Review

Scand J Work Environ Health 2010;36(3):189-201

doi:10.5271/sjweh.2895

Associations between work-related factors and specific disorders of the shoulder – a systematic review of the literature

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Refers to the following texts of the Journal: 2009;35(1):19-36 2009;35(2):113-126 1979;5 suppl 3:48-55

The following articles refer to this text: 2010;36(3):185-187; 2011;37(2):120-128; 2011;37(6):502-511; 2012;38(5):436-446; 2012;38(6):568-576; 2013;39(6):568-577; 2014;40(3):244-251; 2014;40(4):400-410; 2015;41(6):509-510; 2017;43(1):68-74

Key terms: disorder; force; literature review; MSD; musculoskeletal disorder; repetitiveness; review; rotator cuff; shoulder; shoulder disorder; SIS; specific shoulder disorder; subacromial impingement syndrome; systematic literature review; systematic review; work-related factor

This article in PubMed: www.ncbi.nlm.nih.gov/pubmed/20094690

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Associations between work-related factors and specific disorders of the shoulder – a systematic review of the literature

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van Rijn RM, Huisstede BMA, Koes BW, Burdorf A. Associations between work-related factors and specific disorders of the shoulder – a systematic review of the literature. *Scand J Work Environ Health.* 2010;36(3):189–201.

Objective Our aim was to provide a quantitative assessment of the exposure–response relationships between work-related physical and psychosocial factors and the occurrence of specific shoulder disorders in occupational populations.

Methods A systematic review of the literature was conducted on the associations between type of work, physical load factors, and psychosocial aspects at work, on the one hand, and the occurrence of tendinitis of the biceps tendon, rotator cuff tears, subacromial impingement syndrome (SIS), and suprascapular nerve compression, on the other hand. Associations between work factors and shoulder disorders were expressed in quantitative measures as odds ratio (OR) or relative risk (RR).

Results The occurrence of SIS was associated with force requirements >10% maximal voluntary contraction (MVC), lifting >20 kg >10 times/day, and high-level of hand force >1 hour/day (OR 2.8–4.2). Repetitive movements of the shoulder, repetitive motion of the hand/wrist >2 hours/day, hand–arm vibration, and working with hand above shoulder level showed an association with SIS (OR 1.04–4.7) as did upper-arm flexion ≥45° ≥15% of time (OR 2.43) and duty cycle of forceful exertions ≥9% time or duty cycle of forceful pinch >0% of time (OR 2.66). High psychosocial job demand was also associated with SIS (OR 1.5–3.19). Jobs in the fish processing industry had the highest risk for both tendinitis of the biceps tendon as well as SIS (OR 2.28 and 3.38, respectively). Work in a slaughterhouse and as a betel pepper leaf culler were associated with the occurrence of SIS only (OR 5.27 and 4.68, respectively). None of the included articles described the association between job title/risk factors and the occurrence of rotator cuff tears or suprascapular nerve compression.

Conclusions Highly repetitive work, forceful exertion in work, awkward postures, and high psychosocial job demand are associated with the occurrence of SIS.

Key terms force; musculoskeletal disorder; MSD; repetitiveness; review; rotator cuff; subacromial impingement syndrome; SIS.

Shoulder disorders and complaints constitute an important health problem in the working population. In a general population, reported prevalences of shoulder complaints range from 6.9–26% for point prevalence, 18.6–31% for one-month prevalence, and 4.7–46.7% for one-year prevalence (1). In the United Kingdom, shoulder complaints accounted for 12% of the work-related diseases in the period 1997–2000 (2). Silverstein et al reported a claim incidence rate for shoulder disorders of 54.0 per 10 000 fulltime equivalents per year (3). The relationship between shoulder disorders/complaints and work-related factors has been reviewed by several authors (4, 5). They report that highly repetitive work and repeated or sustained shoulder postures with >60° flexion or abduction is associated with shoulder disorders (5). Furthermore, a causal relationship was found between forceful exertions, a high level of static contractions, prolonged static loads, and extreme postures – as well as combinations of these factors – and shoulder disorders (4).

Recently in the Netherlands, consensus was reached on the terminology and classification of complaints of the arm, neck and/or shoulder (known as CANS) (6). Complaints at the shoulder classified as specific CANS were: subacromial impingement syndrome (SIS), tendinitis of the biceps tendon, rotator cuff tears, and suprascapular nerve compression.

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Tendinitis and bursitis around the shoulder are difficult to differentiate but can be identified as a group (6). SIS is the generic term for shoulder-area disorders that include rotator cuff syndrome, bursitis, and tendinitis of the musculus infraspinatus, supraspinatus and subscapularis (6). SIS is the most common disorder of the shoulder, accounting for 44–60% of all complaints of shoulder pain during a physician office visit (7, 8). SIS is characterized by shoulder pain that is aggravated by arm elevation and overhead activities (8, 9). In occupational settings, the prevalence of rotator cuff tendinitis ranged from 1% among data entry operators to 69% among industrial workers working above shoulder height (10). Pooling the OR of occupational groups with work tasks at shoulder level results in an overall OR of 11 (95% CI 2.7–48) (10). Silverstein et al reported a claim incidence rate of 19.9 per 10 000 fulltime equivalents per year for rotator cuff syndrome (3).

Tendinitis of the biceps tendon is an inflammation or irritation of the long head of the biceps brachii, which results in pain and decreased force in the upper arm. In specific occupations, a high prevalence of tendinitis of the biceps tendon has been reported [eg, 7.7% among fish-processing workers, 9.0% among assembly-line packers, and 9.2% among female workers in the laminate industry (11–13)]. Information on the occurrence of tendinitis of the biceps tendon in the general working population remains scarce.

A tear in one of the rotator cuff muscles (musculus supraspinatus, infraspinatus, and subscapularis or musculus teres minor) can be caused, for example, by a chronic irritation. Tears of the rotator cuff tendons are one of the most common causes of pain and disability in the upper extremity (14). However, no detailed information is available on the occurrence of rotator cuff tears in working populations.

Suprascapular nerve compression is a relatively rare neuropathy and accounts for roughly 1–2% of the total number of pathological conditions causing shoulder girdle pain and dysfunction (15); however, a prevalence of 16.7% has been reported in newsreel cameramen (16). The suprascapular nerve travels from the spine over the top of the scapulae to the back of the scapulae. Entrapment of this nerve results in pain around the shoulder that radiates to the upper arm. This disorder can be caused by direct injury, traction, and repetitive activities leading to overuse of the upper limb (17).

The literature presents little guidance to the etiology causing tendinitis of the biceps tendon, rotator cuff tears, SIS, and suprascapular nerve compression in terms of duration and magnitude of exposure to work-related risk factors. Therefore, we conducted a systematic review of the available evidence in the scientific literature with the aim of providing a quantitative assessment of the exposure–response associations between work-related physical and psychosocial exposures, on the one hand, and the occurrence of tendinitis of the biceps tendon, rotator cuff tears, SIS, and suprascapular nerve compression, on the other hand.

Methods

Literature search

The first author conducted comprehensive literature searches using Medline (from 1966 to November 2009), Embase (from 1984 to November 2009) and the Cochrane Central Register of Controlled Trials. The following keywords were used for tendinitis of the biceps tendon, rotator cuff tears, SIS, and suprascapular nerve compression: (biceps tend*), (rotator cuff OR supraspinatus OR infraspinatus), (shoulder impingement syndrome OR subacromial impingement syndrome), (suprascapular nerve compression OR suprascapular nerve entrapment). Keywords used for exposure and association included: (work-related OR physical load OR psychosocial load) AND (association OR risk factors OR odds ratio OR relative risk). The complete search strategy is available on request. The search was extended by screening the reference lists of all relevant articles identified.

Two reviewers independently selected the articles initially based on title and abstract. For final inclusion, articles had to fulfill *all* of the following criteria: (i) report the occurrence of tendinitis of the biceps tendon, rotator cuff tears, SIS, and suprascapular nerve compression in occupational populations, (ii) exclude musculoskeletal complaints that were caused by acute trauma or by any systemic disease, (iii) present a quantitative description of the measures of exposure, and (iv) be published in peer-reviewed scientific journals written in English, German, French, or Dutch.

Assessment of methodological quality

We constructed a quality assessment list using criteria from Huisstede et al (18, 19) Lievense et al (20), van Tulder et al (21), and the Dutch Cochrane Centre (The Cochrane Collaboration, Dutch Cochrane Centre: http://www.cochrane.nl/en/index.html), which were adapted to meet the specific aim of this review (table 1). The list covers 5 topics, totaling 16 items, namely: (i) study population, (ii) assessment of exposure, (iii) assessment of outcome, (iv) study design and analysis, and (v) data presentation. Two reviewers independently assessed the quality of each study by scoring each of the study criterion as "positive", "negative", or "unclear". Disagreements were resolved by consensus. The quality score for every study was calculated by summing the number of positive criteria (summary score). Studies with 11 or

Table 1. Methodological quality assessment. Scoring options included positive, negative, or unclear.

Criteria for quality score	
Study population	
1 Study groups (exposed and unexposed) are clearly defined	Positive if at least 2 of the following 3 items in both groups were reported at baseline: age [mean (standard deviation or confidence interval), or dichotomized groups]; gender (number and/or percentage); sport/leisure time exposure
2 Participation ≥70%	Positive if the participation of both the exposed and unexposed groups was ≥70%
3 Number of cases ≥50	Positive if the total number of cases was ≥50
Assessment of exposure	
4 Exposure definition	Positive if the exposure was clearly defined
5 Assessment of exposure	Positive if the assessment of exposure was described
6 Blind for outcome status	Positive if the exposure was assessed by an independent person and not based on self-report
Assessment of outcome (specific disorder)	
7 Outcome definition	Positive if the outcome was clearly defined
8 Assessment method	Positive if the method of assessment was suitable
9 Blind for exposure status	Positive if the outcome was measured without knowledge of the exposure status by an independent person, thus not based on self-reported symptoms
Study design	
10 Prospective design or a retrospective cohort	Positive if the study design was prospective or a retrospective cohort
11 Inclusion and exclusion criteria	Positive if inclusion and exclusion criteria were described
12 Follow-up period ≥1 year	Positive if the follow-up period was ≥1 year
13 Information on study completers versus withdrawals	Positive if demographic information was given for completers and withdrawals
Analysis and data presentation	
14 Data presentation	Positive if risk estimates were presented or when raw data were given that allow the calculation of risk estimates, such as: odds or prevalence ratios or relative risks
15 Consideration of confounders	Positive if the confounders that were considered were described
16 Control for confounding	Positive if the method used to control for confounding was described

more positive criteria were considered to be of "high quality". In addition, we calculated an item score by summing the studies with a positive score.

Data extraction

The first author extracted relevant data from the articles and, using a standardized form, collected information on the study population, study design, outcome ascertainment, exposure characteristics, measure of association, and confounding factors. The core findings in each article were expressed by measures of association: odds ratios (OR) or relative risks (RR) with corresponding 95% confidence intervals (95% CI). Where possible, these associations were directly extracted from the original article. In articles where this information was not presented, associations were calculated if sufficient raw data were provided.

Statistical analysis

In this review, we distinguished three types of statistical associations. The association was described as "positive" when the occurrence of one of the four disorders at the shoulder (ie, tendinitis of the biceps tendon, rotator cuff tears, SIS, or suprascapular nerve compression) was statistically associated with higher values of the risk factor. In a "negative" association, a higher value of the risk factor was statistically associated with a lower occurrence of one of the four disorders at the shoulder. In "null" associations, the risk estimate was not statistically different from unity. The null associations were further evaluated to assess whether the results actually suggested the absence of an effect or if the studies were inconclusive due to a lack of information. Results of individual studies were pooled when studies were considered sufficiently homogenous with respect to exposure parameters, health outcomes, and study design. The level of heterogeneity was determined across studies to decide whether a random- or a fixed-effects model should be used to calculate a pooled risk estimate for each risk factor.

The characteristics of the study and the methodological quality were used in a descriptive analysis of the exposure–response relationship between risk-factors and the occurrence of specific disorders at the shoulder to evaluate the consistency of the results.

Firstly, we focused on the association between type of work (based on, for example, job title) and the occurrence of one of the four disorders at the shoulder. Then, we focused in more detail on the association between

five types of exposure [(i) force, (ii) repetitiveness, (iii) hand-arm vibration, (iv) combined exposure measure, and (v) posture] and the occurrence of one of the four disorders at the shoulder. Finally, we focused on the association between psychosocial risk factors and the occurrence of these disorders.

Results

Characteristics of included studies

The search of the literature resulted in 1739 potentially relevant articles; figure 1 shows the process of identifying the relevant articles. A total of 17 articles met our inclusion criteria (12, 13, 22–36): 14 cross-sectional studies, 1 case-control study, and 2 cohort studies (table 2). Multiple publications were found for Silverstein et al reporting on the same data (32, 37). Information from both publications was used for the methodological quality assessment and data extraction, but only the first or most prominent publication was used for citation of these studies. None of the included articles described the association between job title/risk factors and the occurrence of rotator cuff tears or suprascapular nerve compression. The occurrence of SIS and tendinitis of the biceps tendon across occupations was compared in ten and two articles, respectively (table 3). Of these, Norander et al (13) described both disorders across occupations. Seven articles reported on the association of physical risk factors and SIS (table 4); of these, one article also compared the occurrence of SIS across occupations. Finally, three articles described the relation between psychosocial work factors and SIS (table 5).

Seven studies did not present measures of associations, but we used the raw data available in these studies to calculate the associations (N=10) (13, 22, 26–28, 30, 36).

Methodological quality

Table 6 presents the methodological quality assessment of the included studies. The two reviewers agreed initially on 77% studies (210 of 272 items); all initial disagreements were resolved in a consensus meeting. Only 3 articles (18%) scored positive on the item's

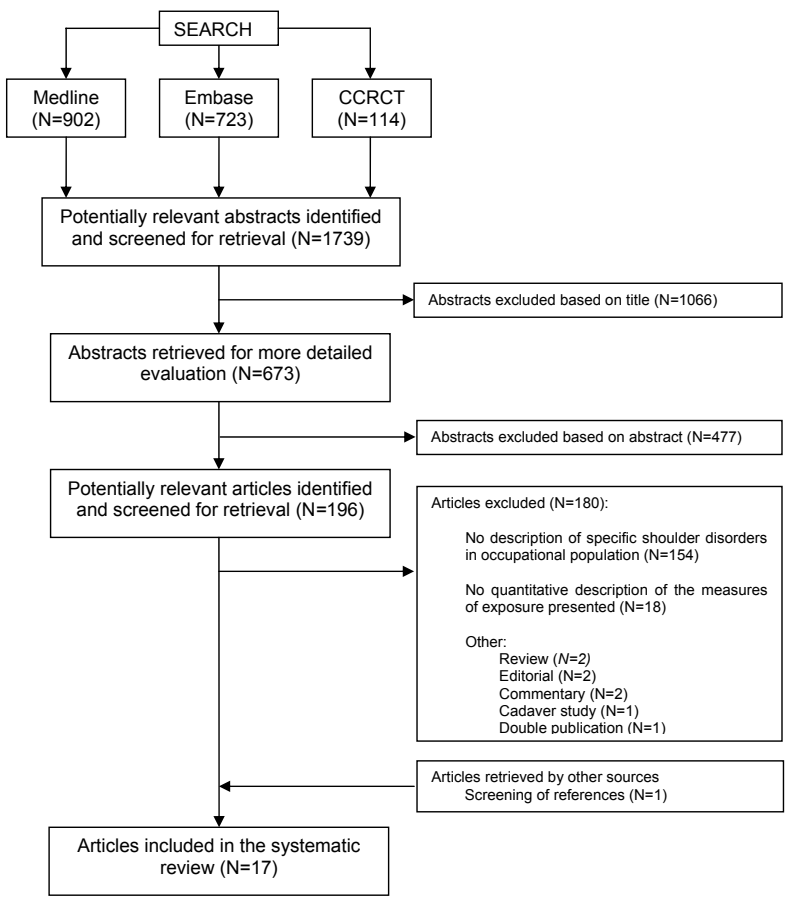

Figure 1. Flow chart of the process to select relevant articles. [CCRCT= Cochrane Central Register of Controlled Trials]

Table 2. Definition and assessment of exposure and outcome for each included article. [MVC=maximal voluntary contraction]

Author	Outcome		Exposure	
	Criteria	Assessment	Definition	Assessment
Andersen et al, 1993 (22)	Rotator cuff syndrome: self-reported chronic shoulder pain. Tenderness at tuberculum majus and positive pain arc test or impingement sign (pain at passive abduction of the arm when the rotation of the scapulae is fixed) [a]	Questionnaire, physical examination	Job title; exposure time of sewing machine work (year)	Questionnaire
Frost et al, 1999 (23)	Self-reported symptoms in the shoulder region for ≥3 months within the past year combined with clinical signs of impingement [a]	Questionnaire, physical examination	Job title	Questionnaire
Frost et al, 2002 (24)	Self-reported shoulder pain in combination with pain at resisted abduction and tenderness of the greater humeral tubercle/impingement [a]	Questionnaire, physical examination	Repetitive hand arm movements (yes/no); frequency of shoulder movements, low: 1–14 movements/minute, high: 15–36 movements/minute; force requirements, low: <10% of MVC (1 on 1–5 scale), high: >10% of MVC (2–5 on 1–5 scale); micro pauses in shoulder flexion (% of task), ≤80% of cycle time without pauses, >80% of cycle time without pauses	Observation by plant walkthrough
Herberts et al, 1981 (25)	Periods of shoulder pain, tenderness by palpation and pain disappeared only after relaxation or change to lighter work [a]	Questionnaire, physical examination	Job title	Not reported
Kaergaard et al, 2000 (26)	Self-reported pain in the shoulder region, palpation tenderness at the tuberculum majus humeri or sign of subacromial impingement and shoulder pain on resisted abduction [a]	Questionnaire, physical examination	Job title	Expert opinion based on types of tasks
Kaerlev et al, 2008 (27)	Rotator cuff syndrome in occupational hospitalization register [b]	Medical records	Job title	Danish Seafarer Register
Luopajärvi et al,1979 (12)	Physiotherapist recorded findings and diagnoses was made afterwards by group of specialists [a]	Physical examination	Job title	Not reported
Melchior et al, 2006 (28)	Intermittent pain in the shoulder region without paresthesias worsened by active elevation movement of the upper arm as in scratching the upper back and 1 of the following tests positive: resisted shoulder abduction, external, or internal rotation; resisted elbow flexion; painful arc on active upper-arm elevation [a]	Questionnaire, physical examination	Manual work (yes/no)	Questionnaire
Miranda et al, 2005 (29)	History of pain in the rotator cuff region lasting for ≥3 months, pain during the month preceding the examination, and pain in the rotator cuff region upon ≥1 resisted active movements: abduction of the arm (supraspinatus), external rotation of the arm (infrasinatus, teres minor) and internal rotation of the arm (subscapualris) or painful arc of shoulder abduction [a]	Physical examination	Frequent lifting, ≥5 kg, >2 times/minute, >2 hours/day (year); heavy lifting, >20 kg, >10 times/day (year); working with hand above shoulder, ≥1 hour/day (year); work requiring high hand force, ≥1 hour/day (year); work requiring repetitive motion hand/wrist, ≥2 hour/day (year); working with a vibrating tool, ≥2 hours/day (year); job demands	Interview, questionnaire
Nordander et al, 1999 (13)	Pain before provocation and palpation of the tissues and complaints in the neck and upper limbs during the past 12 months and past 7 days, as well as inability to work during the past 12 months and clinical signs [a]	Interview, physical examination	Job title	Ergonomic workplace analysis
Ohlsson et al, 1994 (30)	Diagnoses by examiner based on standard set of criteria on symptoms as well as signs [a]	Interview, physical examination	Job title	Questionnaire, observation
Park et al, 1992 (31)	Rotator cuff syndrome in insurance claim [b]	Medical records	Job title	Expert opinion based on job title
Silverstein et al, 2008 (32)	Rotator cuff syndrome: shoulder pain or burning in past 12 months occurring ≥3 times or lasting >1 week, and shoulder pain or burning present in the previous 7 days, and no traumatic injury onset, and resisted shoulder abduction, external rotation, internal rotation, or a "painful arc", and no history of acute trauma to the shoulder or rheumatoid arthritis [a]	Questionnaire, physical examination	Upper-arm flexion & duty cycles of forceful exertion (%time): forceful exertion, pinch grip force ≥8.9 N (0.9 kg) or lifting objects weight, power grip or push/pull forces ≥44.1 N (4.5 kg) upper-arm flexion and pinch grip force (% time): pinch grip force ≥8.9 N; decisions latitude (low / high); job satisfaction (low / high); job security (low / high)	Observation on-site and videotaped, questionnaire
Sutinen et al, 2006 (33)	Typical history of painful arch and intermittent pain and pronounced tenderness locally in the shoulder region were diagnostic or, in addition, at least one of the signs: painful arch test during elevation, pain in resisted abduction or resisted external rotation [b]	Questionnaire, physical examination	Lifelong vibration energy (m^2/s^4) hd)	Measurements on chain saw
Svendsen et al, 2004 (34)	Increased signal intensity on T2-weighted images in two planes or focal areas of tendon discontinuity with T2 bright fluid signal or focal complete discontinuity of tendon fibres from articular to bursal surfaces or complete discontinuity of the tendon with atrophy of the muscle [a]	MRI	Lifetime upper-arm elevation >90° (months); lifetime shoulder force requirements (low/medium/high)	Inclinometer measurements, torque index

(continued)

Table 2. Continued.

Author	Outcome		Exposure	
	Criteria	Assessment	Definition	Assessment
Svendsen et al, 2004 (35)	At least one sign of indirect tenderness (painful arc test positive, pain provoked by isometric abduction, Jobe's test positive) and at least one sign of direct tenderness (Hawkin's test positive, abduction internal rotation test positive) [a]	Physical examination	Upper elevation above 90° (% of working hours); job demands; job control; social support	Inclinometer measurements, questionnaire
Wang et al, 2005 (36)	Shoulder pain and tenderness accompanied the positive supraspinatus test, or positive Hawkins impingement test, with typical findings on ultrasonography, such as wall thickening or fluid collection in the subacromial-subdeltoid bursae, hypoechoic thickening or an anechoic gap of the rotator cuffs, and dynamic impingement [a]	Questionnaire, physical examination, ultrasonography	Job title	Questionnaire

[a] Measure of interest is prevalence
[b] Measure of interest is incidence

Table 3. Studies that report the occurrence of specific disorders in the shoulder across occupations ordered by outcome. (CS=cross-sectional; CC= case–control, BT= tendinitis of biceps tendon; SIS= subacromial impingement syndrome; ST=supraspinatus; IT=infraspinatus; RCS= rotator cuff syndrome; RCT= rotator cuff tendinitis; OR= odds ratio; 95% CI=95% confidence interval; PR= prevalence)

Author	Study design	Study population		Outcome	Results	
		Exposed	Reference		OR	95% CI
Luopajärvi et al, 1979 (12)	CS	Female assembly line workers in a food production factory (N=152)	Female shop assistants (N=133)	BT	2.60	0.91–7.41
Nordander et al 1999 (13)	CS	Fish processing workers (N=322)	Referents employed as caretakers, workers in community parks and gardens, workers repairing and maintaining equipment and machines, day nurses, caretakers (N=337)	BT	2.28	1.13–4.62
Herberts et al, 1981 (25)	CS	Welders at a shipyard (N=131)	Office clerks (N=57)	SIS (ST)	18.3 [a]	14.7–22.1 [b]
Park et al, 1992 (31)	CC	Cases with one or more insurance claims for RCS	Controls with one or more insurance claims for other causes	SIS		
		Frame/body assembly work (N=13)			2.0 [c]	1.1–3.8
		Trim/chassis assembly work (N=36)			1.7 [c]	1.1–2.6
		Sewing work (N=23)			2.5 [c]	1.4–4.5
		Pressing work (N=39)			3.3 [c]	2.1–5.1
		Assembly/finishing stamping work (N=19)			2.1 [c]	1.2–3.7
Andersen et al, 1993 (22)	CS	Sewing machine operators (N=82)	Auxiliary nurses and home helpers (N=25)	SIS (RCS)	6.8	0.85–53.4
Ohlsson et al, 1994 (30)	CS	Female fish processing workers (N=206)	Female employees in municipal workplaces (N=208)	SIS (ST)	3.38	1.6–7.1
				SIS (IT)	4.65	1.9–11.6
Frost et al, 1999 (23)	CS	Slaughterhouse workers (N=576)	Repairmen or chemical workers in chemical plant (N=398)	SIS	5.27	2.09–13.26
Nordander et al, 1999 (13)	CS	Fish processing workers (N=322)	Referents employed as caretakers, workers in community parks and gardens, workers repairing and maintaining equipment and machines, day nurses, caretakers (N=337)	SIS (ST)	3.38	1.68–6.82
				SIS (IT)	4.49	1.93–10.43
Kaergaard et al, 2000 (26)	CS	Sewing machine operators (N=238)	Workers with supervisory jobs, service jobs, office workers and other workers considered to have a good deal of variation in their jobs (N=357)	SIS (RCT)	2.73	1.13–6.60
Wang et al, 2005 (36)	CS	Female betel pepper leaf cullers (N=20)	Female non-cullers (N=47)	SIS	4.68	1.42–15.4
Melchior et al 2006 (28)	CS	Manual occupation (N=1160)	Non-manual occupation (N=1496)	SIS (RCS)	1.76	1.32–2.34
Kaerlev et al, 2008 (27)	Cohort	Fishermen (N=8040)	Officers (N=10436)	SIS (RCS)	2.54	1.50–4.30
		Non-officers (N=11 037)			1.31	0.74–2.29

[a] Prevalence.
[b] 90% confidence interval.
[c] Adjusted for age and gender.

Table 4. Associations between physical risk factors at work and the occurrence of specific disorders at the shoulder. [CS=cross-sectional, SIS= subacromial impingement syndrome, ST=supraspinatus, RCS= rotator cuff syndrome, RCT= rotator cuff tendinitis, OR= odds ratio, 95% CI=95% confidence interval]

Author	Study design	Study population	Outcome	Physical risk factor	Results	
					OR	95% CI
				Force		
Frost et al, 2002 (24)	CS	Workers in food processing companies, textile plants, electronic plants, cardboard industries, postal sorting centres, a bank, and supermarkets (N=3123)	SIS (ST)	Force requirements		
				Low versus reference	2.17[a]	0.84–5.59
				High versus reference	4.21[a]	1.71–10.40
Svendsen et al, 2004 (34)	CS	Male machinists, car mechanics, and house painters (N=136)	SIS (ST)	Lifetime shoulder force requirements		
				Medium versus low	1.24[b]	0.48–3.18
				High versus low	0.71[b]	0.30–1.65
Miranda et al, 2005 (29)	CS	A sample of general population restricted to subjects aged 30–64 years who had held a job during the preceding 12 months (N=8028)	SIS(RCT)	Frequent lifting, ≥5 kg >2 times/minute >2 hours/day		
				1–3 year versus none	1.4	0.5–3.7
				4–13 year versus none	1.5	0.7–3.3
				14–23 year versus none	1.9	0.9–3.9
				>23 year versus none	2.0	0.9–4.3
				Heavy lifting, >20 kg >10 times/day (year)		
				1–3 year versus none	1.5	0.6–4.1
				4–13 year versus none	3.0	1.6–5.8
				14–23 year versus none	2.8	1.4–5.7
				>23 year versus none	1.8	0.8–4.2
				Work requiring high hand force, ≥1 hour/day (year)	2.3	0.9–6.3
				1–3 year versus none	2.8	1.4–6.0
				4–13 year versus none	3.7	1.9–7.1
				14–23 year versus none	1.8	0.8–4.1
				>23 year versus none		
				Repetitiveness		
Frost et al, 2002 (24)	CS	Workers in food processing companies, textile plants, electronic plants, cardboard industries, postal sorting centres, a bank, and supermarkets (N=3123)	SIS (ST)	Repetitive hand–arm movements (yes/no)	3.12[a]	1.33–7.34
				Frequency of shoulder movements		
				Low versus reference	2.93[a]	1.17–7.36
				High versus reference	3.29[a]	1.34–8.11
Miranda et al, 2005 (29)	CS	A sample of general population restricted to subjects aged 30–64 years who had held a job during the preceding 12 months (N=8028)	SIS (RCT)	Work requiring repetitive motion hand/wrist, ≥2 hours/day (year)		
				1–3 year versus none	1.6	0.5–5.2
				4–13 year versus none	0.8	0.3–2.1
				14–23 year versus none	2.4	1.3–4.3
				>23 year versus none	2.6	1.4–4.9
				Hand–arm vibration		
Miranda et al, 2005 (29)	CS	A sample of general population restricted to subjects aged 30–64 years who had held a job during the preceding 12 months (N=8028)	SIS (RCT)	Working with a vibrating tool, ≥2 hours/day (year)		
				1–3 year versus none	0.6	0.1–4.6
				4–13 year versus none	2.5	1.0–5.9
				14–23 year versus none	3.5	1.5–7.8
				>23 year versus none	1.4	0.5–4.4
Sutinen et al, 2006 (33)	Cohort	Professional forestry workers using a chainsaw (N=52)	SIS (RCS)	Lifelong vibration energy [(m^2/s^4) hd]	1.04[b]	1.00–1.07
				Posture		
Andersen et al, 1993 (22)	CS	Sewing machine operators (N=82)	SIS (RCS)	Exposure time		
				8–15 versus 0–7 years	6.32	0.69–57.45
				>15 versus 0–7 years	8.80	1.05–74.04
Frost et al, 2002 (24)	CS	Workers in food processing companies, textile plants, electronic plants, cardboard industries, postal sorting centres, a bank, and supermarkets (N=3123)	SIS (ST)	Micro pauses in shoulder flexion		
				≤80% of cycle time without pauses versus reference	2.82[a]	1.10–7.28
				>80% of cycle time without pauses versus reference	3.33[a]	1.37–8.13
Svendsen et al, 2004 (34)	CS	Male machinists, car mechanics, and house painters (N=136)	SIS (ST)	Lifetime upper-arm elevation >90° (months)		
				10–<20 versus 0–<10	0.95[b]	0.41–2.20
				≥20 versus 0–<10	2.33[b]	0.93–5.84
Svendsen et al, 2004 (35)	CS	Male machinists, car mechanics, and house painters (N=1627; 3067 shoulders)	SIS (ST)	Upper-arm elevation >90° (% of working hours)		
				3–6% versus 0–3%	0.94	0.37–2.39
				6–9% versus 0–3%	4.70	2.07–10.68
Miranda et al, 2005 (29)	CS	A sample of general population restricted to subjects aged 30–64 years who had held a job during the preceding 12 months (N=8028)	SIS (RCT)	Working with hand above shoulder, ≥1 hour/day (year)		
				1–3 years versus none	2.3	0.9–5.4
				4–13 years versus none	3.2	1.6–6.5
				14–23 years versus none	4.5	2.3–8.6
				>23 years versus none	2.3	1.1–4.8

(continued)

Table 4. Continued.

Physical risk factor	Study design	Study population	Outcome	Physical risk factor	Results	
					OR	95% CI
				Combined exposure measure		
Frost et al, 2002 (24)	CS	Workers in food processing companies, textile plants, electronic plants, cardboard industries, postal sorting centres, a bank, and supermarkets (N=3123)	SIS (ST)	Frequency and force		
				Low frequency and low force versus reference	2.49[a]	0.94–6.64
				High frequency and low force versus reference	1.73[a]	0.56–5.33
				Low frequency and High force versus reference	2.89[a]	0.77–10.77
				High frequency and High force versus reference	4.82[a]	1.86–12.51
				Frequency and micro-pauses		
				Low frequency and no pauses ≤80% of cycle time versus reference	3.08[a]	1.20–7.93
				Low frequency and no pauses >80% of cycle time versus reference	2.33[a]	0.68–8.02
				High frequency and no pauses >80% of cycle time versus reference	3.53[a]	1.43–8.70
				Force and micro-pauses		
				Low force and no pauses ≤80% of cycle time versus reference	2.29[a]	0.82–6.36
				Low force and no pauses >80% of cycle time versus reference	2.10[a]	0.74–5.97
				High force and no pauses ≤80% of cycle time versus reference	3.45[a]	0.90–13.23
				High force and no pauses >80% of cycle time versus reference	4.48[a]	1.73–11.61
Silverstein et al, 2008 (32)	CS	Workers were recruited from manufacturing (electronics, automotive parts, windows, cabinets, medical and fitness equipment) and healthcare (hospitals and health research areas excluding direct patient care) sectors in Washington State (N=733)	SIS (RCS)	Upper-arm flexion ≥45° and duty cycle of forceful exertion (% time)		
				Flexion ≥15% or duty cycle ≥9% versus flexion <15% and duty cycle <9%	2.02[c]	0.88–4.64
				Flexion ≥15% and duty cycle ≥9% versus flexion <15% and duty cycle <9%	2.43[c]	1.04–5.68
				Upper arm flexion ≥45° and pinch grip force (% time)		
				Flexion ≥15% or pinch >0% versus flexion <15% and no pinch	1.01[c]	0.49–2.11
				Flexion ≥15% and pinch >0% versus flexion <15% and no pinch	2.66[c]	1.26–5.59

[a] Adjusted for center, age, age squared, gender, shoulder injury, shoulder operation, physical activity during leisure time, overhead sport, body mass index, and pressure algometry.
[b] Adjusted for age.
[c] Adjusted for age, gender, body mass index, and job security.

Table 5. Associations between psychosocial risk factors at work and the occurrence of specific disorders at the shoulder. (CS=cross-sectional, SIS= subacromial impingement syndrome; ST=supraspinatus; RCT= rotator cuff tendinitis; RCS= rotator cuff syndrome; OR= odds ratio; 95% CI=95% confidence interval)

Author	Study design	Study population	Outcome	Psychosocial risk factor	Results	
					OR	95% CI
Svendsen et al, 2004 (35)	CS	Male machinists, car mechanics, and house painters (N=1627; 3067 shoulders)	SIS (ST)	Job demands (high versus low)	3.19	1.62–6.31
				Job control (low versus high)	1.83	0.93–3.60
				Social support (low versus high)	0.91	0.46–1.77
Miranda et al, 2005 (29)	CS	A sample of general population restricted to subjects aged 30-64 years who had held a job during the preceding 12 months (N=8028)	SIS (RCT)	Job demands (high versus low)	1.7	1.0–3.0
Silverstein et al, 2008 (32)	CS	Workers were recruited from manufacturing (electronics, automotive parts, windows, cabinets, medical and fitness equipment) and health care (hospitals and health research areas excluding direct patient care) sectors in Washington State (N=733)	SIS (RCS)	Decision latitude (high versus low)	0.55[a]	0.31–1.0
				Job satisfaction (high versus low)	0.61[a]	0.34–1.07
				Job security (high versus low)	0.56[a]	0.31–0.98

[a] Adjusted for age, gender, body mass index.

Table 6. Methodological quality scores of the included articles. Score of ≥11=high quality. [SIS = subacromial impingement syndrome, BT = tendinitis of biceps tendon, + = positive, - = negative, ? = unclear]

		Item numbers (see figure 1 for item criteria)																
Author	Outcome	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Summary score
Svendsen et al (34)	SIS	-	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	13
Svendsen et al (35)	SIS	-	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	13
Frost et al (24)	SIS	-	+	+	+	+	+	+	+	+	-	+	-	-	+	+	+	12
Miranda et al (29)	SIS	+	+	+	+	+	+	+	+	?	-	+	-	-	+	+	+	12
Sutinen et al (33)	SIS	-	?	-	+	+	+	+	+	+	+	+	+	-	+	+	+	12
Silverstein et al (32)	SIS	+	-	+	+	+	+	+	+	+	-	+	-	-	+	+	+	12
Frost et al (23)	SIS	+	-	+	+	+	+	+	+	-	-	+	-	-	+	+	+	11
Melchior et al (28)	SIS	-	+	+	+	+	+	+	+	-	-	+	-	-	+	+	+	11
Kaergaard et al (26)	SIS	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	10
Andersen et al (22)	SIS	+	?	-	-	+	+	+	+	+	-	+	-	-	+	+	+	10
Nordander et al (13)	SIS/BT	-	+	+	+	+	+	+	+	-	-	+	-	-	+	-	-	9
Ohlsson et al (30)	SIS	-	+	+	+	+	+	+	+	-	-	+	-	-	+	-	-	9
Kaerlev et al (27)	SIS	+	+	+	-	-	+	+	-	?	+	+	+	?	+	-	-	9
Park et al (31)	SIS	-	+	+	-	-	+	-	-	+	-	+	-	+	-	+	+	8
Wang et al (26)	SIS	-	+	-	-	-	-	+	+	-	-	+	-	+	+	-	-	6
Luopajarvi et al (12)	BT	-	+	-	-	+	+	-	-	-	-	+	-	+	+	-	-	6
Herberts et al (25)	SIS	-	?	-	-	+	+	-	-	-	-	+	-	-	-	-	-	3
Item score		5	11	11	11	14	16	14	13	8	3	17	3	6	14	10	10	

"prospective design" and "follow-up period ≥1 year". Other critical items were "blinding to exposure status" (N=8), "information presented between completers versus withdrawals" (N=6), and "study groups (exposed and unexposed) are clearly defined" (N=5). A significantly lower quality score was found in studies reporting shoulder disorders by job title compared to articles reporting the risk of shoulder disorders by physical and psychosocial risk factors, 8.20 versus 12.00 (P=0.05). Since 1979, an increasing number of high-quality studies have been published. Seven articles with the highest scores (≥11) have been published since 2002 (figure 2).

Job title and shoulder disorders

Two articles with a low quality score (<11) described differences in the occurrence of tendinitis of the biceps tendon between occupations (12, 13). A significantly increased risk was reported in fish processing workers (OR=2.28) (13). SIS was found to be a common disorder in shipyard welders, with a prevalence of 18.3% (25). Other jobs with increased occurrence of SIS included: (i) work in slaughterhouses (OR=5.27), (ii) fish processing work (OR=4.49, and 4.65), (iii) betel pepper leaf cullers (OR=4.68), and (iv) fishermen (OR=2.54); these data were reported in four low-quality (13, 27, 30, 36) and one high-quality study (23).

Exposure and occurrence of SIS

Force. Two of the three articles with a high-quality score (≥11) found significant associations between exposure to force and SIS, with OR ranging from 2.8–4.21 (24, 29). In the cross-sectional study of Frost et al (24), force requirements of >10% of maximal voluntary contraction (MVC) was a risk factor for SIS. Lifting >20 kg, >10 times/day (duration 4–13 years and 14–23 years), and work requiring high hand force ≥1 hour/day (4–13 years and 14–23 years) were associated with SIS (29). Null associations were found for lifetime shoulder force requirements and frequent lifting ≥5 kg, >2 times/minute for >2 hours/day, with OR ranging from 0.71–2.0 (29, 34).

Repetitiveness. Two articles with a quality score ≥11 reported a significant association between exposure to repetition and SIS (24, 29). An increased risk for SIS was found in jobs that required low

(1–14 movements/minute) and high (15–36 movements/minute) frequency of shoulder movements, with OR of 2.93 and 3.29, respectively (24). In the cross-sectional study of Miranda et al (29), work with repetitive motion of the hand/wrist ≥2 hours/day (14–23 years and >23 years) was associated with SIS.

Hand–arm vibration. Significant associations were found in two articles (quality score ≥11), with OR of 1.04–3.5 (29, 33). Increased risk for SIS was found in workers using a vibrating tool ≥2 hours/day (4–13 years and 14–23 years) (29). Further, a mean vibration energy dose of 84×10^6 (m^2/s^4)hd was associated with the occurrence of SIS (33).

Posture. Five articles presented significant associations between postural load and SIS (22, 24, 29, 34, 35). Three articles with a quality score ≥11 presented significant associations between, on the one hand, upper-arm elevation of >90° (6–9% of working hours or ≥20 months) and working with hand above shoulder ≥1 hour/day (4–13 years, 14–23 years and >23 years) and, on the other hand, the occurrence of SIS, with OR ranging from 1.27–4.70 (29, 34, 35). A lack of micro pauses in shoulder flexion ≤80% and >80% of the cycle time was associated with SIS, with OR of 2.82 and 3.33, respectively (24). Studying sewing machine operators, Andersen et al (22) (quality score 10) found positive associations (albeit not all significant) between duration of exposure (8–15 years and >15 years) and the occurrence of SIS, with OR of 6.32 (95% CI 0.69–57.45) and 8.80 (95% CI 1.05–74.04).

Combined exposure measure. Two articles reported on the association between exposure to a combination of risk factors and SIS (24, 32). The study of Frost et al (24) presented significant associations between the occurrence of SIS and (i) exposure to high frequency–high force (OR=4.82), (ii) low frequency (ie, ≤80% of work cycle without pauses: OR=3.08), (iii) high frequency (ie, >80% of work cycle without pauses: OR=3.53), and (iv) high force (ie, >80% of work cycle without pauses: OR=4.48). In the cross-sectional study of Silverstein et al (32), upper-arm flexion ≥45° for ≥15% of the time and either duty cycle of forceful exertions for ≥9% of the time (OR=2.43) or forceful pinch >0% (OR=2.66) were significantly associated with the occurrence of SIS. A stratified analysis by gender showed that upper-arm flexion ≥45° for ≥5% of the time and forceful pinch >0% were significantly associated with the occurrence of SIS among women (OR=6.68) compared to a non-significant association with the occurrence of SIS among men (OR=1.45) (32).

Psychosocial risk factors

Two high quality studies reported a significant association between high psychosocial job demands and SIS, with OR of 1.7 and 3.19, respectively (29, 35). The high quality study of Silverstein et al (32) presented a significant association between high job security and the occurrence of SIS, with an OR of 0.56. Null associations were found between the occurrence of SIS and low job control, low social support, high decision latitude and high job satisfaction, with OR ranging from 0.55–1.83 (32, 35).

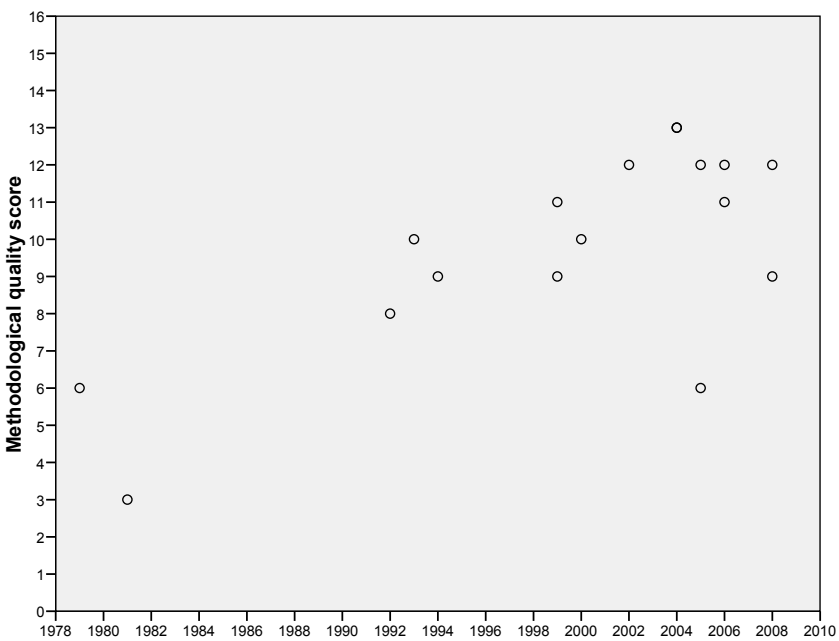

Figure 2. The association between methodological quality and year of publication of all articles which evaluated the association between job title/risk factors and the development of shoulder disorders.

Discussion

This review evaluated the associations between exposure to physical and psychosocial factors and the occurrence of shoulder disorders. Several studies of high quality indicated that the occurrence of SIS was associated with the handling of loads frequently or with high force, highly repetitive work, hand–arm vibration, and work above shoulder level. A single study, with a low quality score, indicated that computer work was associated with SIS. Occupations with the highest increased risk for SIS were jobs in the fish processing and slaughterhouse industries and betel pepper leaf cullers. In addition, high job demands and security were associated with the occurrence of SIS, as reported in three high quality studies. Unfortunately, we did not find any articles that reported associations between work-related factors and the occurrence of rotator cuff tears and suprascapular nerve compression. Only two articles described the occurrence of tendinitis of the biceps tendon across occupations.

The associations reported here are based on the results of 14 cross-sectional studies, 2 cohort studies, and 1 case–control study. Only 8 (47%) of these studies were considered to be of high quality (methodological quality score ≥11). However, due to a lack of cohort studies (in particular of high quality), the causality of the reported associations cannot be established.

The quality score of the studies ranged from 3–13 (on a scale from 0–16). The consequences of a lack of cohort studies can be seen in the methodological quality assessment; only three articles (26, 27, 33) scored positively for items 10 (prospective of retrospective study design) and 12 (follow-up period ≥1 year). Nevertheless, the methodological quality has improved over time, with almost all the high quality studies being published in the past six years. The increase in quality score is attributable to positive scores on item 3 (number of cases ≥50), item 4 (exposure definition), item 15 (consideration of confounders) and item 16 (control for confounding) in almost all high quality studies compared to maximum 44% in the low quality studies.

From different reviews, it is known that shoulder disorders are labeled and defined in diverse and conflicting ways (38, 39). In our study, SIS is defined as a specific disorder as achieved in the multidisciplinary consensus on terminology and classification of CANS (6). However, there is a wide variation in diagnostic criteria for SIS. For example, six studies discussed the association between work-related factors and tendinitis of the musculus supraspinatus. None of these studies used the same criteria to diagnose this condition; authors used their own clinical findings combined with self-reported complaints. Although clinical diagnostic tests have been developed for the physical examination of the shoulder (40, 41), 11 of 14 studies (79%) did not use any of these diagnostic tests. However, the sensitivity, specificity, and accuracy of these diagnostic tests are limited (42). Therefore, future research should focus on developing standardized diagnostic tools with good diagnostic value.

Heterogeneity was also found in the exposure assessment. None of the studies used the same definitions; moreover, in five studies (29%) only questionnaires were used for the assessment of exposure to physical and psychosocial risk factors, which may easily lead to imprecise and invalid estimates. Therefore, pooling of the results of the individual studies, although desirable, was not possible. This heterogeneity was also observed in a previous systematic review on work-related risk factors and carpal tunnel syndrome, whereby lack of sufficient similarity was much lager for risk factors than for the health outcome (43). The lack of uniformity in diagnostic labeling and definitions, and the heterogeneity in the exposure assessment, makes it difficult to implement the results in daily practice (39).

This review was focused on several specific shoulder disorders, and it is an interesting question whether the identified work-related risk factors for specific shoulder disorders also hold true for non-specific shoulder complaints. Three reviews reported that both repetitive and overhead work are risk factors for musculoskeletal disorders of the shoulder (5, 44, 45). One recent review found that shoulder symptoms occurred more frequently in subjects working in passive jobs (low demand and-control) or high-strain jobs (high demand, low control) (46). Furthermore, particular combinations of exposures (eg, holding a tool while working overhead) were associated with increased prevalence of musculoskeletal disorders at the shoulder (44). No evidence was found for an association between shoulder disorders and force and vibration (5). In contrast, van der Windt et al (45) reported vibration as a potential risk factor for shoulder pain. These last mentioned reviews have used "shoulder pain", "shoulder musculoskeletal disorders" and "shoulder symptoms" as relevant measures and, thus, included specific as well as non-specific shoulder disorders. Their results are in agreement with our findings that the occurrence of SIS is associated with repetitive work, working with the hand above shoulder level, and high job demand, but there is disagreement with respect to the influence of hand–arm vibration.

Jobs with the highest increased risk for SIS were jobs in the fish and meat processing industry and betel pepper leaf cullers. Employees in the fish and meat processing industry are exposed to repetition, force, heavy lifting, sustained arm elevation, or a combination of these factors (13, 23). Betel pepper leaf cullers are exposed to repetitive manual work, with the hands above shoulder level (36). These findings support the above-mentioned results. However, the available data presented suggest

that work-related risk factors for non-specific shoulder complaints may also play a role in specific disorders of the shoulder. There is insufficient information available to identify unique exposure patterns for specific shoulder disorders.

In summary, our review provides indications that the occurrence of SIS is associated with the following physical risk factors: (i) force requirements of ≥10% of MVC, (ii) lifting ≥20 kg ≥10 times/day, (iii) high hand force ≥1 hour/day, (iv) repetitive movements of the shoulder and repetitive motion of the hand/wrist ≥2 hours/day, (v) using a vibrating tool ≥2 hours/day, (vi) a mean vibration energy dose of 84×10^6 (m^2/s^4)hd, (vii) upper-arm elevation >90°, (viii) working with the hand above shoulder level ≥1 hour/day, (ix) upper-arm flexion ≥45° ≥15% of time and duty cycle of forceful exertions ≥9% time, and (x) upper-arm flexion ≥45° ≥15% of time and duty cycle of forceful pinch >0% of time. However, these associations were based on single studies, and, therefore, need confirmation in future studies.

Acknowledgements

Funding for this project was gratefully received from WorksafeBC, Richmond, Canada [grant number RS2006-SR05].

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Received for publication: 28 July 2009