of upper limb disorders OR: 2.94 (1.33–6.52)				
		Repetition				
		Performing work task "turn and screw" OR: 2.07 (1.16–3.70)				
		Wrist tendinitis				
		Co-morbidities				
		Somatic problems OR: 3.78 (1.63–8.75)				
		Carpal tunnel syndrome				
		Heavy physical work				
		Tighten with force OR: 4.09 (1.43–11.7)				
		Press with the hand OR: 0.28 (0.09–0.82)				
		Hold in position OR: 3.59 (1.06–12.1)				
		BMI				
		BMI increase of ≥2 kg/m^2 OR: 2.38 (1.04–5.47)				
Lassen et al. [2004]	Upper limb WMSD (elbow and wrist/ hand pain)	Elbow pain	Prospective cohort	5658 Danish engineering technical assistants and machine technicians	Questionnaire and clinical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Unclear case definition
		Computer work				
		Using the mouse 0–<2.5 hr/week (reference) OR: 1.00				

		Using the mouse 5−<10 hr/week OR: 2.35 (1.51−3.70) Using the mouse 10−<15 hr/week OR: 2.20 (1.42−3.45) Using the mouse 15−<20 hr/week OR: 3.12 (2.01−4.92) Using the mouse 20−<25 hr/week OR: 3.21 (2.03−5.17) Using the mouse 25−<30 hr/week OR: 4.83 (2.79−8.40) Using the mouse ≥30 hr/week OR: 4.74 (2.51−8.95) Ergonomic issues Workers unsatisfied with workplace design OR: 1.63 (1.18−2.23) Psychosocial Factor High job demands OR: 1.33 (1.02−1.74) Age (year) Age (an individual ten years older than another individual) OR: 1.35 (1.19−1.53) Gender Women OR: 1.59 (1.26−2.02) Wrist/hand pain Computer work Using the mouse 0−<2.5 hr/week (reference) OR: 1.00 Using the mouse 5−<10 hr/week OR: 2.16 (1.46−3.22) Using the mouse 10−<15 hr/week OR: 2.05 (1.37−3.07) Using the mouse 15−<20 hr/week OR: 2.46 (1.65−3.72) Using the mouse 20−<25 hr/week OR: 2.07 (1.32−3.26) Using the mouse 25−<30 hr/week OR: 3.16 (1.82−5.46) Using the mouse ≥30 hr/week OR: 3.05 (1.63−5.67) Use of arm/wrist support ≥50% of the time OR: 1.55 (1.14−2.13) Using the keyboard 0−<2.5 hr/week (reference) OR: 1.00 Using the keyboard 2.5 < 5 hr/week OR: 0.63 (0.41−0.98) Gender Women OR: 1.32 (1.06−1.66)			
Miranda et al. [2001]	Shoulder WMSD	Individual factors Age (years) <35 (reference) OR: 1.0 45−54 OR: 1.8 (1.1−2.8) ≥55 OR: 2.6 (1.4−4.7) BMI (kg/m^2) <23.0 (reference) OR: 1.0 26.0−28.9 OR: 1.7 (1.1−2.6) ≥29.0 OR: 2.2 (1.4−3.6) Psychological factor Mental stress Not at all (reference) OR: 1.0 Rather much or much OR: 1.9 (1.1−3.3)	Prospective cohort	2,984 workers from a large forestry company in Finland	Questionnaire, to investigate physical risk factors in the workplace, physical activity, health-related factors, and other individual factors	Enrollment response rate of 47%

(*Continued*)

TABLE II. (*Continued*)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
		Physical activity Jogging Not at all or only little (reference) OR: 1.0 Actively OR: 0.3 (0.1–0.8) Heavy physical work Physical strenuousness of work Not at all or rather light (reference) OR: 1.0 Somewhat strenuous OR: 1.6 (1.1–2.3) Rather or very strenuous OR: 2.0 (1.3–3.1)				
Harkness et al. [2003b]	Shoulder WMSD	Heavy physical work	Prospective cohort	476 newly employed workers from 12 diverse occupational groups	Questionnaire to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Unclear case definition
		Never performing activities that require pushing/pulling (reference) OR: 1.0 Performing activities that require pushing/pulling $\geq$70 lbs OR: 1.9 (1.1–3.3) Psychosocial factor Never/occasionally performing monotonous work (reference) OR: 1.0 Performing monotonous work at least half of the time OR: 1.7 (1.1–2.8)				Follow-up response rate of 59%
Leclerc et al. [2004]	Shoulder WMSD	Repetition	Prospective cohort	598 individuals from 18 different companies exposed to repetitive work in one of the following: assembly line work, clothing and shoe industry, food industry, packaging, and supermarket cashiers. The sample also included 326 subjects not exposed to repetitive work	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported
		Repetitive use of tool OR: 4.34 (1.58–11.9) Psychosocial factor Low level of job control OR: 3.68 (1.44–9.41)				Co-linearity not assessed Unclear case definition
Descatha et al. [2004]	Elbow WMSD (ulnar nerve entrapment)	Posture	Prospective cohort	598 individuals that performed repetitive tasks at work (assembly line, clothing and shoe industry, food industry, packaging, and supermarket cashiering)	Questionnaire and clinical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported

		Holding a tool in position OR: 4.11 (1.38–12.23) Co-morbidities Presence of another upper limb work-related disorder OR: 5.09 (1.54–16.82) BMI BMI (kg/m^2) $\geq$ OR: 4.30 (1.13–16.39)				Co-linearity not assessed
Descatha et al. [2003]	Elbow WMSD (medial epicondylitis)	Heavy physical work	Prospective cohort	598 individuals that performed repetitive tasks at work (assembly line, clothing and shoe industry, food industry, packaging, and supermarket cashiering)	Questionnaire and clinical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Use of stepwise regression
		Performing forceful work OR: 1.95 (1.15–3.32)				Co-linearity not assessed
Macfarlane et al. [2000]	Forearm WMSD	Repetition	Prospective cohort	Sample of 1,260 individuals from the adult general population of Greater Manchester, England. A subgroup of 782 individuals employed during the study was analyzed for occupational risk factors. It was not mentioned the types of jobs performed by this subgroup	Questionnaires to investigate physical risk factors in the workplace, psychosocial factors at work, and health-related factors	Response rate of the subgroup of workers cannot be analyzed
		No repetitive movement of arms (reference) OR: 1.0 Half or most of the time performing repetitive movement of arms OR: 2.9 (1.2–7.3) Psychological factor Score from 4 to 7 on illness behavior scale OR: 6.6 (1.5–29) Score from 8 to 24 on illness behavior scale OR: 6.6 (1.5–29) Psychosocial factor Most of the time satisfied with support form supervisor or colleagues (reference) OR: 1.0 Occasionally or never satisfied with support form supervisor or colleagues (reference) OR: 2.6 (1.1–5.8)				Co-linearity not assessed Unclear case definition. Use of stepwise regression
Kryger et al. [2003]	Forearm WMSD	Computer work	Prospective cohort	4,340 individuals from various public and private companies that performed computer-based tasks	Questionnaire regarding physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors. Was also conducted a standardized clinical examination	Use of stepwise regression
		0–9 hr/per week with mouse in right hand (reference) OR: 1.0 $\geq$30 hr per/week with mouse in right hand OR: 8.4 (2.5–29) Personal factor Age (an individual ten years older than another individual) OR: 1.4 (1.1–2.0) Female gender OR: 2.2 (1.1–4.5)				Unclear case definition

(*Continued*)

TABLE II. (*Continued*)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Nahit et al. [2003]	Forearm WMSD	Repetition	Prospective cohort	666 newly employed workers from 12 occupational groups that presented high rates of musculoskeletal disorders	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Use of stepwise regression
		Repetitive movement of wrists ≥2 hr per day OR: 2.9 (1.5–5.3)				
		Posture				
		Working with hands above shoulder ≥15 min per day OR: 2.2 (1.1–4.3)				
		Monotonous work At least half of the work day OR: 3.0 (1.5–5.8)				
Andersen et al. [2003b]	Carpal tunnel syndrome	Computer work	Prospective cohort	9,480 participants from 3,500 workplaces with a wide distribution of both mouse and keyboard use were recruited from the Danish Association of Professional Technicians (a trade union)	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported
		Mouse use 20 to <25 hr/week OR: 2.6 (1.2–5.5)				
		Mouse use 25 to <30 hr/week OR: 3.2 (1.3–7.9)				
		Abnormal mouse position OR: 0.4 (0.1–0.9)				
Gell et al. [2005]	Carpal tunnel syndrome	Physical examination	Prospective cohort	501 workers from four industrial and three clerical work sites	Questionnaires and physical examination to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Enrollment response rate not reported
		Median ulnar peak latency difference (per 0.1 ms increment) OR: 1.29 (1.2–1.4)				Follow-up response rate of 51%
		Numbness, tingling, burning, and/or pain in the hand at baseline OR: 5.22 (2.1–6.5)				Method of regression not reported
						Co-linearity not assessed
Fung et al. [2007]	Carpal tunnel syndrome	Posture, loading and repetitive motion	Case–control study	166 cases and 111 controls	Questionnaire	Used only self-reported measures of wrist postures and motion
		Frequent wrist flexion OR: 4.44 (1.83–10.73)				
		Frequent wrist extension OR: 2.69 (1.11–6.55)				
		Forceful wrist motion OR: 2.59 (1.14–5.85)				

Nathan et al. [2002]	Carpal tunnel syndrome	Age	Prospective cohort	256 workers from 4 industrial sites (a steel mill, meat/food packaging, electronics, and plastics)	Medical history questionnaire and nerve conduction tests. It was also used direct observation and a 5-point Likert scales to assess: amount of keyboard time; amount of heavy lifting; and amount of force, repetition, and vibration present in the work tasks	Response rate of 54%
		<30 years (reference) OR: 1.0				
		≥50 years OR: 10.56 (2.68–41.63)				
		BMI				
		BMI (kg/m^2) ≤21.58 (reference) OR: 1.00				
		BMI (kg/m^2) ≥28.24 OR: 5.37 (1.24–23.26)				
		Smoking				
		Cigarette smoking OR: 2.42 (1.06–5.51)				
		Gender				
		Men (reference) OR: 1.00				
		Women OR: 4.28 (1.69–10.84)				
Roquelaure et al. [2001]	Carpal tunnel syndrome	BMI	Prospective cohort	134 workers from 6 production units of a large, modern mechanized footwear factory	Physical examination and questionnaire on psychosocial and ergonomic factors	Use of stepwise regression
		BMI (kg/m^2) >30 OR: 4.4 (1.1–17.1)				Co-linearity not assessed
Jensen [2003]	Wrist/hand WMSD	Computer work	Prospective cohort	2,576 computer users from 11 Danish companies. The computer workers performed different computer tasks (i.e., data entry, word processing, graphic work, etc.)	Questionnaire regarding physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported
		Spending 50% of working time at the computer (reference) RR: 1.0				Co-linearity not assessed
		Spending 75% of working time at the computer RR: 2.0 (1.1–3.9)				Unclear case definition.
		Spending 100% of working time at the computer RR: 2.3 (1.2–4.3)				
Thomsen et al. [2007]	Wrist WMSD	Heavy physical work	Prospective cohort	1,546 workers from 19 different industrial settings	Questionnaires and physical examination. Questionnaires and video recordings of work tasks, wrist movements and postures, and hand forces	Method of regression not reported
		High level of force measured continuously OR: 1.7 (1.3–2.2)				Co-linearity not assessed
		High level of force measured dichotomously OR: 2.0 (1.3–3.0)				Response rate of 49.5%

TABLE III. Overview of Studies Investigating Risk Factors for Lower Limb Work-Related Musculoskeletal Disorders (WMSD)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Lau et al. [2000]	Lower limb WMSD (hip and knee osteoarthritis)	Hip osteoarthritis in men Repetition Climbing stairs (≥15 flights/day) OR: 12.5 (1.5–104.3) Hip osteoarthritis in women Lifting Lifting 10 kg or more >10 times/week OR: 2.4 (1.1–5.3) Knee osteoarthritis in men Lifting Lifting 10 kg or more >10 times/week OR: 5.4 (2.4–12.4) Knee osteoarthritis in women Repetition Climbing stairs (≥15 flights/day) OR: 5.1 (2.5–10.2) Lifting Lifting 10 kg or more >10 times/week OR: 2.0 (1.2–3.1)	Case–control	Cases: 138 patients with hip osteoarthritis and 658 patients with knee osteoarthritis recruited from Hong Kong hospitals Controls: 3 controls per each hip osteoarthritis case and 1 control per each knee osteoarthritis case matched by gender and age (within 1 year)	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, work history, health-related factors, and other individual factors	Method of regression not reported Co-linearity not assessed
Yoshimura et al. [2000]	Hip WMSD (osteoarthritis)	Lifting Regular lifting of 25 kg or more in the first job OR: 3.5 (1.3–9.7) Regular lifting of 50 kg in the main job OR: 4.1 (1.1–15.2)	Case–control	Hip arthroplasty patients Age ≥ 45 and matched controls	Questionnaire	Sample: the number of cases in occupations with regular heavy lifting (>25 kg) was small: n = 11 men and 21 women

Baker et al. [2003]	Knee WMSD (meniscectomy)	Posture Kneeling for >1 hr/day OR: 2.5 (1.3–4.8) Squatting for >1 hr/day OR: 2.5 (1.2–4.9) Working on occupations which were predefined as likely to occur kneeling or squatting OR: 2.3 (1.1–4.8)	Case–control	Cases: 2,806 men from eight general practices in Southern Hampshire Controls: Five controls matched to within one year of age were randomly selected for each men who reported undergoing meniscectomy	Questionnaire with questions regarding lifetime occupational history	Method of regression not reported Co-linearity not assessed Response rate of 50%
Coggon et al. [2000]	Knee WMSD (osteoarthritis)	Health-related factor BMI (kg/m^2) 25.0–29.9 OR: 3.2 (2.2–4.7) ≥30.0 OR: 8.3 (5.2–13.4) Heberden's node Yes OR: 2.3 (1.5–3.6) Previous knee injury Yes OR: 4.5 (3.0–6.8) Workplace physical factor Lifting ≥25 kg >10 times/week ≥20.0 years OR: 1.9 (1.1–3.5) Kneeling >1 hr/day in total or squatting >1 hr/day 1.0–9.9 years OR: 2.6 (1.6–4.2) Getting up from kneeling or squatting >30 times/day 1–9.9 years OR:1.8 (1.1–3.0) ≥20 years OR: 2.3 (1.2–4.6) Walking >2 miles/day in total 1–9.9 years OR: 1.9 (1.2–2.9) 10–20 years OR: 1.9 (1.2–3.1) ≥20 years OR: 2.0 (1.3–3.0)	Case–control	Cases: 518 individuals placed on a waiting list for knee surgery (total knee arthroplasty, osteotomy, or patellar replacement) residents of 3 English health districts Controls: 1 control per case matched by gender and date of birth and that had not undergone previous knee surgery for osteoarthritis	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, work history, health-related factors, and other individual factors	Method of regres sion not reported Co-linearity not assessed Response rate of 37.5%

(*Continued*)

TABLE III. (*Continued*)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Jones et al. [2007]	Knee WMSD	Lifting	Prospective cohort	859 newly employed workers from 12 different occupational settings in England and that were free of knee pain	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Use of stepwise regression
		No lifting or carrying weights in one hand (reference) RL: 1.0 Lifting or carrying weights $<$20 lbs in one hand RL: 2.1 (1.3–3.2) Lifting or carrying weights $>$20 lbs in one hand RL: 1.7 (1.03–2.8) Psychological factor Low general psychological distress (reference) RL: 1.0 High general psychological distress RL: 1.6 (1.02–2.6)				Co-linearity not assessed Unclear case definition
Miranda et al. [2002b]	Knee WMSD	Smoking	Prospective cohort	1,656 employees of a large forestry industry in Finland	Questionnaires with questions regarding the following domains: physical risk factors in the workplace, health-related factors, and other individual factors	Method of regression not reported
		Non-smoker (reference) OR: 1.0 Ex-smoker OR: 2.2 (1.4–3.6) Co-morbidities Previous knee injury OR: 2.4 (1.4–4.3)				Co-linearity not assessed Unclear case definition

TABLE IV. Overview of Studies Investigating Risk Factors for Fibromyalgia, and Mixed and Non-Specified Body Parts Work-Related Musculoskeletal Disorders (WMSD)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Cole et al. [2005]	Repetitive strain injuries	Gender Female gender OR: 1.98 (1.24–3.18) Education Having some college/university education OR: 1.98 (1.06–3.7) Psychosocial factor High job insecurity OR: 1.76 (1.07–2.91) High psychological demands OR: 1.61 (1.02–2.52) Heavy physical work High physical exertion OR: 2.00 (1.29–3.12)	Prospective cohort	2806 randomly sampled individuals who answered to the Canadian National Population Health Survey	Data from the Canadian National Population Health Survey, and item-scales regarding physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Unclear case definition
Harkness et al. [2004]	Fibromyalgia	Posture Never squatting (reference) OR: 1.0 Squatting ≥15 min OR: 2.0 (1.1–3.6) Monotonous work Never/occasionally monotonous work (reference) OR: 1.0 Monotonous work at least half of the time OR: 1.9 (1.1–3.2)	Prospective cohort	520 newly employed workers from a range of 12 occupational settings	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Response rate of 58%
McBeth et al. [2003]	Fibromyalgia	Repetition Repetitive movements of wrists Never/occasionally (reference) RL: 1.0 Half/most of the time RL: 1.8 (1.2–2.7) Psychological factor Illness behavior 0–3 (reference) RL: 1.0 ≥7 RL: 2.1 (1.2–3.9) Co-morbidities (Any pain at baseline) No (reference) RL: 1.0 Yes RL: 2.1 (1.3–3.3)	Prospective cohort	Random sample of 978 adults aged 18–65 years from south Manchester in the UK	Questionnaires with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported Co-linearity not assessed

(*Continued*)

TABLE IV. (*Continued*)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Leino-Arjas [1998]	Musculoskeletal pain	Smoking	Prospective cohort	598 individuals from 18 different companies exposed to repetitive work in one of the following: assembly line work, clothing and shoe industry, food industry, packaging, and supermarket cashiers. The sample also included 326 subjects not exposed to repetitive work	Questionnaires to investigate how much an individual smoked, and how much musculoskeletal pain they had; and clinical investigation of pain in the joints and muscles through palpation. All of tests were scored from 1 to 4, being "1" absence of the construct and "4" the construct at is worse	Method of regression not reported
		Worsening of musculoskeletal symptoms Neck–shoulder Score of "3" in questionnaire OR: 3.07 (1.39–6.80) Score of "4" OR: 2.6 (1–6.7) Upper limb Score of "2": 1.90 (1.01–3.57) Low back Score of "3": 2.35 (1.09–5.08) Lower limb Score of "3": 3.44 (1.52–7.76) Total Score of "3": 2.82 (1.24–6.40)				Co-linearity not assessed Unclear case definition
Malchaire et al. [2001]	Musculoskeletal pain	Personal factor	Prospective cohort	Three groups of male workers investigated:	Interview with questions regarding the following domains: past and actual physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors. Direct measurement of hand-transmitted vibration and biomechanical factors	Method of regression not reported
		Bad health OR: 3.54 (1.05–11.93)		Group1 (G1) included 69 workers exposed to vibration in different industrial environments: car assembly plant, quarries, wood industry, and metal industry		Co-linearity not assessed
		Sleeping troubles OR: 4.84 (1.54–15.19)		Group 2 (G2) included 62 workers from a steel industry performing heavy and repetitive hand and arm work, without vibration		Unclear case definition
		Headaches OR: 3.84 (1.14–12.92)		Group 3 (G3) served as the control group and included 46 workers performing light and non-repetitive tasks without vibration		
		Weight OR: 1.48 (1.04–2.11) Height OR: 0.76 (0.62–0.92) Hobbies OR: 3.15 (1.10–8.99)				
		Smoking Smoking OR: 0.15 (0.04–0.57)				

		Vibration G1 vs. G2 and G3 OR: 28.51 (6.22-130-76) Weighted personal exposure acceleration *A*EPw (ms.2) OR: 18.45 (3.84–88.67) Weighted vibration dose (ms.2 year 0.5) OR: 2.04 (1.30–3.21) Time using vibrating tools per day OR: 2.50 (1.65–3.80)				
Rosenblum and Shankar [2006]	Musculoskeletal pain	Isokinetic screening	Prospective cohort	1,926 newly employed workers from l ocations of gypsum	Pre-employment isokinetic screening of workers. Shoulders, knees and back were tested along their full range of motion using Cybex isokinetic testing and rehabilitation systems as a pre-employment, pre-offer, strength and agility test meeting the Americans with Disability Act's requirements for business necessity and testing job-related ness reflecting manifest relationship to the employment in question	Method of regression not reported
		Individuals that were not isokinetically screened OR: 2.38 (1.72–3.28)		Management & Supply, Inc. (GMS), the largest privately held distributor of drywall in the United States		Unclear case definition
		Job type Combination of incentive and hourly paid workers OR: 0.61 (0.48–0.77) Field material handlers: 2.70 (1.69–4.34) Race Non-Caucasian workers: 1.40 (1.12–1.76)				
Pihl et al. [2002]	Musculoskeletal pain	Physical activity	Case–control	Cases: 86 male full-time physical education teachers from Estonia	Physical work capacity (workload at the HR_{max} and PWC_{max}/kg) was estimated by a graded cycle ergometer	Method of regression not reported
		Physically active individuals OR: 0.52 (0.29–0.94)		Controls: 102 teachers of other subjects of the same age and gender, from Estonia		Co-linearity not assessed
Andersen et al. [2007]	WMSD of the neck/ shoulder, low back, and upper and lower limbs	Neck/shoulder	Prospective cohort	General working population in western Denmark from 39 different work places (19 in the service sector and 20 in different kinds of industry)	Questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	No method of regression reported
		Lifting Lifting $\geq$50 kg/hr at or above shoulder level HR: 1.9 (1.1–3.3) Psychosocial factor Low job satisfaction HR: 2.1 (1.2–3.6) Upper limb Psychosocial factor Medium levels of fear avoidance HR: 1.9 (1.1–3.5) Co-morbidities Presenting another chronic disease HR: 1.9 (1.2–3.1)				Unclear case definition

(*Continued*)

TABLE IV. (*Continued*)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
		Low back Posture Standing >30 min/hr HR: 1.9 (1.2–3.0) Psychosocial factor Job control (decision and freedom at work) HR: 1.5 (1.1–2.2) Lower limb BMI Body mass index ≥30 HR: 2.3 (1.3–3.9) Psychosocial factor High levels of fear avoidance HR: 1.8 (1.1–3.2) Co-morbidities Presenting another chronic disease HR: 1.7 (1.1–2.5)				
IJzelenberg and Burdorf, [2005]	WMSD of the low back and neck/upper limbs	Low back	Prospective cohort	407 order pickers and operators in warehouses, maintenance workers in a stevedoring company and a petrochemical plant, railway workers, and operators in chemical plants. Subjects were recruited from nine different Dutch companies	Questionnaire to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Method of regression not reported
		Heavy physical work High perceived physical workload OR: 1.67 (1.05–2.68) Psychosocial factor High job strain OR: 1.75 (1.08–2.84) Less social support from supervisor OR: 2.06 (1.35–3.14) Neck/upper limbs Psychosocial factor High job strain OR: 2.07 (1.31–3.26)				Co-linearity not assessed Unclear case definition
Gillen et al. [2007]	WMSD of the trunk, neck, and upper and lower limbs	Neck/Upper limb	Case–control	Cases: 497 hospital workers with a new presentation of an acute or cumulative WRMSD	Structured telephone interviews to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors; and on-site ergonomics observations to assess exposure	Method of regression not reported
		Job type		Controls: 3 controls per case from a reference cohort of non-injured hospital employees		Response rate of 59% for structured telephone interviews
		Administrating staff reference Health care providers except for nurses and physicians OR: 4.1 (1.3–12.5)				Unclear case definition

		Clerical workers OR: 2.8 (1.1–7.2) Psychosocial factor Effort–reward ratio OR: 1.3 (1.04–1.6) Back/lower limb Psychosocial factor Job strain OR: 1.5 (1.2–2.0) Non-specified WMSD Health care providers except for nurses and physicians OR: 4.5 (1.7–12.1) Technical staff OR: 3.2 (1.1–9.0) Clerical OR: 3.1 (1.3–7.3) Psychosocial factor Effort–reward ratio OR: 1.2 (1.03–1.4)				
Gerr et al. [2002]	WMSD of the neck/shoulder, and hand/arm	Neck/shoulder Co-morbidities Previous history of neck shoulder pain RR: 3.6 (2.1–6.0) Gender Female gender RR: 1.9 (1.1–3.1) Age (years) 30–39 RR: 1.8 (1.1–2.9) ≥40 RR: 1.9 (1.1–3.5) Hand/arm Gender Female gender RR: 2.4 (1.3–4.7) Computer work 2–5 years of previous computer work RR: 2.7 (1.3–5.5) >5 years of previous computer work RR: 2.3 (1.1–4.5)	Prospective cohort	Individuals who were newly hired into computer-using jobs from 8 large employers in Atlanta, USA. These individuals reported spending about 20 hr/week keying in their computers. 538 individuals were followed for the examination of the incidence of neck/shoulder disorders and 574 individuals were followed for the examination of the incidence of hand/arm disorders	Questionnaire to investigate previous computer work, health-related factors, and other individual factors Physical examination to determine whether participants met the case definitions for specific disorder	Follow-up response rate of 56% for neck/shoulder and 60% for hand/arm

(*Continued*)

TABLE IV. (*Continued*)

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
Marcus et al. [2002]	WMSD of the neck/ shoulder and hand/arm	Neck/ shoulder	Prospective cohort	Individuals who were newly hired into computer-using jobs from 8 large employers in Atlanta, USA. These individuals reported spending about 20 hr/week keying in their computers. 538 individuals were followed for the examination of the incidence of neck/ shoulder disorders and 574 individuals were followed for the examination of the incidence of hand/arm disorders	Weekly diary for the registration of use of medication and symptom intensity on a visual analogue scale	Follow-up response rate of 56% for neck/shoulder and 60% for hand/arm
		Posture			Standard checklist for the examination of the workstations	
		Keyboard inner elbow angle $>121^\circ$ (vs. $\leq 121^\circ$) HR: 0.11 (0.02–6.0)			Goniometer for the measurement of the habitual posture performed by workers in their workstation	
		Presence of telephone shoulder rest HR: 2.71 (1.40–5.23)			Physical examination to determine whether participants met the case definitions for specific disorder	
		Hand/arm				
		Posture				
		Presence of keyboard wrist rest HR: 1.96 (1.05–3.65)				
		Mouse wrist ulnar deviation $<-5^\circ$ (vs. $>5^\circ$)				
		Keyboard "J" key >12 cm from table edge (vs. ≤ 12 cm) HR: 0.38 (0.20–0.71)				
Hannan et al. [2005]	WMSD of the neck/ shoulder, and arm/hand	Psychosocial factor	Prospective Cohort Study	Computer workers	Job Content Questionnaire	Sample size: high-strain group n = 69, low-strain group n = 78
		Psychosocial stress				Used only self-reported measures
		Associated with neck–shoulder symptoms—high-strain vs. low-strain: HR = 1.65 (0.91–2.99), but not with arm-hand symptoms				
Feveile et al. [2002]	Neck/shoulder and wrist/hand WMSD	Neck/shoulder	Prospective cohort	3,990 Danish workers who responded to a nationwide follow-up survey	Telephone interview with structured questionnaires to investigate physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors	Follow-up response rate of 67%
		Men				Co-linearity not assessed
		Posture, repetition				Unclear case definition

		Seldom/never twisting or bending (reference) OR: 1.0 Twisting or bending for 1/4–1/2 of working hours OR: 1.56 (1.10–2.22) Twisting or bending ≥3/4 of working hours OR: 1.51 (1.01–2.26) Lifting-sedentary work Seldom/never—seldom/never (reference) OR: 1.0 Seldom/never—≥3/4 of the working hours OR: 1.50 (1.05–2.15) ≥3/4 of the working hours—seldom/never 2.35 (1.10–5.00) Psychosocial factor Low social support at work OR: 1.76 (1.24–2.50) Women Smoking Never (reference) OR: 1.0 Former smoker OR: 1.80 (1.14–2.82) Wrist/hand Men Posture, repetition Seldom/never twisting or bending (reference) OR: 1.0 Twisting or bending for 1/4–1/2 of working hours OR: 1.80 (1.25–2.60) Twisting or bending ≥3/4 of working hours OR: 1.74 (1.18–2.57) Psychological factor No stress symptoms (reference) OR: 1.0 Presenting stress symptoms OR: 1.74 (1.12–2.71) Women Posture, repetition Seldom/never twisting or bending (reference) OR: 1.0 Twisting or bending ≥3/4 of working hours OR: 1.94 (1.34–2.80) Psychological factor No stress symptoms (reference) OR: 1.0 Presenting stress symptoms OR: 1.67 (1.16–2.41)				
Myers et al. [2002]	WMSD of the shoulder and low back	Nursing activity Working night shift with non-Alzheimer's dementia patients OR: 1.66 (1.02–2.79)	Prospective cohort	175 nursing assistants from a nursing home in Washington state	Patients characteristics were taken from the Health Care Financing Administration Minimum Data Set. Patients' characteristics were considered the "work-place risk factors"	Method of regression not reported Co-linearity not assessed

(*Continued*)

TABLE IV. *(Continued)*

Refs.	Type of WMSD	Risk factor evaluated and main findings	Study design	Study population	Method of investigation	Study limitations
						Small sample size (Minimum should be around 260 participants)
Rugulies and Krause [2005]	WMSD of the neck and low back	Psychosocial factor Supervisor support High supervisor support (reference) HR: 1.00 Low supervisor support HR: 1.42 (1.06–1.90) Total support High total support (reference) HR: 1.00 Low total support HR: 1.39 (1.03–1.89)	Prospective cohort	1,221 transit vehicle operators employed by the San Francisco Municipal Railway	At baseline: medical examination and questionnaire with questions regarding the following domains: physical risk factors in the workplace, psychosocial factors at work, health-related factors, and other individual factors. At follow up: Review of company employment records, worker's compensation insurer's database, and medical bill review	Method of regression not reported Co-linearity not assessed

WMSD was heavy physical work. The psychosocial risk factor identified was fear avoidance. Individual risk factors were older age, associated upper limb WMSD, smoking, and high BMI.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Co-morbidities	Psychosocial factors
		Older age
		Smoking
		Heavy physical work
		High BMI

Shoulder. Biomechanical risk factors identified were heavy physical work and repetitive work. The psychosocial risk factors identified were high levels of distress, performing monotonous work, and low level of job control. Individual risk factors identified were older age, high BMI, and sedentary lifestyle.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Heavy physical work	Repetitive work
	Psychosocial factors	Older age
		High BMI
		Sedentarism

Elbow/forearm. The biomechanical risk factors identifiedfor the development of elbow/forearm WMSD were heavy physical work, awkward static and dynamic working postures, repetitive work, and prolonged computer work. The psychosocial risk factors identified were negative affectivity, low level of job control, high psychological demands and high work dissatisfaction. Individual risk factors identified were older age, female gender, associated upper limb WMSD, and high BMI.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Awkward posture	High BMI
	Co-morbidity	Heavy-physical work
	Repetitive work	Female gender
	Older age	Monotonous work
		Associated upper limb WMSD

Wrist/hand. The biomechanical risk factors identified for the development of wrist/hand WMSD including carpal tunnel syndrome were heavy physical work, awkward static and dynamic working postures, repetitive work, and prolonged computer work. The psychosocial risk factor identified was high level of distress. Individual risk factors identified were older age, female gender, smoking, high BMI, and co-morbidity.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Prolonged computer work	Smoking
	Heavy physical work	Co-morbidity
	High BMI	Psychosocial factor
	Older age	
	Female gender	
	Awkward posture	
	Repetitive work	

Lower limbs

Table III presents an overview of the studies investigating risk factors for lower limbs WMSD.

Non-specified lower limb WMSD. No biomechanical risk factor for non-specified lower limb WMSD was identified. The psychosocial risk factor identified was fear avoidance. Individual risk factors identified were concurrent chronic disease, smoking, and high BMI.

Strong evidence	Reasonable evidence	Insufficient evidence
None	None	Co-morbidity
		Psychosocial factors
		Smoking
		High BMI

Hip. The biomechanical risk factors identified were frequent stair climbing, and frequent heavy loads lifting and carrying.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Lifting	Repetitive work
	Heavy physical work	

Knee. The biomechanical risk factors identified for the development of knee WMSD were heavy physical work, prolonged kneeling or squatting, prolonged standing, frequent climbing, and frequent heavy loads lifting and carrying. The psychological risk factor identified was high general psychological distress. Individual risk factors identified were previous knee injury, smoking, and high BMI.

Strong evidence	Reasonable evidence	Insufficient evidence
None	Awkward posture	Psychological factor
	Lifting	Smoking
	Repetition	Heavy physical work
	Co-morbidity	High BMI

Fibromyalgia, mixed and non-specified WMSD

Table IV presents an overview of the studies investigating risk factors for fibromyalgia, and mixed and non-specified WMSD.

Two studies reporting occupational risk factors for widespread work-related musculoskeletal pain satisfied the inclusion criteria used. The biomechanical risk factors identified were repetitive work, and frequent squatting. Monotonous work was the psychosocial risk factor identified, and reporting any kind of pain at baseline and illness behavior were the individual risk factors identified.

Strong evidence	Reasonable evidence	Insufficient evidence
None	None	Co-morbidity
		Psychosocial factor
		Repetitive work
		Awkward posture
		Illness behavior

DISCUSSION

This systematic review confirms a plausible causal relationship between some commonly reported risk factors such as high biomechanical and psychosocial demands, smoking, high body mass index, and the presence of co-morbidities and WMSD. The results of recent longitudinal studies have confirmed some of the findings of previous reviews that have evaluated causal relationships between risk factors and specific types of WMSD. This review also highlights the scarce evidence regarding some of the frequently reported risk factors for WMSD.

It is important to underline that the lack of evidence for a causal relationship between a factor and a WMSD does not show that the factor is not a risk, but points out that further investigation is required. Factors do not require studies showing that they are indeed risks in order to affect musculoskeletal health. Similarly, the factors reported more frequently are not necessarily the ones with the highest level of evidence demonstrating their causal relationship with WMSD. Finally, the risk factors presenting a specific ''level of evidence'' associated with them, are not the only ones that should be considered; they are just the ones that have already been tested. In the following paragraphs we compare the findings of the present review with those of previous reviews. In light of this discussion, we propose future research and potential practical applications for our findings.

Current Versus Previous Reviews

A comparison of the findings of the present review with the findings of the NIOSH review and of other body part

specific reviews was conducted. We used a different (more stringent) selection criteria and definitions for the classification of the levels of evidence. To some extent, these differences limited our ability to compare and contrast our results with those of the other reviews. Thus, these methodological differences should be taken into account.

In general, the results of the current review were similar to the results of the previous NIOSH review. However, as opposed to the NIOSH report, we did not find sufficient evidence to support body vibration as a WMSD risk factor; future studies are therefore suggested to clarify this relationship. Once more, we would like to emphasize the fact that presenting insufficient evidence does not imply that the variable represents no risk for the development of WMSD. We interpret the seemingly conflicting findings as a result of the more stringent classification scheme used in the current review for the strength of evidence. The next sections compare and contrast our findings with the previous reviews' findings for each body part integrating the results.

Neck

In this review, the main risk factors found to have reasonable evidence supporting their causal relationship with neck WMSD were psychosocial factors, smoking, female gender, awkward postures, and co-morbidities. It was also stated on the NIOSH report that awkward postures were a risk factor for the development of neck WMSD. On the other hand, while it was reported in the NIOSH report that forceful and repetitive work had sufficient evidence to support them as risk factors for WMSD, we have not found reasonable evidence to confirm these relationships as we were only evaluating case–control and cohort studies. Thus, future case–control and cohort studies examining the potential physical risk factors for neck WMSD are recommended.

Shoulder

In this review, the main risk factors found to have reasonable evidence supporting their causal relationship with shoulder WMSD were heavy physical work and psychosocial factors. This is a novel conclusion that supplements the findings of the NIOSH report, which reported repetitive work as a potential risk factor but presented limited evidence in the literature at that time (Bernard et al., 1997). However, our results are based in only three studies. Due to the paucity of data, further investigation of the potential risk factors for shoulder WMSD in longitudinal studies with case–control and cohort designs is encouraged.

Wrist/hand

In this review, the main risk factors found to have reasonable evidence supporting their causal relationship with wrist/hand WMSD were computer work, heavy physical work, awkward posture, repetitive work, increased BMI, older age, and female gender. It was stated on the NIOSH report that computer work, heavy physical work and vibration are risk factors for the development of wrist/hand pain. Similarly, a previous systematic review reported that the combination of heavy physical work, repetitive work and vibration is a risk factor for wrist/hand WMSD [NRC/IOM, 2001]. The results of the previous reviews along with the findings of the current review support the causal relationship between computer work, heavy physical work, and repetitive work and wrist/hand pain.

On the other hand, although the NIOSH review identified vibration as an independent risk factor for hand/wrist WMSD, we did not find sufficient evidence on longitudinal studies to support vibration as a risk factor for hand/wrist WMSD in isolation. Longitudinal studies are required to clarify the potential role of this factor.

Low back

In this review, the main risk factors found to have reasonable evidence supporting their causal relationship with low back WMSD were heavy physical work, awkward postures, lifting, psychosocial factors, increased BMI and younger age. It was stated in the NIOSH report that awkward working postures, lifting and whole-body vibration were risk factors for the development of low back WMSD. Similar findings were reported on a systematic review conducted by the NRC/IOM, which also investigated causality and reported dynamic awkward postures, heavy physical work, whole-body vibration and psychosocial factors as risk factors for low back WMSD [NRC/IOM, 2001].

Hoogendoorn et al. [1999] conducted a systematic review to evaluate occupational and recreational physical loading as potential risk factors for ''back pain'' [Hoogendoorn et al., 1999]. Their review included studies with cohort ($n = 28$) or case-referent ($n = 3$) designs and excluded cross-sectional studies. The methodological quality and the consistency of the findings were assessed. The authors classified factors as having strong evidence when ''provided by generally consistent findings in multiple high-quality studies.'' Moderate evidence was operationally defined as ''provided by generally consistent findings in 1 high-quality and 1 low-quality study, or in multiple low-quality studies.'' Finally, no evidence was defined as ''only 1 study available or inconsistent findings in multiple studies.'' Based on their criteria, the authors found the following levels of evidence supporting the respective factors as risks for ''back pain'': strong evidence for manual materials handling, bending and twisting, and whole-body vibration; moderate evidence for patient handling and heavy physical work, and no evidence for standing or walking, sitting, sports, and total leisure-time physical activity. The factors identified as having strong or

moderate evidence supporting their relationship with back disorders were similar to the ones classified as having reasonable evidence in our review. The main difference was that using our criteria we did not find reasonable evidence supporting whole-body vibration as a risk factor for back disorders. The divergences may be explained by the distinct criteria used for classification of strength of evidence and outcome assessed (''back pain'' in general, as opposed to only ''low back pain'').

On a following review, Hoogendoorn et al. [2000a] conducted a systematic review of cohort and case–control studies to investigate a causal relationship between psychosocial factors and ''back pain.'' To evaluate strength of evidence, they used the same definitions used in Hoogendoorn et al. [1999]. They declared strong evidence had been found to show that low social support in the workplace and low job satisfaction are risk factors for ''back pain.'' Moreover, they reported finding insufficient evidence that high work pace, high qualitative demands, low job content, low job control, and psychosocial factors in private life lead to back pain. Based on our definition, we did not find strong evidence to support a causal relationship between any psychosocial factors and ''back pain.'' We found reasonable evidence to support a causal relationship between ''low back pain'' and low job satisfaction, high work pace, and low job content. In addition, we found insufficient evidence to support a causal relationship between low social support in the workplace and ''low back pain.'' Again, comparisons between reviews are limited since Hoogendoorn and associates' review investigated ''back pain'' without further explanation of which part(s) of the back was investigated and used different definitions to evaluate strength of evidence.

Our findings partially corroborate the previous reviews' results supporting heavy physical work, awkward working postures, lifting, and psychosocial factors as risk factors for low back WMSD. However, likewise our findings for wrist/hand WMSD, we did not find longitudinal studies providing evidence for the relationship between vibration and low back WMSD.

Hip

In this review, the main risk factors found to have reasonable evidence supporting their causal relationship with hip WMSD were heavy physical work and lifting. The hip was not investigated in the NIOSH report or by other reviews. Thus, future studies are also suggested to establish the risk factors for hip WMSD.

Knee

In this review, the main risk factors found to have reasonable evidence supporting their causal relationship with knee WMSD were awkward postures, lifting, repetition, and co-morbidities. These risk factors were found to have reasonable evidence and should consequently be taken into consideration when analyzing and modifying the workplace to reduce knee WMSD. As the hip, the knee was not investigated by the NIOSH report or by other reviews, therefore the results cannot be compared and further research is suggested.

Ankle and feet

As mentioned in the results session, we did not find longitudinal studies investigating ankle/feet WMSD. Although these body parts are also affected by WMSD and deserve consideration, the lack of studies meeting the established criteria limited our ability to provide information about these important disorders.

Methodological Challenges of Studying Risk Factors

Methodological problems are inherent to epidemiological studies of the association between work-related factors and musculoskeletal disorders [Walker-Bone and Cooper, 2005]. Study design issues are one of the main problems in this field of study. Most of the studies conducted in WMSD causation and prevention that have been done so far used cross-sectional designs, which impairs their ability to establish a causal relationship between work-related factors and WMSD. Moreover, problems such as different diagnostic criteria (due to lack of gold standard for the clinical diagnosis of most WMSD), different outcome assessments and different methods for measuring exposure make the establishment of risk factors a very difficult task to accomplish [Punnett et al., 2004; Walker-Bone and Cooper, 2005]. To deal with these problems, we have included only cohort and case–control studies, and classified the risk factors identified in our review using similar categories used in the NIOSH 1997 review [Bernard et al., 1997]. However, our definitions were somewhat different and, consequently, so were our results. Assembling the identified information was particularly difficult due to the high heterogeneity among the included studies, mainly regarding measurement of exposure and outcome. Thus, we recommend that the international community of WMSD investigators facilitate a collaborative effort to standardize the conduct, assessment, and reporting of WMSD trials. Such effort would be of significant benefit to trial end-users (e.g., clinicians, ergonomists, workers, policy makers, systematic reviewers). For instance, the Outcome Measures in Rheumatoid Arthritis Clinical Trials (OMERACT) initiative, has made a significant contribution to the field of rheumatology by taking the first steps towards standardizing the conduct, assessment and reporting of clinical trials in this field [Goldsmith et al., 1993; Tugwell and Boers, 1993].

Most risk factors coexist with other potential factors and most studies investigated the combined effect of these factors towards the development of WMSD. It is expected that a risk factor (e.g., forceful exertion) in the presence of another risk factor (e.g., repetitive work) or factors (e.g., high repetition in an awkward posture) will interact resulting on WMSD precipitation, even though definite multipliers for the interactions still needs to be defined [Vieira and Kumar, 2006]. Moreover, it is important to consider the external validity of potential risk factors. For instance, when analyzing individual risk factors such as age, careful interpretation is required. Although younger individuals were reported to have a higher predisposition to develop low back WMSD, other studies reported that upper limb WMSD is more common in older individuals. This may have occurred because it is more common for younger individuals to perform activities that require forceful movements and postures, thus becoming more susceptible to develop low back WMSD. In contrast, older individuals may perform activities that do not require as much physical effort; they are more likely to perform activities that demand more precise upper limb tasks instead, such as computer-related activities and line assembly tasks. Thus, risk factors need to be carefully evaluated in context rather than in isolation.

Strengths and Limitations of the Current Review

Factors not currently presenting strong evidence supporting them as being risks for WMSD should not be considered risk free. In this review we focus on evaluating the evidence available in cohort or case–control studies providing evidence that factors ''are'' actual risks for WMSD. Future reviews could focus on reviewing the evidence that factors ''are not'' risks for WMSD. Unlike most legal systems, any variable should be suspected until proven otherwise when considering risks. WMSD may occur when the musculoskeletal system is pushed over its physiological limits, which means a cumulative or single event exposure to one or more prolonged or excessive exertions [Kumar, 2001]. However, this review did not identify ''strong evidence'' in the currently published cohort or case–control studies for any of the acknowledged WMSD risk factors. The reason may be the rigorous definition used for ''strong evidence.'' Therefore, future research should be conducted to further investigate the risk factors that show some evidence or logical rationale for causing WMSD, taking into account the considerations regarding methodological issues and interpretation of the research findings.

As far as we know, this is the first review of risk factors for WMSD including only cohort or case–control studies to evaluate the available evidence for each body part. Information from cohort or case–control studies can reliably support risk evaluations and workplace modifications to reduce the rates of WMSD, and guide the design of future research. Nevertheless, the risk factors identified in the present review are similar to the ones reported in reviews that also included cross-sectional studies [Bernard et al., 1997; Keyserling, 2000; Walker-Bone and Cooper, 2005]. The constant appearance of risk factors in different studies reinforces the fulfillment of the ''consistency'' criteria for causality.

Implications for Practice

Interventions to prevent WMSD should not be based solely on individual risk factors that have fulfilled the criteria for causality. A supposed risk factor should be evaluated in relation to its potentially harmful effects when interacting with other variables, since some factors probably only become risks when presenting concomitantly. Future studies are necessary to clarify these aspects.

Studies investigating risk factors for the development of WMSD should report in detail the exposure levels. For instance, if repetition is identified as a risk factor, the number of necessary repetitions for it to become a risk should be reported as accurately as possible. This way, ergonomists will be able to make specific interventions to create a safer environment and to evaluate the results.

Using risk factors with weaker or no evidence may lead to unfounded, expensive and time-consuming modifications in the workplace which may be detrimental to production, without a significant benefit to the health of the workers. Thus, it is important for workplace interventions to address the risk factors that present at least reasonable evidence demonstrating their causal relationship with WMSD. Work-place interventions should be based on (1) risk factors (in isolation or in combination with other factors) identified in studies of high methodological quality, (2) the expertise of qualified professionals (e.g., ergonomists), (3) and the expertise and educated opinion of workers and work-place administrators (Fig. 2). This way, modifications may become more feasible and more likely to succeed.

Risk factors with reasonable evidence of a causal relationship with WMSD include high biomechanical and psychosocial demands, smoking, high body mass index, and the presence of co-morbidities. The most commonly reported biomechanical risk factors with reasonable evidence for causing WMSD include excessive repetition, awkward postures, and heavy lifting. Additional high methodological quality studies are needed for further understanding and for stronger evidence of the causal relationship between risk factors and WMSD to be found. The information provided in this article may be useful to healthcare providers, researchers, and ergonomists interested in risk identification and design of interventions to reduce the rates of WMSD.

FIGURE 2. Triad of evidence-based intervention proposed to reduce the risk of work-related musculoskeletal disorders.

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APPENDIX 1: SPECIFIC SEARCH STRATEGIES BASED ON EACH DATABASE

Medline

Search terms for ''work''

(1) exp employment/
(2) exp work/
(3) (worker OR job$ OR occupation$).ti. OR (worker OR job$ OR occupation$).ab.
(4) 1 OR 2 OR 3

Search terms for ''risk factors''

(5) exp risk factors/
(6) exp causality/
(7) 5 OR 6
(8) exp epidemiologic$ studies/
(9) 7 AND 8

Search terms for ''musculoskeletal disorder''

(10) exp cumulative trauma disorder/
(11) musculoskeletal disorder$.tw. OR injur$.tw. OR overuse syndrome$.tw
(12) ((injur$ OR disorder$) adj3 (repetition strain OR repetitive motion OR repetitive strain OR cumulative trauma)).tw.
(13) 10 OR 11 OR 12

Combination of search terms:

(14) 4 AND 9 AND 13

Search terms for limiting results

(15) limit 14 to (english language and yr=''1997–2008'')
(16) (child$ NOT adult$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
(17) (animal NOT human).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
(18) review.pt
(19) 16 OR 17 OR 18
(20) 15 NOT 19

Embase

Search terms for ''work''

(1) exp employment/
(2) exp work/
(3) (worker OR job$ OR occupation$).ti. OR (worker OR job$ OR occupation$).ab.
(4) 1 OR 2 OR 3

Search terms for ''risk factors''

(5) exp risk factors/
(6) exp causality/

(7) 5 OR 6
(8) exp epidemiologic$ studies/
(9) 7 AND 8

Search terms for ''musculoskeletal disorder''

(10) exp cumulative trauma disorder/
(11) musculoskeletal disorder$.tw. OR injur$.tw. OR overuse syndrome$.tw
(12) ((injur$ OR disorder$) adj3 (repetition strain OR repetitive motion OR repetitive strain OR cumulative trauma)).tw.
(13) 10 OR 11 OR 12

Combination of search terms:

(14) 4 AND 9 AND 13

Search terms for limiting results

(15) limit 14 to (english language and yr=''1997–2008'')
(16) (child$ NOT adult$).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
(17) (animal NOT human).mp. [mp=title, original title, abstract, name of substance word, subject heading word]
(18) review.pt
(19) 16 OR 17 OR 18
(20) 15 NOT 19

Cinahl

Search terms for ''work''

(1) (AB (work* OR job* or occupation*) OR TI (work* OR job* OR occupation*) OR (MM ''Work''))

Search terms for ''risk factors''

(2) ((MH ''Risk Factors'') OR (MH ''Epidemiological Research''))

Search terms for ''musculoskeletal disorder''

(3) ((MH ''Cumulative Trauma Disorders'') OR (MH ''Tendon Injuries'' OR AB injur* OR TI injur* OR AB musculoskeletal disorder* OR TI musculoskeletal disorder*))

Search term for limiting results

(4) NOT PT review

Combination of search terms:

(5) 1 AND 2 AND 3 AND 4

Limits provided by database

Published year: 1997 to 2008

Language: ENGLISH

Age groups: ALL ADULTS

PEER REVIEWED option selected

The Cochrane Library

Search terms for ''work''(work* OR job* OR occupation*):ti,ab,kw

Search terms for ''risk factors''

(2) MeSH descriptor Risk Factors explode all trees
(3) MeSH descriptor Causality explode all trees
(4) MeSH descriptor Epidemiologic Studies explode all trees
(5) #2 AND #3 AND #4

Search terms for ''musculoskeletal disorder''

(6) MeSH descriptor Sprains and Strains explode all trees
(7) injur* OR overuse syndrome* OR musculoskeletal disorder*
(8) ((injur* OR disorder*) NEAR/3 (repetition strain OR repetitive motion OR repetitive strain OR cumulative trauma))
(9) #6 AND #7 AND #8

Combination of search terms:

(10) #1 AND #5 AND #9

Search terms for limiting results

(11) child* NOT adult*
(12) (#10 AND NOT #11), from 1997 to 2008

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