Association between occupational mechanical exposures and subacromial impingement syndrome: A reference document

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FINAL REPORT

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Foreword

The National Board of Industrial Injuries and the Occupational Diseases Committee in Denmark has requested a detailed scientific reference document, in form of a systematic review, of the causality between occupational mechanical shoulder exposures and the development of shoulder disorders. According to the National Board of Industrial Injuries and the Occupational Diseases Committee, specific guidelines are currently needed as to which occupational mechanical shoulder exposures are associated with an increased risk of shoulder disorders and when exposures are sufficient to cause shoulder disorders (e.g. how many years, hours of exposure per day). Occupational mechanical shoulder exposures of interest include forceful shoulder exposure, arm posture, repetitive shoulder movement, use of hand-arm vibration tools (HAVs) and the combination of different mechanical exposures.

The reference document was conducted by post.doc. Annett Dalbøge, Professor Susanne Wulff Svendsen, senior consultant Poul Frost and Professor Johan Hviid Andersen. The reference document followed the specific guidelines for preparation and quality approval provided by the Danish Work Environment Fund. Professor Alexis Descatha from INSERM UMS 011, Population Based Epidemiological cohorts Unit and University Versailles St-Quentin, Versailles, France and Professor Bradley Evanoff from Washington University School of Medicine, Division of General Medical Sciences, St. Louis, MO, USA independently evaluated the reference document. The Danish Work Environment Fund granted the conduction of the reference document.

CONTENT

1. BACKGROUND

Subacromial impingement syndrome (SIS) is the most frequently diagnosed shoulder disorder, accounting for 44–65 % of all shoulder disorders seen in primary care.[1-4] SIS is frequently reported in both the general and working population. In the general population, the prevalence of SIS has been reported to be 2–8 %, [4,5] while the prevalence in occupational groups with high occupational mechanical shoulder exposures ranges between 6–10 %.[6]

SIS is considered an umbrella term for non-traumatic disorders in tissues that occupy the subacromial space in the shoulder. Thus, SIS encompasses a variety of disorders including rotator cuff syndrome, subacromial bursitis, biceps tendinitis/tendinopathy, tendinitis/tendinosis of the rotator cuff muscles, subacromial bursitis, and partial or complete tear of the long head of the biceps or rotator cuff tendons.[7-9] Symptoms of SIS include pain localized around the acromion, pain when lying on the affected extremity oftentimes with wakening patients at night, and painful performance of daily activities often worsening during or subsequent to lifting of the arm.[10,11] Symptoms are often long-lasting, with approximately 41–50% of patients reporting ongoing symptoms after 12 months.[1,12] Initial management may include rest, reduction in aggravating activities, analgesics, physiotherapy exercises, and corticosteroid injections.[13-15] In case of severe shoulder pain combined with functional restriction that fails to improve after 3 to 6 months of initial treatment, surgery may be considered.[16] Since early nineties, there has been a substantial increased incidence of surgery for SIS in several countries.[17-20] In Denmark, the incidence increased from 3.3 to 14.8 per 10,000 person-years in the period 1996–2008.[20] After surgery, ten percent of employed patients left the labour market within two years due to health-related disabilities, which was about 10 times the background population.[20]

Knowledge of potential risk factors associated with an increased risk of SIS is important in order to initiate primary and secondary preventive intervention. Risk factors may include both occupational and non-occupational factors, of which the first-mentioned can be subdivided into mechanical and psychosocial exposures. Occupational mechanical exposures may include forceful shoulder exertion, arm posture, repetitive shoulder movement, and exposure to hand-arm vibration (HAVs).[21] Occupational psychosocial exposures may include job demand, job control, and support, while non-occupational exposures may comprise age, body mass index (BMI), smoking, leisure time physical activity, prior shoulder injury, diabetes mellitus, and metabolic syndrome.[6,21,22] In relation to occupational mechanical exposures, the previous reference document from 2007 requested by the National Board of Industrial Injuries and the Occupational Diseases Committee in Denmark, concluded that a causal association is (very) likely for working with upper arm elevation, likely for forceful shoulder exertion, and less clear for repetitive shoulder movement; there was insufficient evidence to suggest a causal association between HAVs and SIS.[21] It was further concluded that insufficient studies presented robust exposure-response data, and therefore it was not possible to inform exposure standards – for example, by identifying "safe limits" for exposure intensity or duration. Since 2007, new epidemiological studies have been published, which could contribute to the clarification of the causal relationship between occupational mechanical shoulder exposures and SIS. Two systematic reviews have also been published.[6,22]

The overall aim of the scientific reference document was to perform a systematic review to summarize the existing epidemiological evidence of the causal relationship between occupational mechanical shoulder exposures and SIS in the working population. The specific aims were to evaluate which occupational mechanical exposures are associated with an increased risk of SIS, and when occupational mechanical exposures are sufficient to increase the risk of SIS (e.g. intensity, duration and frequency). A secondary aim was to evaluate the effect of psychosocial exposures.

2. MATERIALS AND METHODS

2.1 Protocol and registration

The reference document was conducted as a systematic review, which follows the specific guidelines for preparation and quality approval provided by the Danish Work Environment Fund, supplemented by guidelines from the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement.[23] The study protocol was registered in PROSPERO: CRD42017079068.

2.2 Eligibility criteria

We performed a systematic literature search for peer-reviewed epidemiological studies (cross-sectional, case-control and cohort studies) based on definitions described in PECO (Population, Exposure, Comparison, Outcome) (appendix 1)). Specific shoulder disorders included SIS, rotator cuff syndrome, subacromial bursitis, biceps tendinitis/tendinopathy, tendinitis/tendinosis of the rotator cuff muscles, non-traumatic partial or complete tear of rotator cuff tendons or long head of the biceps tendon, primary or secondary calcifications of the rotator cuff or biceps tendons, osteoarthritis of the acromioclavicular joint or variations in the shape of the acromion leading to development of impingement. These shoulder disorders covers the following diagnoses in the 10th version of the International Classification of Diseases (ICD-10): M19, M75.1-M75.9. We did not include non-specific shoulder disorders or pain as these outcomes might be associated with more adverse mechanical and psychosocial factors.[5] Eligible criteria for outcome assessment included clinically assessed disorders or disorders diagnosed using imaging modalities (e.g. x-ray, computed tomography, diagnostic ultrasound, arthrography and magnetic resonance imaging (MRI)). Occupational mechanical shoulder exposures included forceful shoulder exertion, arm posture, repetitive shoulder movement, HAVs and a combination of these mechanical exposures. Occupational psychosocial exposures included job demand, job control, and social support. Eligible criteria for occupational exposures included self-report (e.g. questionnaire and interview), expert rating, job exposure matrix (JEM), observation, and direct (or technical) measurement.

2.3 Literature search and study selection

A systematic literature search was conducted by AD in collaboration with librarian Jane Kjemstrup Andersen using the following international electronic databases: the National Library of Medicine (PubMed), Embase, and Web of Science (WoS) on the 26th of October 2016. The full literature search string for Medline/Embase is presented in appendix 2. All potential relevant articles published before the 26th of October 2016, were transferred to the online software tool Covidence (https://www.covidence.org). In Covidence, article duplicates were excluded, and identification of potentially relevant articles was performed in three steeps (i.e. title screening, abstract screening, and full paper reading) based on exclusion criteria presented in appendix 3. Title and abstract screening was performed by two reviewers; in case of disagreement articles were moved to the next step (i.e. abstract screening or full paper reading). After full paper reading performed by two reviewers, articles were included or excluded from the review, and disagreement was solved by consensus. The search was extended by screening the reference lists of all relevant articles included in the systematic review.

2.4 Data extraction and methodological quality assessment

From each included study, we extracted core study information such as study design, population, outcome, outcome assessment, exposure, and exposure assessment. The methodological quality of each included study was performed using a quality assessment tool provided in the two previous systematic reviews of the association between occupational mechanical shoulder exposures and SIS.[6,22] In total, 16 items across five categories for quality assessment were assessed in relation to study design, population, outcome, exposure, and data analysis (appendix 4-5). Each item was scored as "positive", "negative" or "not clear"; positive was given the value of 1, negative and unclear was given the value of 0. For studies, which have been quality assessed in the two previous reviews, we used the quality assessment presented in these reviews.[6,22] Quality assessment of studies not included in the previous reviews was performed by two reviewers, and disagreements were resolved by consensus. A total quality score was summed across all 16 items and a high quality study was defined as having a total quality score ≥11. From the included studies, we extracted information on measure of the occurrence/association between occupations/job titles and mechanical/psychosocial exposures and SIS (or calculated if possible). One reviewer extracted study data, which were quality checked by another reviewer.

2.5 Analysis

The association between occupational mechanical/psychosocial exposures and SIS was evaluated using forest plots and tables (appendix 6-7). In the forest plots, sex-combined associations were presented when available; if only sex-specific associations were available we used the most frequent sex. In the meta-analysis, we excluded studies which were based on identical source population and outcome of interest; exclusion of studies with the lowest total quality scores. In case of several studies with similar score, we included the study with the largest study population. In the study of Svendsen et al. (2013), risk estimates were recalculated using a follow up period restricted to 1996-2002 to avoid study overlap with Dalbøge et. al. (2014). In the meta-analysis, we only included measure of association (OR_{adj}) of the highest exposure category. The average effect size and 95% confidence interval using random effect variances was calculated. Sensitivity analyses were performed by restricting the meta-analysis to studies with high quality (total score ≥11). For studies included in meta-analysis, publication bias was evaluated using funnel plots (appendix 8), and we tested asymmetry of the funnel plots by Egger’s test. The analyses were performed using STATA 14.2 (Stata Corp, College Station, TX, USA).

2.6 Quality of evidence

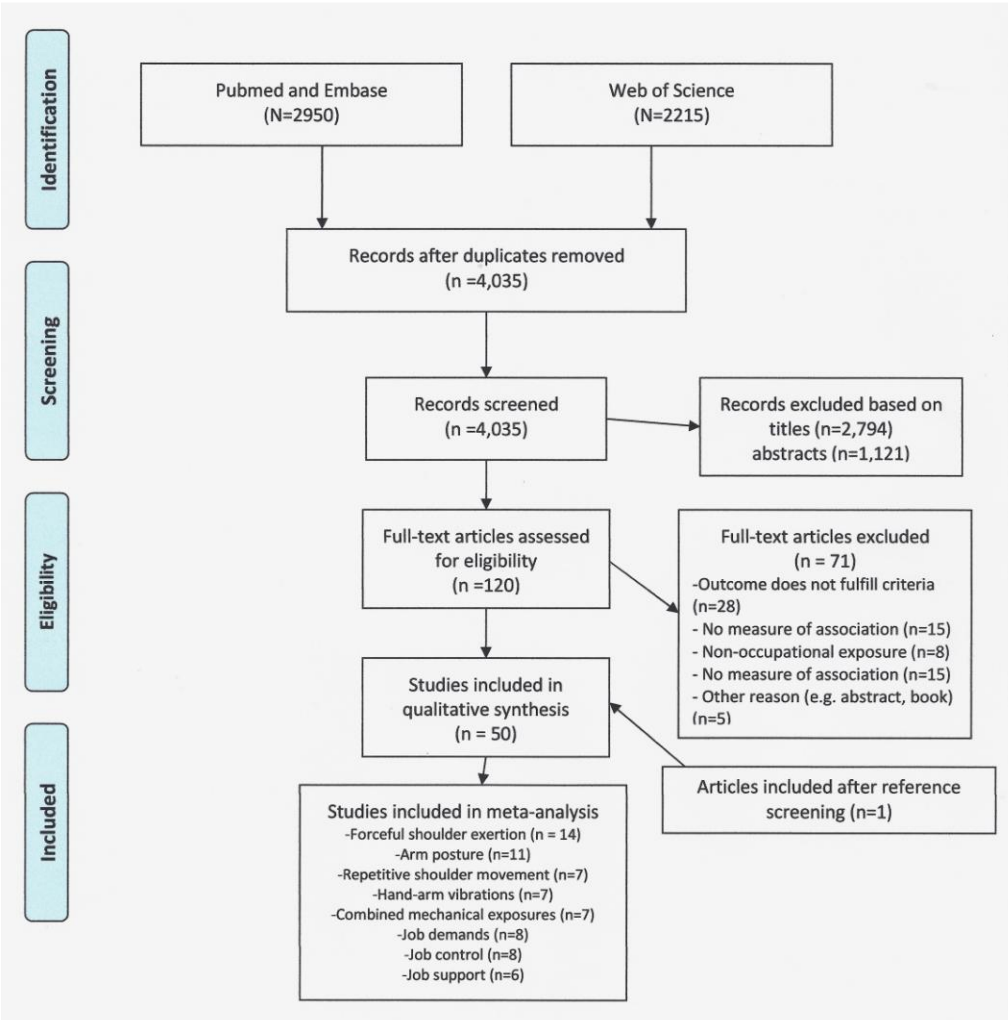
The quality of evidence of the association between occupational mechanical/psychosocial exposures and SIS was assessed according to guidelines provided by The Danish Work Environmental fund (appendix 9).

3. RESULTS

3.1 Literature search and exclusion of studies

A flow chart of the literature search and exclusion of studies is presented in figure 1. The literature search included 5165 articles with 1130 duplicates, providing 4035 potential relevant articles.

Figure 1. PRISMA Flow diagram of the literature search and exclusion of studies



Two reviewers (AD and JHA) screened all 4035 articles at title level; 2794 articles were excluded and 1241 articles were moved to abstract level. After abstract screening (AD and JHA), additional 1121 articles were excluded, providing 120 articles for full paper reading. After full paper reading (AD and JHA/SWS/PF), a total of 49 articles were included in the review. One article was added after full paper reading, providing a total of 50 relevant articles in the review.

3.2 Overall study characteristic

Table 1 summarizes the study characteristic of the 50 included studies; 32 cross-sectional, 15 cohort and three case-control studies. Outcome was assessed using physical examination in 32 studies, register information in nine studies, imaging modalities in four studies, and five studies used both physical examination and imaging modalities. Exposure information was based on occupations/job titles in 25 studies, occupational exposures in 22 studies, and three studies were based on both job titles and occupational exposures. Among the 25 studies of occupational exposures, 15 studies were based on self-reports, two studies were based on an expert-based JEM, four studies were based on observations, and four studies were based on technical measurements.

3.3 Quality assessment

Appendix 5 presents the quality assessment of the 50 included studies. Thirty of the studies were quality assessed in the two previous systematic reviews;[6,22] including all studies published by the main working group (AD, SWS, PF and JHA). The total quality score of the 50 studies varied from scoring 3 to 16 out of 16 quality items. The most frequent quality items scored "negative" or "unclear" were lack of information about completers versus withdrawals from the study, lack of prospective design including ≥1 year follow up, and lack of blinding of exposure status.

3.4 Association between occupation/job title and SIS

Table 2 shows the occurrence/association between occupations/job titles and SIS. High risk occupations included workers in fishing, hunting and trapping, workers in textiles, furs and leather goods, construction and interior workers, and workers in manufactures of paper products and printers. High risk job titles included sewing machine operators, slaughterhouse workers, fish processing workers, painters and varnishers, wallboard installation workers, and welders.

Table 1. Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Andersen, 1993[24]	CS	Sewing machine operators, auxiliary nurses and home helpers (N=107)	RCS: Self-reported chronic pain ≥30 days during the previous year and positive clinical test (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))	Interview, physical examination	Job title	Questionnaire
Arcury, 2014[25]	CS	Poultry processing workers and other manual workers e.g. landscaping, hotel, construction, restaurant (N=234)	RCS: Self-reported pain ≥2 days during the previous month and positive clinical test (presence of pain with resisted abduction, internal rotation, external rotation, forward flexion of the shoulder, or tenderness to palpation over the bicipital/lateral shoulder)	Interview, physical examination	Heavy load, awkward posture, job psychological demand, and job control, support	Interview
Arvidsson, 2016[26]	CS	Teachers, sonographers, and anaesthetic, theatre, assistance nurses (N=485)	ST: Shoulder pain, local tenderness over the tendon insertion and pain at resisted isometric abduction Acrimioclavicular syndrome: Shoulder pain, palpable tenderness of the joint, pain provoked by horizontal adduction and/or by outward rotation of the arm (90° abduction with flexed elbow)	Physical examination	Job title	Questionnaire
Bodin, 2012[27]	CS	Workers of a French region e.g. service industry and meat/ manufacturing industry (N=3710)	RCS: Shoulder pain during last 12 months, current intermittent pain worsened by active elevation and ≥1 positive clinical test (resisted shoulder abduction, external or internal rotation, resisted elbow flexion, painful arc on active upper arm test)	Questionnaire, physical examination	Perceived physical exertion (RPE-Borg scale), repeated and sustained posture with arms above shoulder level, repetiveness of tasks, psychological demand, skill discretion, and supervisor support	Questionnaire
Bodin, 2012[28]	Cohort	Workers of a French region e.g. service industry and meat/ manufacturing industry (N=1611)	RCS: Shoulder pain during last 12 months, current intermittent pain worsened by active elevation and ≥1 positive clinical test (resisted shoulder abduction, external or internal rotation, resisted elbow flexion, painful arc on active upper arm test)	Questionnaire, physical examination	Perceived physical exertion (RPE-Borg scale), repeated and sustained posture with arms above shoulder level, high perceived physical exertion and repeated and sustained posture with arms above shoulder level, and coworker support	Questionnaire
Bugajska, 2013[29]	Cohort	Workers with various job (office workers, welders toolmakers) (N=725)	Rotator cuff tendinitis (not further specified)	Questionnaire, physical examination	Job demand, decision latitude, social support and job insecurity	Questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Chung, 2013[30]	Cohort	Nurses, other workers and non-workers (N=15,658)	RCS: ICD-9-CM; 726.1	Register information	Job title	Register information
Dalbøge, 2014[31]	Cohort	Total Danish working population (N=2,374,403)	SIS: ICD-10:; M19 or M75.1-75.9 and surgery codes: KNBA, KNBE-H, or KNBK-M	Register information	Forceful shoulder exertion, upper-arm elevation >90°, repetitive shoulder movements, and HAV	Expert-based JEM
Frost, 1999[32]	CS	Slaughterhouse workers, repairmen and chemical workers in chemical plant (N=1591)	SIS: Self-reported symptoms in the shoulder region for ≥3 months within the past year combined with clinical signs of impingement	Questionnaire, physical examination	Job title	Questionnaire
Frost, 2002[33]	CS	Workers in food processing, textile and electronic plants, cardboard industries, postal sorting centers, banks, supermarkets (N=2743)	Shoulder tenditinis: Self-reported shoulder pain, tenderness of the greater humeral tubercle/impingement and positive clinical test (pain at resisted abduction)	Questionnaire, physical examination	Repetitive hand-arm movements, shoulder movements, force requirements, micro-pauses in shoulder flexion, and combination of difference exposures	Observation
Grzywacz, 2012[34]	CS	Latino poultry and non-poultry manual workers (N=742)	RCS: Presence of pain with resisted abduction, internal rotation, external rotation, or forward flexion of the shoulder, or tenderness to palpation over the bicipital groove or lateral shoulder	Interview, physical evaluation	Job title, heavy load, awkward posture, and repetitive movements	Interview
Hansson, 2000[35]	CS	Workers in laminate industry with and without repetitive work (N=169)	Acromialclavicular syndrome, bicipital tendinitis and RCS: localized pain or tenderness of muscles or tendon insertions, and signs from e.g. pain-provocation test *(specified in Ohlsson 1994, Ergonomics 5)*	Physical examination	Job title	Not reported
Herberts, 1981[36]	CS	Welders at a shipyard and office clerks (N=188)	ST: Periods of shoulder pain, tenderness by palpation and pain disappeared only after relaxation or change to lighter work	Questionnaire, physical examination	Job title	Not reported
Herin, 2012[37]	Cohort	Executives, artisans, clerks and blue collar workers (N=12,714)	Chronic shoulder pain: Shoulder pain present for at least 6 months (duration of current episode or intermittent complaints over the last 6 months) and presenting positive clinical signs (active or passive functional limitations, stiffness, tenderness)	Interview, physical examination	Physical effort, carrying heavy loads, long/difficult working positions and awkward posture, precise movements and repetitive work, considerable vibrations and exposure to jolts, decision latitude, and psychological demand	Questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	**Assessment**	**Definition**	**Assessment**
Hsiao, 2015[38]	Cohort	United State military (N=13,768,534)	SIS: ICD-9-CM; 726.10	Register information	Job title	Register information (military records)
Jacobsson, 1992[39]	CS	Persons living in Malmö, Sweden (N=502)	Subacromial shoulder pain: Continuous/ intermittent shoulder pain/stiffness ≥6 weeks´ duration during the proceeding 12 months and tenderness over tendon insertion, and increased pain when active force was applied to the tendon against resistance	Questionnaire, physical examination	Heavy workload	Questionnaire
Kaergaard, 2000[40]	CS	Sewing machine operators, workers with supervisory jobs, service jobs, office workers and other workers considered to have a good deal of variation in their jobs (N=600)	Rotator cuff tendinitis: 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	Questionnaire, physical examination	Job title	Expert opinion
Kaerlev, 2008[41]	Cohort	Fishermen, non-officers and officers (N=29.513)	RCS: ICD-10; M75.1	Register information	Job title	Register information
Luopajarvi, 1979[42]	CS	Assembly line workers in a food production factory and shop assistants (N=285)	BT/ST: Shoulder pain and ≥1 positive clinical test (active, passive, isometric tests, palpation and observation)	Physical examination	Job title	Not reported
Melchior, 2006[43]	CS	Manual occupation and non-manual occupation (N=2656)	RCS: Shoulder pain during the last 12 months and ≥1 clinical tests (resisted shoulder abduction, external or internal rotation; elbow flexion; active upper-arm elevation)	Questionnaire, physical examination	Job title divided into manual work vs. not-manual work	Questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Miranda, 2005[5]	CS	Workers of the Finish general population (N=8028)	RCT: Pain in rotator cuff region lasting ≥3 months, pain during the month preceding the examination, and ≥1 positive clinical test (abduction of the arm, external rotation of the arm and internal rotation of the arm or painful arc of shoulder abduction)	Physical examination	Frequent lifting, heavy lifting, work requiring high hand force, working with hand above shoulder, work requiring repetitive motion of the hand/wrist, working with a vibration tool, and job demand	Interview, questionnaire
Miranda, 2008[44]	Cohort	A sample of the Finish general population (N=883)	RCT, BT, frozen shoulder, inflammatory arthritis, post-traumatic disorder or other non-specific shoulder disorders: History of shoulder pain for ≥3 months and positive clinical examination (not specified)	Physical examination, x-rays	Lifting heavy loads, working in awkward postures, work involving vibration, work involving repetitive movements, work paced by machine, and a combination of physical exposures	Interview, questionnaire
Mora, 2016[45]	Cohort	Farmers and non-farmers (N=272)	RCS: Shoulder pain and positive clinical test (pain with resisted abduction, internal rotation, external rotation, forward flexion of the shoulder; active elevation of the upper arm; or tenderness to palpation over the bicipital tendon or supraspinatus tendon	Physical Examination	Job title	Interview
Nordander, 1999[46]	CS	Fish processing workers, caretakers, workers in parks/ gardens, repairing/ maintaining equipment and machines, day nurses (N=659)	BT, IT and ST: 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 positive clinical examination *(specified in Ohlsson 1994, Ergonomics 5)*	Interview, physical examination	Job title	Questionnaire
Nordander, 2009[47]	CS	55 different occupational groups (N=7638)	ST: Shoulder pain, local tenderness over the tendon insertion, pain at resisted isometric abduction IT: Shoulder pain, local tenderness over the tendon insertion, pain at resisted isometric outward rotation BT: Shoulder pain, local tenderness over the tendon(s); pain at resisted isometric elevation of the arm (straight and elevated 90°) and/or resisted isometric flexion of the elbow (flexed 90° and hand supinated)	Questionnaire, physical examination	Job title	Questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Nordander, 2016[48]	CS	33 different occupational groups engaged in industrial, office and other work (e.g. dentistry, hair-dressing, and cleaning) (N=3141)	ST: Shoulder pain, local tenderness over the tendon insertion, pain at resisted isometric abduction IT: Shoulder pain, local tenderness over the tendon insertion, pain at resisted isometric outward rotation BT: Shoulder pain, local tenderness over the tendon(s), pain at resisted isometric elevation of the arm (straight and elevated 90°), and/or resisted isometric flexion of the elbow (flexed 90° and hand supinated)	Questionnaire, physical examination	Head inclination, head angular velocity, upper arm elevation and velocity, trapezius and forearm extensor muscles activity, wrist flexion and angular velocity, job demand, job control, and job strain	Direct measurement, questionnaire
Northover, 2007[49]	CC	Cases with rotator cuff impingement and controls attending a shoulder clinic (N=300)	Rotator cuff impingement: History of pain (not specified) and clinical test (Neer's and Hawkins' provocative impingement signs with relief of symptoms with a subacromial injection of Lignocaine (Neer's test)) and the absence of osteoarthritis on radiographic examination	Physical examination, ultrasound	Job title, manual work, overhead work, and use of vibration tool	Questionnaire
Ohlsson, 1994[50]	CS	Fish processing workers and employees in municipal work-places (e.g. office workers, caretakers, gardeners) (N=414)	ST, IT, BT and AC syndrome: 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 positive clinical examination *(specified in Ohlsson 1994, Ergonomics 5)*	Interview, physical examination	Job title	Interview or questionnaire
Park, 1992[51]	CC	Cases with one or more insurance claims for RCS (N=130)	RCS: ICD-9; 726.1X and HCPCS; 25005, 25115, 25116, 25295, 26055, 26440, 26445, 26449	Register information	Job title	Register information
Roquelaure, 2011[52]	CS	A sample of the French general working population (N=3710)	RCS: Shoulder pain during last 12 months, current intermittent pain worsened by active elevation and one positive clinical test (resisted shoulder abduction, external or internal rotation, resisted elbow flexion, painful arc on active upper arm test)	Questionnaire, physical examination	Perceived workload (RPE–Borg scale), sustained or repeated arm posture in abduction, high repetiveness of tasks, psychological demand, skill discretion, decision authority	Questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Rosenbaum, 2013[53]	CS	Poultry processing workers and non-poultry manual labour workers (N=516)	RSC: Self-reported shoulder pain ≥2 days in the previous month and ≥1 positive clinical test (presence of pain with resisted abduction, internal rotation, external rotation, or forward flexion of the shoulder; or tenderness to palpation over the bicipital groove or lateral shoulder)	Interview, physical examination	Job title	Interview
Rosenbaum, 2014[54]	CS	Poultry processing workers (N=286)	RSC: Self-reported shoulder pain ≥2 days in the previous month and ≥1 positive clinical test (presence of pain with resisted abduction, internal rotation, external rotation, or forward flexion of the shoulder; or tenderness to palpation over the bicipital groove or lateral shoulder)	Interview, physical examination	Heavy load, awkward posture, job control, and psychological demand	Interview
Sansone, 2014[55]	CS	Cashiers and supermarket customers (N=498)	Bilateral shoulder abnormalities: Thickening/thinning of the structure, foci of increased and/or reduced echogenicity, significant calcifications, partial/full-thickness discontinuity, or calcifying tendinopathy of the shoulder	Ultrasound, MRI	Job tile	Supermarked register or questionnaire
Sansone, 2015[56]	CS	Cashiers and supermarket customers (N=503)	CT: Non-uniformity of tendon	Ultrasonography	Job title	Supermarked register or questionnaire
Seidler, 2011[57]	CC	Construction, interior workers, service workers (N=483)	Supraspinatus lesion: Shoulder pain and radiographic tear	Interview, MRI	Job title, lifting and carrying loads ≥20 kg in hours; work above shoulder level in hours; handheld vibration in years on job	Questionnaire
Silverstein, 1998[58]	Cohort	Workers included in Washington State Fund (N=?)	RCS: ICD-9; 726.1, 726.10, 727.61, 840.4, current procedural terminology, CPT; 23410, 23412, 23415 and 23420	Register information	Job title/occupation	Register information
Silverstein, 2006[59]	Cohort	Workers at 12 different worksites e.g. manufacturing and health care facilities (N=436)	RCT: Shoulder pain/burning in the past 12 months occurring >3 times or lasting >1 week, and shoulder pain/burning present in the 7 days, and ≥1 positive shoulder test (resisted abduction, internal rotation, or external rotation or painful arc)	Interview, physical examination	Lifting, high forces, upper arm abduction >60°, upper arm flexion >45°, job demand, decision latitude, social support Note: Descriptive study presenting prevalence proportion at baseline. This study will not be presented further due to overlapping study population (ref. 60)	Observation, questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Silverstein, 2008[60]	CS	Workers at 12 different worksites e.g. manufacturing and health care facilities (N=733)	RCS: Shoulder pain/burning in past 12 months occurring >3 times or lasting >1 week, and shoulder pain/burning present in the previous 7 days, and no traumatic injury onset, and ≥1 positive shoulder test (resisted shoulder abduction, external rotation, internal rotation, or painful arc), no traumatic injury onset or rheumatoid arthritis	Interview, physical examination	Forceful exertion, upper-arm flexion ≥45°, frequency of shoulder movements, upper arm flexion ≥45° and duty cycle of forceful exertion, upper arm flexion ≥45° and pinch grip force, and decision latitude	Observation, questionnaire
Silverstein, 2009[61]	CS	Workers at 12 different worksites e.g. manufacturing and health care facilities (N=733)	RCS: Shoulder pain/burning in past 12 months occurring >3 times or lasting >1 week, and shoulder pain/burning present in the previous 7 days, and no traumatic injury onset, and ≥1 positive shoulder test (resisted shoulder abduction, external rotation, internal rotation, or painful arc), no traumatic injury onset or rheumatoid arthritis	Interview, physical examination	Forceful exertion, upper arm flexion, upper arm abduction, pinch grip force ≥8.9 N (0.9 kg), and vibration	Observation, questionnaire
Stenlund, 1993[62]	CS	Bricklayers, rockblasters and foremen (N=207)	ST: Pronounced palpable pain of the muscle attachment or pronounced pain reaction to the isometric contraction in the RC or biceps muscles, positive clinical test (forced passive adduction of each arm in the horizontal shoulder plane which is a frequently used clinical sign of osteoarthrosis of the AC joint)	Physical examination, radiography	Job title	Interview
Stenlund, 1993[63]	CS	Bricklayers, rockblasters and foremen (N=207)	ST: Pronounced palpable pain of the muscle attachment or pronounced pain reaction to the isometric contraction in the RC or biceps muscles, positive clinical test (forced passive adduction of each arm in the horizontal shoulder plane which is a frequently used clinical sign of osteoarthrosis of the AC joint)	Physical examination,	Load lifted, and exposure to vibration	Interview
Stucchi, 2016[64]	CS	Retail workers and clerks (N=6414)	SIS: Tendinopathies of the rotator cuff and the long head of the biceps, subacromial bursitis (not further specified)	Physical examination	Job title	Questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Sutinen, 2006[65]	Cohort	Professional forestry workers (N=52)	RCS: Typical history of painful arch and intermittent pain and pronounced tenderness locally in the shoulder region or, in addition ≥1 positive clinical test (painful arch test during elevation, pain in resisted abduction or resisted external rotation)	Questionnaire, physical examination	Lifelong vibration energy	Technical measurement
Svendsen, 2004[66]	CS	Male machinists, car mechanics, and house painters (N=1886)	ST: Moderate shoulder pain/discomfort during previous 12 months and ≥1 positive clinical test ((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))	Questionnaire, physical examination	Upper elevation >90°, job demand, job control, and social support	Technical measurement, questionnaire
Svendsen, 2004[67]	CS	Male machinists, car mechanics, and house painters (N=136)	ST: 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 fibers from articular to bursal surfaces or complete discontinuity of the tendon with atrophy of the muscle	MRI	Shoulder force requirements, and upper arm elevation >90°	Technical measurement
Svendsen, 2013[68]	Cohort	Workers from musculoskeletal research database (N=37,402)	SIS: ICD-10; M19 or M75.1-M75.9, and NOMESCO; KNBA, KNBE, KNBF, KNBG, KNBH, KNBK, KNBL, and KNBM	Register information	Forceful work, upper arm elevation >90°, repetitive work, shoulder load, job demand, job control, and social support at work	Expert-based JEM
Thygensen, 2016[69]	Cohort	Baggage handlers and unskilled workers (N=67,305)	SIS: First-time surgery ICD-10; M75.1-M75.5, and M75.8-9, NOMESCO; NBA01-02, NBA11-12, NBE01-02, NBE11-12, NBE21-22, NBG09, NBH51-52, NBL49, and NBM79	Register information	Job title	Register information
Wang, 2005[70]	CS	Betel pepper leaf cullers and non-cullers (N=67)	SIS: Shoulder pain and tenderness and positive clinical test (supraspinatus test, Hawkins impingement test) with typical findings on ultrasonography (e.g. wall thickening or fluid collection in the subacromial-subdeltoid bursae, hypoechoic thickening or an anechoic gap of the rotator cuffs, and dynamic impingement)	Physical examination, ultrasonography	Job title	Questionnaire

Table 1 (continued). Study description of the 50 included studies included in the systematic review

Author	Design	Population	Outcome		Exposure	
			Criteria	Assessment	Definition	Assessment
Yamamoto, 2010[71]	CS	Residents of mountain village in Japan (N=683)	Rotator cuff tear: Current symptoms and positive clinical test (impingement sign (Neer´s procedure), active range of motion (forward elevation at the scapula plane), and loss of muscle strength)	Physical examination, ultrasonography	Heaviness of labor	Questionnaire
Zakaria, 2004[72]	Cohort	Workers registered in the Ontario Workplace Safety and Insurance Board (N=not specified)	RCS and rotator cuff tear: Coding of Work Injury or Disease Information Standard; 17391 and 02101	Register information	Job title	Register information

BT; Bicipital tendinotis, CC; Case-control, CPT; Current Procedural Terminology, CS; Cross-sectional, CT; Calcifying tendinopathy, D-ISCO 88; The Danish version of International Standard Classification of Occupations, HAV; Hand-arm vibration, IT; Infraspinatis tendinotis, JEM; Job exposure matrix, MRI; Magnetic resonance imaging, NOMESCO; The Nordic Medico-Statistical Committee, RCS; Rotator cuff syndrome, RCT; Rotator cuff tendinitis, SIS; Subacromial impingement syndrome, ST; Supraspinatus tendinotis

Table 2. Studies reporting the occurrence or association between occupations/job titles and subacromial impingement syndrome

Author	Population		Results					
			Men		Women		Total	
	Reference	Exposed	Measure of association	95% CI	Measure of association	95% CI	Measure of association	95% CI
Andersen, 1993[24]	Auxiliary nurses and home helpers (N=25)	Sewing machine operators (N=82)	–	–	6.8^{OR}	0.85-53.4	–	–
Arvidsson, 2016[26]	Theatre nurses (N=?)	Anaesthetic nurses (N=?)						
	- Supraspinatus tendinitis	- Supraspinatus tendinitis	–	–	1.2^{PPR}	–	–	–
	- AC syndrome	- AC syndrome	–	–	1.5^{PPR}	–	–	–
Skal AC med?	Sonographers (N=?)	Theatre nurses (N=?)						
	- AC syndrome	- AC syndrome	–	–	1.5^{PPR}	–	–	–
Chung, 2013[30]	Other workers/non-workers (N=11.774)	Nurses (N=3914)	–	–	–	–	4.33^{OR}	2.51-7.47
Frost, 1999[32]	Repairmen or chemical workers in chemical plant (N=398)	Slaughterhouse workers						
		Current (N=576)	–	–	–	–	5.27^{PR}	2.09–13.26
		Former (N=167)	–	–	–	–	7.90^{PR}	2.94-21.18
Grzywacz, 2012[34]	Other manual workers (N=?)	Poultry workers (N=?)	–	–	–	–	0.95^{OR}	0.62-1.45
Hansson, 2000[35]	Industrial workers (=35)	Workers in laminate industry (N=33)	–	–	2.8^{POR}	1.2-6.6	–	–
	Office workers (N=33)		–	–	3.0^{POR}	1.3-7.3	–	–
Herberts, 1981[36]	Office clerks (N=57)	Welders at a shipyard (N=131)	18.3^{PP}	14.7-22.1				
Hsiao, 2015[38]	Navy (N=3,587,430)	Army (N=4,897,019)	–	–	–	–	1.42^{IRR}	1.39-1.46
		Air Force (N=3,513,408)	–	–	–	–	1.46^{IRR}	1.42-1.50
		Marines (N=1,770,677)	–	–	–	–	1.31^{IRR}	1.26-1.36
Kaergaard, 2000[40]	Workers with supervisory jobs, service jobs, office workers and other workers considered to have a good deal of variation in their jobs (N=357)	Sewing machine operators (N=238)	–	–	2.63^{PPR}	1.08-6.35	–	–
Kaerlev, 2008[41]	Officers (N=10436)	Fishermen (N=8040)	–	–	–	–	2.54^{OR}	1.50–4.30
		Non-officers (N=11 037)	–	–	–	–	1.31^{OR}	0.74–2.29
Luopajarvi, 1979[42]	Shop assistants (N=133)	Assembly line workers, food production factory (N=152)	–	–	2.45^{OR}	0.86-6.98	–	–
Melchior, 2006[43]	Non-manual occupation (N=1496)	Manual occupation (N=1160)	2.07^{PR}	1.38-3.08	1.90^{PR}	1.31-2.77	–	–

Table 2 (continued). Studies reporting the occurrence or association between occupations/job titles and subacromial impingement syndrome

Author	Population		Results					
			Men		Women		Total	
	Reference	Exposed	Measure of association	95% CI	Measure of association	95% CI	Measure of association	95% CI
Mora, 2016[45]	Non-farmers (N=119)	Farmers (N=157)	–	–	–	–	0.36^{OR}	0.20-0.64
Nordander, 1999[46]	Workers employed as caretakers, workers in community parks and gardens, workers repairing and maintaining equipment and machines, day nurses, caretakers (N=337)	Fish processing workers (N=322) - Outcome: BT - Outcome: IT - Outcome: ST	 – – –	 – – –	 – – –	 – – –	 2.18^{OR} 4.19^{OR} 3.14^{OR}	 1.08-4.41 1.80-9.72 1.16-6.32
Nordander, 2009[47]	Varied/mobile (N=1178)	Repetitive/constrained workers (N=1499) - Outcome: ST - Outcome: IT - Outcome: BT	 2.7^{PR} 4.0^{PR} 3.3^{PR}	 1.3-5.4 1.6-9.9 1.3-8.5	 2.5^{PR} 3.1^{PR} 2.4^{PR}	 1.4-4.2 1.6-6.4 1.4-4.1	 – – –	 – – –
Northover, 2007[49]	Clerical (N=?)	Light manual workers (N=?) Heavy manual workers (N=?)	– –	– –	– –	– –	1.85^{OR} 3.81^{OR}	1.08-3.17 1.93-7.51
Ohlsson, 1994[50]	Employees in municipal workplaces (N=208)	Fish processing workers (N=206) Outcome: ST	–	–	3.4^{OR}	1.6–7.1	–	–
Park, 1992[51]	Controls with one or more insurance claims for other causes than RCS	Frame assembly work (N=13) Trim assembly work (N=36) Sewing work (N=23) Pressing work (N=39) Assembly/finishing stamping work (N=19)	– – – – –	– – – – –	– – – – –	– – – – –	2.0^{OR} 1.7^{OR} 2.5^{OR} 3.3^{OR} 2.1^{OR}	1.1–3.8 1.1–2.6 1.4–4.5 2.1–5.1 1.2–3.7
Rosenbaum, 2013[53]	Non-poltry manual labour workers (N=227)	Poltry processing workers (N=289)	–	–	1.51^{OR}	0.91-2.51	–	–
Sansone, 2014[55]	Cashiers (N=196)	General population with low exposure to repetition and force (N=302)	–	–	5.44^{OR}	1.26-23.59	–	–
Sansone, 2015[56]	General population with low exposure to repetition and force (N=304)	Cashiers (N=199) - Dominant shoulder - Non-dominant shoulder	 – –	 – –	 0.84^{OR} 0.99^{OR}	 0.53-1.33 0.58-1.33	 – –	 – –
Seidler, 2011[57]	Service workers (N=?)	Construction/interior workers (N=487) Painter or varnisher (N=?) Manufacturers of paper products and printers (N=?) Metal workers (N=?)	11.5^{OR} 5.5^{OR} 4.0^{OR} 2.5^{OR}	2.5-52.5 0.7-43.7 0.5-32.8 1.3-4.9	– – – –	– – – –	– – – –	– – – –

Table 2 (continued). Studies reporting the occurrence or association between occupations/job titles and subacromial impingement syndrome

Author	Population		Results					
			Men		Women		Total	
	Reference	Exposed	Measure of association	95% CI	Measure of association	95% CI	Measure of association	95% CI
Silverstein, 1998[58]	All industries combined (N=?)	Wallboard installation (N=?)	–	–	–	–	7.7^{RR}	–
		Roofing (N=?)	–	–	–	–	6.1^{RR}	–
		Garbage collection (N=?)	–	–	–	–	5.6^{RR}	–
		Logging (N=?)	–	–	–	–	5.5^{RR}	–
		Commercial concrete construction	–	–	–	–	5.3^{RR}	–
		Masonry (N=?)	–	–	–	–	5.1^{RR}	–
		Insulation installation (N=?)	–	–	–	–	4.8^{RR}	–
		Meat/poultry wholesale (N=?)	–	–	–	–	4.6^{RR}	–
		Plywood manufacturing (N=?)	–	–	–	–	4.1^{RR}	–
		Sawmills (N=?)	–	–	–	–	4.0^{RR}	–
Stenlund, 1993[63]	Foremen (N=207)	Bricklayers and rock blasters						
		- Right side (N=?)	1.29^{OR}	0.60-2.75	–	–	–	–
		- Left side (N=?)	2.72^{OR}	1.06-2.72	–	–	–	–
Stucchi, 2016[64]	Clerks (N=3048)	Retail workers (N=3366)	–	–	–	–	3.39^{OR}	2.23-5.17
Thygensen, 2016[69]	Unskilled workers (N=63,909)	Baggage handlers (N=3396)						
		Non-baggage handler	0.89^{IRR}	0.55-1.43	–	–	–	–
		0.1-2.9 years	1.00^{IRR}	-	–	–	–	–
		3.0-9.9 years	1.33^{IRR}	0.82-2.16	–	–	–	–
		10.0-19.9 years	1.55^{IRR}	0.95-2.55	–	–	–	–
		≥20.0 years	1.21^{IRR}	0.64-2.29	–	–	–	–
Wang, 2005[70]	Non-cullers (N=47)	Betel pepper leaf cullers (N=20)	–	–	3.02^{OR}	0.99–9.24	–	–
Zakaria, 2004[72]	No control group	Fishing, hunting, trapping & related	298.15^{IR}	–	–	–	–	–
		Textiles, furs & leather goods	61.70^{IR}	9.10-114.30	18.11^{IR}	1.84-34.37	–	–
		Other transportation operators	56.31^{IR}	11.43-101.20	61.70^{IR}	9.10-114.30	–	–
		Other machining occupations	16.77^{IR}	4.96-28.84	–	–	–	–
		Other constructions	15.96^{IR}	8.21-23.71	–	–	–	–
		Other crafts and equipment operator	–	–	84.43^{IR}	0.00-269.44	–	–
		Other service	–	–	20.92^{IR}	0.00-50.56	–	–
		Nursing, therapy and related	–	–	16.56^{IR}	0.01-33.11	–	–

AC; Acromioclavicular, BT; Bicipital tendinotis, CI; Confidence interval, IR; Incidence rate, IRR; Incidence rate ratio, IT; Infraspinatus tendinitis, N; number, OR; Odds ratio, POR; prevalence odds ration, PP; Prevalence proportion, PR; Prevalence ratio, RR; Risk ratio, ST; Supraspinatus tendinotis. Note: IR in Zakaria expressed as rate of claims per 100.000 full-time equivalents

3.5 Association between occupational mechanical exposures and SIS

Figures 2-6 show forest plots of the associations between occupational mechanical exposures and SIS. Twenty-five studies reported the association between occupational mechanical exposures and SIS; 20 studies of forceful shoulder exertion, 17 studies of arm posture, 10 studies of repetitive shoulder movement, eight studies of HAVs, and eight studies of combined mechanical exposures.

Forceful shoulder exertion: The 20 studies of forceful shoulder exertion had a total quality score between 8 and 16; 10 studies were of high quality (total quality score $\geq$11). Exposure was defined heterogeneously; most frequently characterized as perceived physical exertion, forceful effort/requirements, and lifting/carrying heavy loads. Fifteen studies applied exposure intensity (11 studies based on self-report, three studies based on observation, and one study based on a JEM), two studies applied exposure duration (one study based on self-report, and one study based on technical measurement), two studies applied cumulative exposure (one study based on self-report, and one study based on a JEM), and in one study the exposure dimension could not be characterized (based on self-report). The majorities of studies did not control for co-existing mechanical exposures; this applies all mechanical exposures discussed below. Reported OR_{adj} ranged from 0.6 to 5.4 with statistically significant results found in 13 studies (appendix 6). Among the 20 studies, 10 studies were based on four identical source populations and outcome of interest. Six studies were therefore excluded from the meta-analysis,[25,27,44,52,54,61] providing a total of 14 studies. In the meta-analysis, we found a pooled OR of 1.44 (95% CI 1.14-1.75). Sensitivity analysis of high quality studies (N=9) showed a pooled OR of 1.45 (95% CI 1.06-1.84). The funnel plot (figure 10, appendix 8) did not indicate publication bias, and the p-value of the Egger's test was not statistically significant (p=0.885). The funnel plot indicated study heterogeneity.

Arm posture: The 17 studies had a total quality score between 8 and 16; 11 studies were of high quality. Arm posture was defined heterogeneously; most frequently characterized as arm elevation (>60° or 90°), working with hand(s) above shoulder level or awkward posture. The exposure dimension comprised intensity in 12 studies (eight based on self-report, two based on observation, one based on a JEM, and one based on technical measurement), duration in three studies (one based on self-report, and two based on technical measurement), cumulative exposures in two studies (based on self-report and a JEM), and in one study exposure dimension could not be characterized (based on self-report). Reported OR_{adj} ranged from 0.7 to 4.7 with statistically significant results reported in 13 of these studies (appendix 6). Eleven studies were based on five overlapping populations and outcome of interest; six studies were therefore excluded from the meta-analysis.[25,27,44,52,61,67] The meta-analysis of the 11 remaining studies showed a pooled OR of 1.79 (CI 95% 1.37-2.21). Sensitivity analysis of high quality studies (N=7) showed a pooled OR of 1.78 (95% CI 1.29-2.27). The funnel plot indicated a tendency toward publication of smaller studies with positive association (figure 11, appendix 8), but the p-value of the Egger's test was not statistically significant (p=0.563).

Repetitive shoulder movement: The 10 studies had a quality score between nine and 16; eight studies were of high quality. Exposure was defined heterogeneously. Eight studies reported the association for exposure intensity (four based on self-report, two based on observation, one based on a JEM, and one based on technical measurement), one study reported the association for duration (based on self-report), and one study for cumulative exposure (based on a JEM). OR_{adj} ranged from 0.6 to 4.0 with statistically significant results found in eight studies (appendix 7). Four studies were based on overlapping study populations and outcome of interest, and two studies were therefore excluded from the meta-analysis.[44,52] We further excluded one study in which a ß-coefficient was converted to a OR.[48] Meta-analysis of 7 studies, showed a pooled OR of 1.72 (CI 95% 1.17-2.27); all studies were of high quality. The funnel plot indicated a tendency toward publication of smaller studies with positive association (figure 12, appendix 8), but the p-value was not statistically significant (p=0.753).

Hand-arm vibration (HAVs): In the eight studies, a quality score between eight and 16 was found; six studies of high quality. HAVs were more consistently defined as working with a hand-arm vibration tool. Four studies reported the association for exposure intensity (all based on self-report), one study for exposure duration (based on self-report), and three studies for cumulative exposures (based on self-report, JEM and technical measurement). OR ranged from 0.6 to 4.2 with statistically significant results found in six studies (appendix 6). Two studies were based on overlapping study population and outcome criteria, and one study was therefore excluded from the meta-analysis.[44] Pooled OR based on 7 studies was 1.31 (CI 95% 1.00-1.62), while pooled OR for high quality studies (N=5) was 1.25 (95% CI 0.92-1.58). The funnel plot should be evaluated with caution due to the low number of studies (figure 13, appendix 8). Based on available studies, a tendency toward publication bias of small studies with positive association was indicated, however the p-value was not statistically significant (p=0.291).

Combined mechanical exposures: In the eight studies, a quality score between 10 and 16 was found; six studies were of high quality. Combined mechanical exposures were most frequently defined as forceful shoulder exertion in combination with arm elevation or repetitive shoulder movement. Seven studies reported the association for the exposure intensity (four based on self-report, two based on observation, and one based on a JEM), and one study reported the association for cumulative exposures (based on a JEM). Exposure to a combination of mechanical exposures was statistically significantly associated with an increased risk in all studies with a maximum OR_{adj} of 4.5 (CI 95% 1.7-11.6) (appendix 6). Two out of eight studies were based on identical source population and outcome criteria. Pooled OR was 1.81 (CI 95% 1.37-2.24) after excluding one study,[61] while high quality studies (N=5) showed a pooled OR of 2.00 (95% CI 1.90-2.10). A non-statistically significant (p=0.856) tendency toward biased publication of small studies with positive association was indicated (figure 15, appendix 8).

Figure 2. Forest plot of the association between forceful shoulder exertion and subacromial impingement syndrome (N=20)

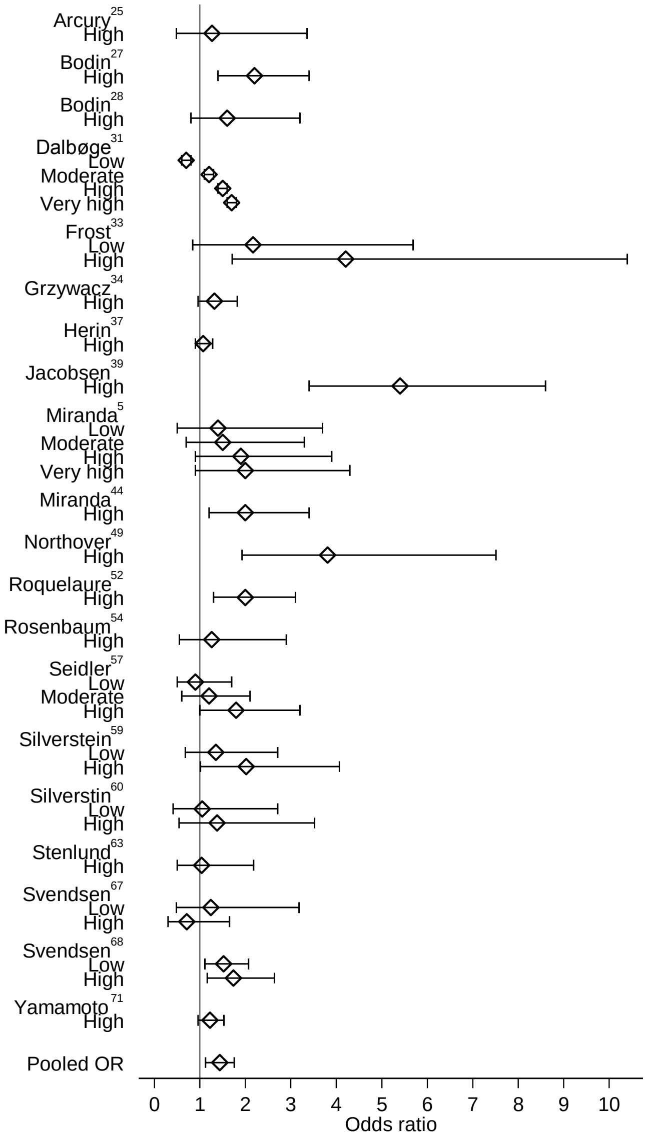


Figure 3: Forest plot of the association between arm posture and subacromial impingement syndrome (N=17)

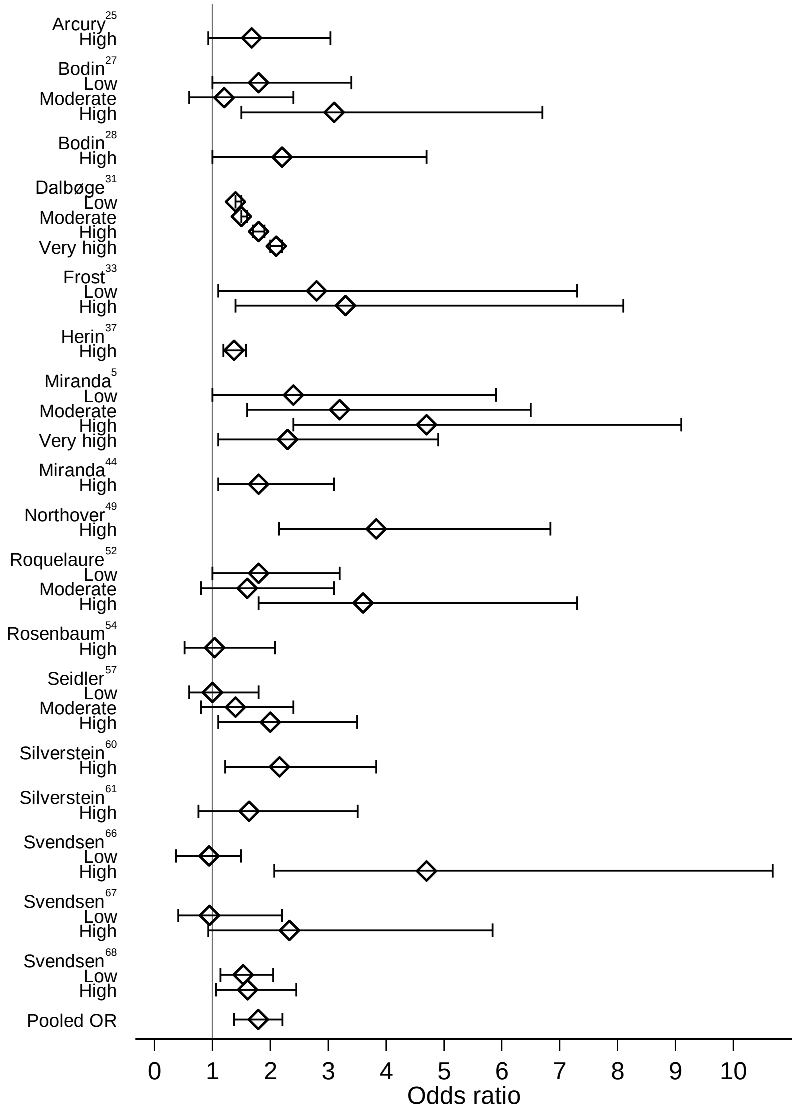


Figure 4: Forest plot of the association between repetitive shoulder movements and subacromial impingement syndrome (N=10)

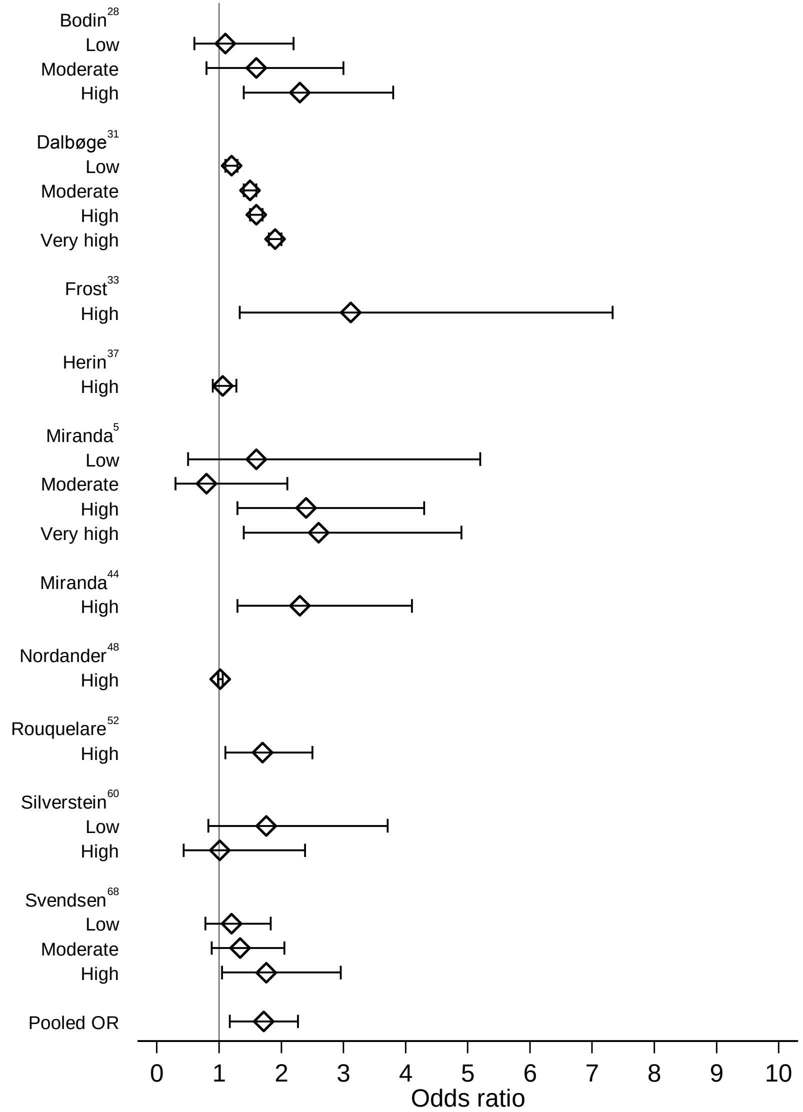


Figure 5: Forest plot of the association between HAV and subacromial impingement syndrome (N=8)

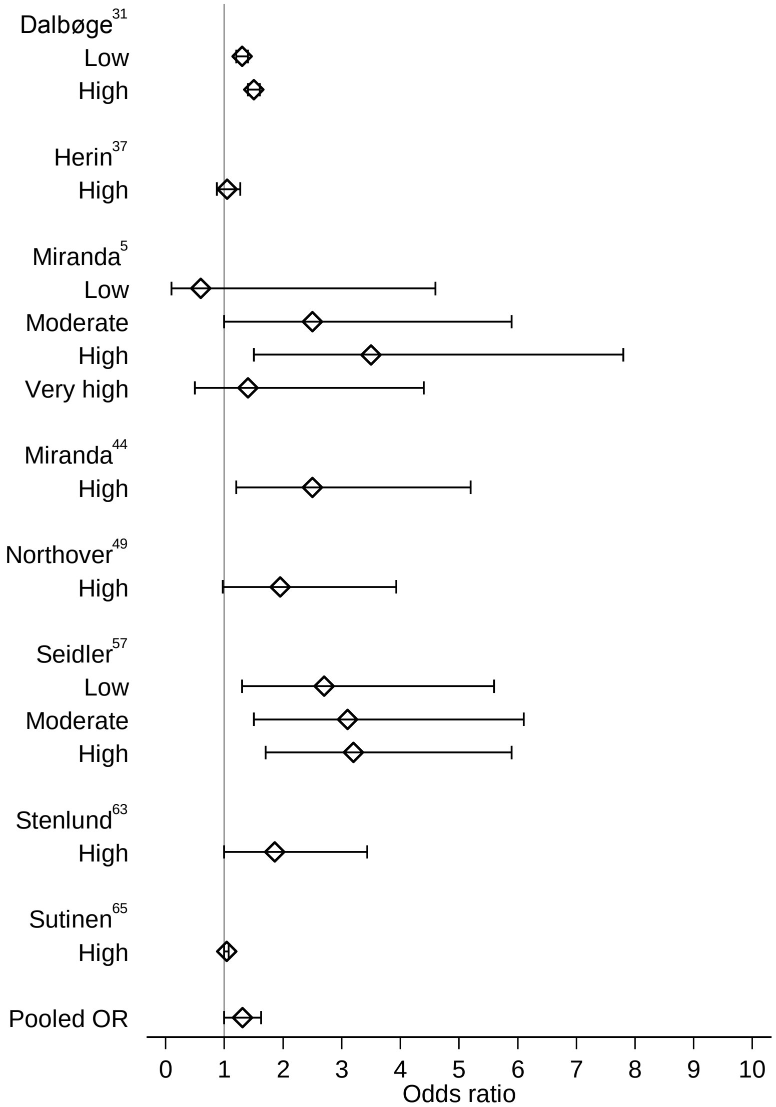
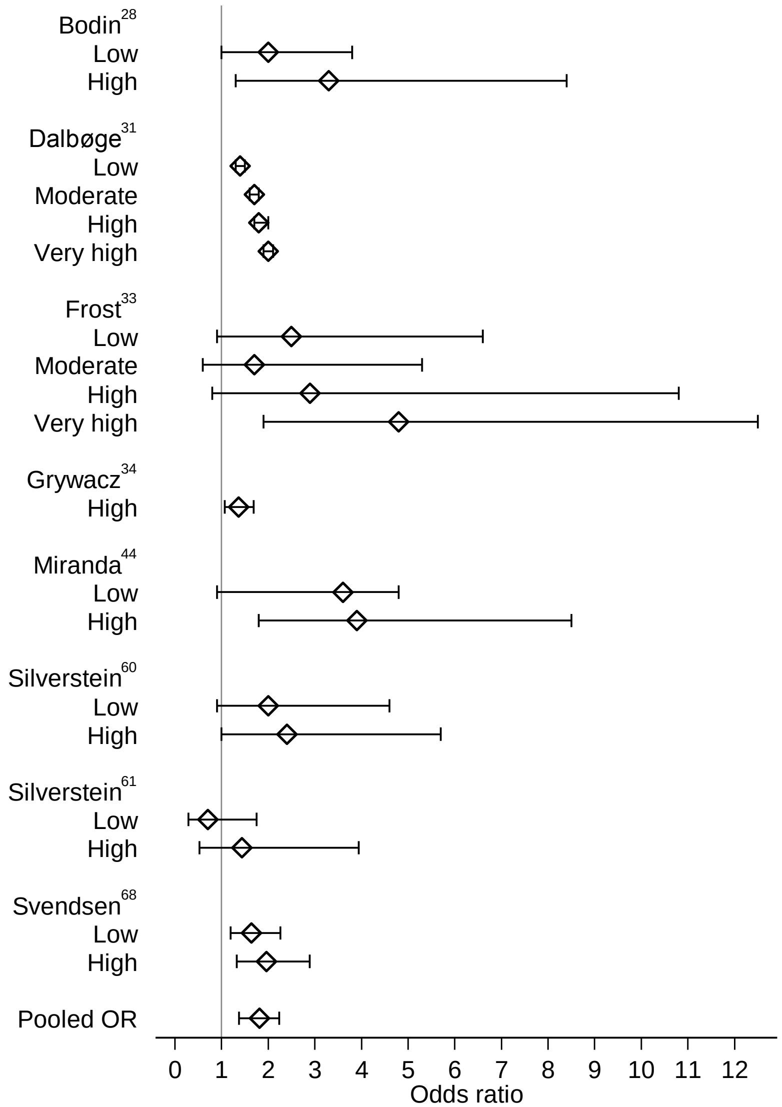


Figure 6: Forest plot of the association between combined exposures and subacromial impingement syndrome (N=8)



Based on appendix 6, we evaluated exposure-response differences between men and women. For forceful shoulder exertion, one study found a higher risk among men, three studies found a higher risk among women, while inconsistent results were found in one study (2 out of 3 exposure variables showed a higher risk among men). For arm posture, one study found a higher risk among men, while five studies found a higher risk among women. When comparing the exposure-response differences between sexes for repetitive shoulder movement, three studies found a higher risk among men, one study found a higher risk among women, while inconsistent results were found in one study. Two out of three studies showed a higher risk among men for HAV, while two studies of combined mechanical exposures both indicated a higher risk among women.

3.5 Association between occupational psychosocial exposures and SIS

Figures 7-9 show forest plots of the associations between occupational psychosocial exposures (i.e. job demand, job control, and social support) and SIS. The exposure labels on the y-scale were re-formulated uniformly; exposed groups were defined as high job demands, low job control and low job support.

Job demand was studied in 11 studies with a quality score between eight and 14; six studies were of high quality (total quality score ≥11) and OR_{adj} ranging from 0.9 to 3.19; statistically significant results were reported in seven studies. Three studies were excluded from the meta-analysis,[25,52,54] providing a pooled OR of 1.14 (CI 95% 1.05-1.24). Sensitivity analysis of high quality studies (N=6) showed a pooled OR of 1.19 (95% CI 1.02-1.36). The funnel plot indicated biased publication (p=0.001) of small studies with positive association (figure 16, appendix 8).

Job control was studied in 11 studies with a quality score between 8 and 14 (6 studies ≥11) and OR_{adj} ranging from 0.8 to 2.0; statistically significant results were found in two studies. Three studies were excluded from the meta-analysis,[25,52,54] providing a pooled OR of 1.09 (CI 95% 0.94-

1.23). Sensitivity analysis of high quality studies (N=6) showed a pooled OR of 1.19 (95% CI 0.99-1.40). The funnel plot indicated a tendency toward biased publication of small studies with positive association (p=0.093) (figure 17, appendix 8)).

Job support was studied in six studies with quality scores between eight and 14 (3 studies ≥11) and OR_{adj} between 0.6 and 2.0; statistically significant results were found in two studies (appendix 7). Based on five studies (one study excluded),[27] a pooled OR of 0.98 (CI 95% 0.90-1.07) was found. Sensitivity analysis of high quality studies (N=3) also showed a pooled OR of 0.99 (95% CI 0.90-1.07). The funnel plot did not indicate biased publication toward a positive association ((p-value=0.886) (figure, 18, appendix 8).

Figure 7: Forest plot of the association between high job demand and subacromial impingement syndrome (N=11)

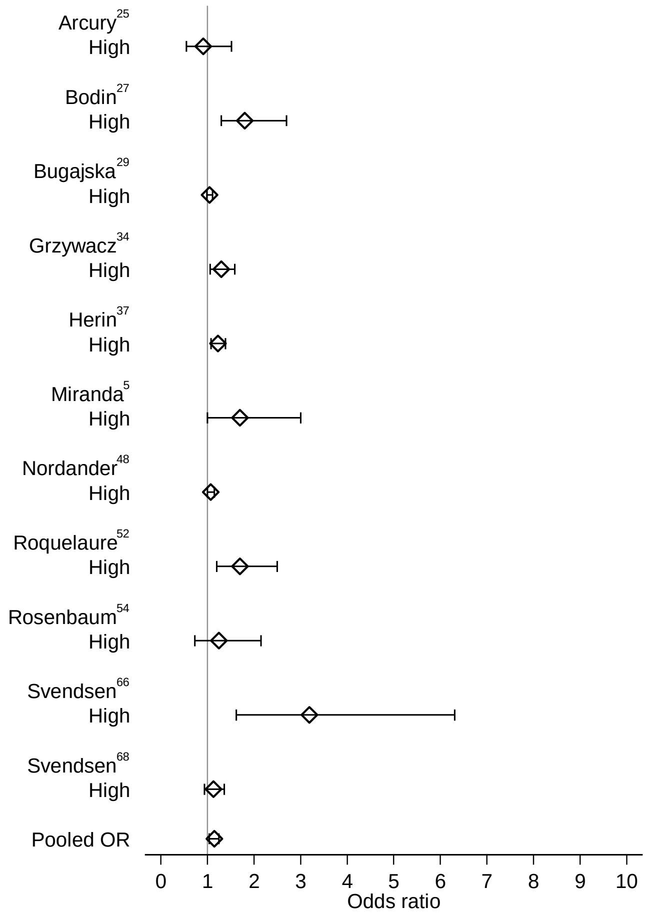


Figure 8: Forest plot of the association between low job control and subacromial impingement syndrome (N=11)

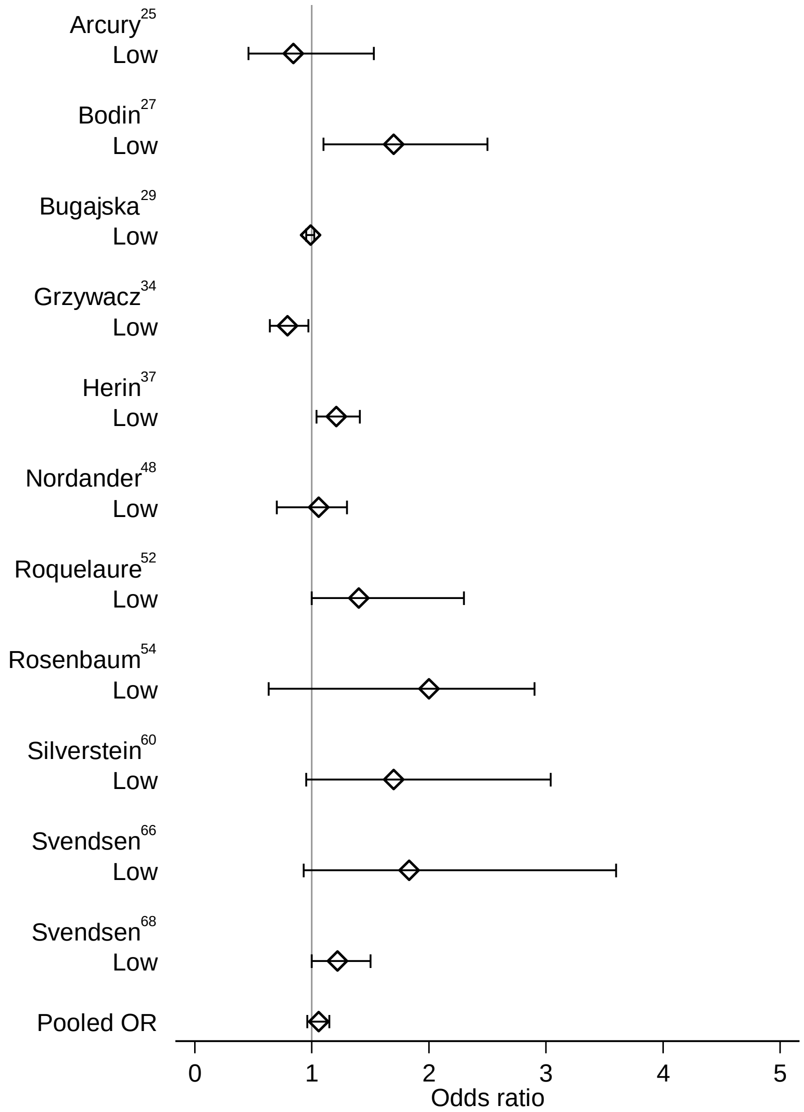
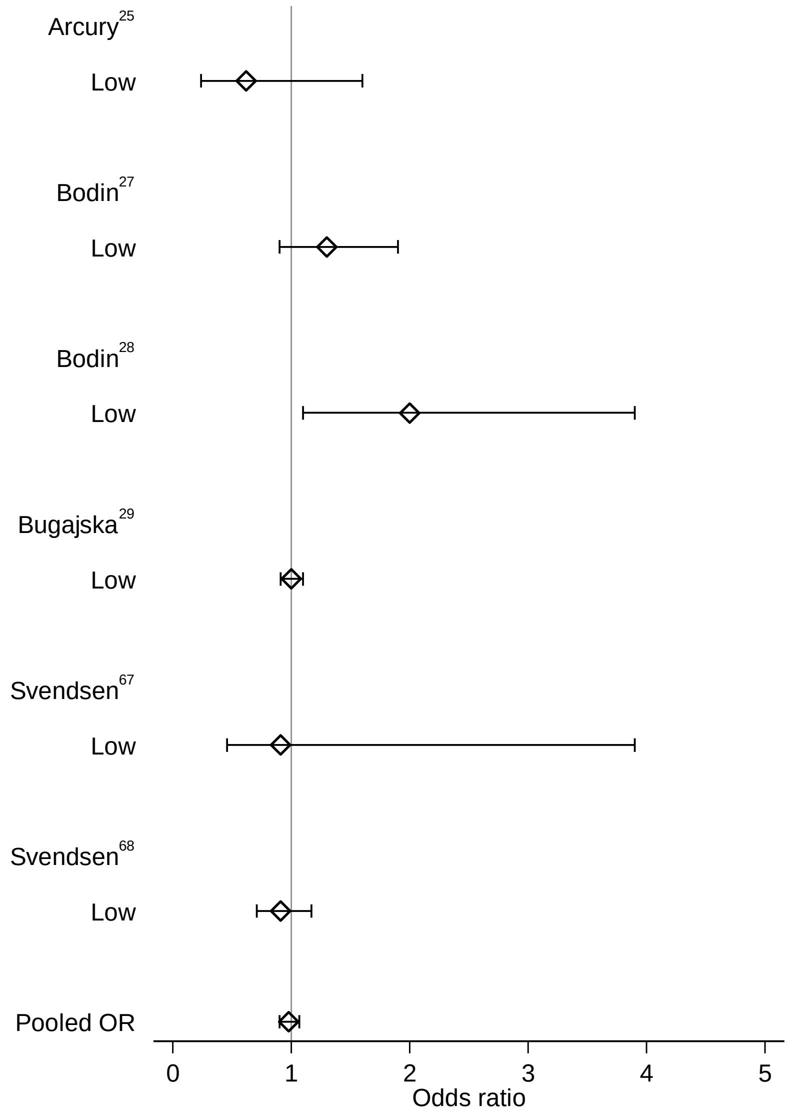


Figure 9: Forest plot of the association between low job support and subacromial impingement syndrome (N=6)



3.6 Quality of evidence

The quality of evidence of each occupational mechanical and psychosocial exposure was evaluated based on the existing literature.

Forceful shoulder exertion: Forceful shoulder exertion was studied in several studies (N=20). Based on 14 studies with unique study populations, a pooled OR of 1.44 (95% CI 1.14-1.75) was found (high quality studies showed a pooled OR of 1.45 (95% CI 1.06-1.84)). In general, the majorities of studies did not control for co-existing occupational mechanical exposures, thus the results found might be confounded. There was no indication of publication bias. Based on these results, moderate evidence of a causal association (++) between forceful shoulder exertion and SIS exist.

Arm posture: Arm posture was studied in several studies (N=17), in which 11 studies were based on unique study populations. A pooled OR of 1.79 (CI 95% 1.37-2.21) was found; OR was 1.78 (95% CI 1.29-2.27) when restricting to high quality studies. The majorities of studies did not control for co-existing occupational mechanical exposures. We found a non-statistically significant indication of biased publication of small studies with positive association. Based on these results, moderate evidence of a causal association (++) between arm posture and SIS exist.

Repetitive shoulder movement: Based on seven out of 10 studies, we found a pooled OR of 1.72 (CI 95% 1.17-2.27) (all high quality studies). The association might be confounded by co-existing mechanical exposures. We found a non-statistically significant tendency toward biased publication of small studies with positive association. Moderate evidence of a causal association (++) exist.

HAVs: Seven out of eight studies were based on unique study populations, providing a non-statistically significant pooled OR of 1.31 (CI 95% 1.00-1.62); OR was 1.25 (95% CI 0.92-1.58) when restricting to high quality studies. Co-existing mechanical exposures might have confounded the association. We also found a non-statistically significant indication of biased publication of small studies with positive association. Limited evidence of a causal association (+) was indicated.

Combined mechanical exposures: Seven out of eight studies were based on unique study populations, providing a pooled OR of 1.81 (CI 95% 1.37-2.24), which increased to 2.00 (95% CI 1.90-2.10) when restricting to studies with high quality. A non-statistically significant tendency toward biased publication of small studies with positive association was indicated. In combination with several studies based on job title/occupation with high risk in jobs with presumably combined exposures[24,32,35,40,42,46,47,57,58,72] the evidence of a strong causal association (+++) is indicated.

Occupational psychosocial exposures: Studies of *high job demands* showed pooled OR of 1.14 (CI 95% 1.05-1.24) and 1.19 (95% CI 1.02-1.36) indicating a slight increased risk of SIS. For *low job control*, pooled ORs of 1.09 (CI 95% 0.94-1.23) and 1.19 (CI 95% 0.99-1.40) indicated a non-statistically significant increased risk of SIS. For *low job support*, a pooled OR of 0.98 (CI 95% 0.90-1.07) and 0.99 (CI 95% 0.90-1.07) was found. For job demands, we found publication bias (p=0.013) of studies with positive association, which was insignificant for job control and job support. For all occupational psychosocial exposures, the evidence suggested lack of a causal association.

4. DISCUSSION

4.1 Main results

This reference document, conducted as a systematic review, of the association between occupational exposures and SIS showed strong evidence of an association between combined mechanical exposures and SIS, and moderate evidence for forceful shoulder exertion, arm posture, repetitive shoulder movement; limited evidence was found for HAVs. We found a lack of an association between occupational psychosocial exposures (high job demands, low job control and low social support) and SIS.

The reference document supports the findings reported in the previous reference document from 2007, which indicated moderate evidence of an association between forceful shoulder exertion and arm posture and SIS.[21] Based on results from this reference document, moderate evidence also exist for repetitive shoulder movement and strong evidence for the combination of occupational mechanical exposures, while limited evidence now exist for HAVs. Mechanical exposures seem to be more related to the risk for SIS than psychosocial exposures as higher pooled OR were found for mechanical exposures (pooled OR between 1.31 and 1.79) than for psychosocial exposures (pooled OR between 0.98 and 1.14).

4.2 Methodological considerations

In clinical settings, the specific underlying SIS disorders are difficult to differentiate and are often present as mixed forms. The existing literature used different outcome criteria, which might reduce the possibility of meta-analysis. However, a recent review indicated that variations in case definition of upper limb disorders have less impact on measure of association than might be expected, which could justify pooling data.[73] In this reference document, we only pooled data for specific occupational mechanical exposures independent of exposure metric, to provide an indication of whether specific occupational mechanical exposures are associated with an increased risk of SIS.

Heterogeneity was found when comparing exposure definitions; e.g. for upper arm elevation, the following definitions were used: micro pauses in shoulder flexion, current and lifetime upper arm elevation >90°, working with hands above shoulder level, and sustained and repeated arm abduction. Heterogeneity was also found when comparing the exposure dimension; the majority of studies applied exposure intensity, while few studies applied exposure duration or cumulative exposures. Categorical exposure scales were often applied, dividing exposures into two or three groups (e.g. no/yes, low/medium/high) using different cut-points. Based on these perspectives and in relation to the different use of exposure assessment (i.e. self-report, expert rating, observation and technical measurement), the existing literature has not provided exposure information using a common metric and scale, which would allow pooling of data across studies to identify safe exposure intensities and durations. More studies using quantitative and generic exposure information is essential to define the relation between the exposure dimensions and the risk of SIS.

4.3 Sex differences and time windows

When comparing potential sex-differences in exposure-response relationship, we found inconsistent results. A tendency toward a somewhat higher risk was found among women for forceful shoulder exertion and arm posture, but higher quality studies did not support these findings. Other aspects of the association between occupational mechanical exposures and SIS have been only briefly addressed. Knowledge of the relevant time window would increase our understanding of injury mechanisms that may link exposure and outcome. Studies of exposure duration indicated an increased risk of SIS with increasing duration. But only one study evaluated the relevant time window in which exposure may influence the disease mechanism.[31] This study showed that within a 10-year time window, the risk of SIS increased gradually with number of years contributing to the cumulative exposure estimates; two to four years of accumulation of exposure were sufficient to increase the risk.

4.4 Conclusion

This reference document confirmed and strengthened the evidence of a causal association between occupational mechanical exposures as reported in the previous reference document[21] and two systematic reviews.[6,22] Based on more recent published studies used in this reference document, the most important risk factors for SIS were forceful shoulder exertion, arm elevation, repetitive shoulder movements, and especially combined occupational mechanical exposures. Limited evidence of a causal relationship for the association between HAVs and SIS was found. Based on this reference document, lack of a causal association was found for occupational psychosocial exposures. The possible role of psychosocial work place exposures for the prognosis of SIS lies beyond the scope of this review. Safe exposure intensities and durations for occupational mechanical exposures could not be identified from the included studies.

5. ENGLISH RESUME

Aim: The primary aim was to examine which occupational mechanical exposures are associated with an increased risk of subacromial impingement syndrome (SIS). A secondary aim was to evaluate the effect of occupational psychosocial exposures on SIS.

Materials and methods: A systematic review was conducted. Eligible criteria for inclusion of studies comprised clinically or imaging assessed SIS, while exposure included occupational mechanical exposures (i.e. forceful shoulder exertion, arm posture, repetitive shoulder movement, use of hand-arm vibration tools (HAVs), and the combination of different mechanical exposures) and psychosocial exposures (job demand, job control and support). A systematic literature search was performed in Medline, Embase and Web of Science for peer-reviewed articles published before 26th of October 2016. Identification of potential relevant articles was performed in three steps (i.e. exclusion based on title screening, abstract screening and full paper reading), which was performed independently by two of the reviewers. From each included study, we extracted core study information, and performed a quality assessment. Forest plots and meta-analysis were performed to evaluate the association between occupational exposures and SIS.

Results: A total of 5165 articles were identified including 1130 duplicates. From the 4035 articles, we excluded 2794 and 1121 articles based on title and abstract screening; after full paper reading a total of 50 relevant studies were included. In meta-analysis, pooled OR of 1.44 (95% CI 1.14-1.75), 1.79 (95% CI 1.37-2.21), 1.72 (CI 95% 1.17-2.27), 1.31 (95% CI 1.00-1.62) and 1.81 (95% CI 1.37-2.10) were found for forceful shoulder exertion, arm posture, repetitive shoulder movement, HAVs and the combination of different mechanical exposures, while pooled OR between 0.98 and 1.14 were found for job demand, job control and support.

Conclusion: We found moderate evidence of an association between forceful shoulder exertion, arm posture, repetitive shoulder movement, and strong evidence for the combination of different

mechanical exposures and SIS, while limited evidence was found for HAVs. A lack of a causal association was found for psychosocial exposures. Safe exposure intensities and durations could not be identified with available data.

6. DANSK RESUME

Baggrund og formål

Subakromiel impingementsyndrom (SIS) er en fællesbetegnelse for ikke-traumatiske subakromielle lidelser herunder rotator cuff syndrom, betændelsesreaktion i slimsækken under skulderloftet, betændelsesreaktion i den lange bicepssene og hel eller delvis overrivning af rotator cuff-senerne og bicepssenen. SIS er den hyppigst forekommende skulderlidelse, og udgør op til 65 % af alle skulderlidelser set i almen praksis. I den generelle befolkning forekommer SIS hos 2-8 %, imens lidelsen forekommer hyppigere i skulderbelastede erhverv såsom slagteriarbejdere, fiskeriarbejdere og syersker.

Potentielle risikofaktorer for SIS omfatter henholdsvis ikke-arbejdsrelaterede og arbejdsrelaterede faktorer. De ikke-arbejdsrelaterede faktorer omfatter bl.a. alder, køn, Body Mass Index (BMI), rygning, diabetes mellitus, fysisk aktivitet samt tidligere skulderskader. De arbejdsrelaterede risikofaktorer omfatter mekaniske eksponeringer såsom kraftbetonede skulderbevægelser, arbejde med løftede arme, repetitive skulderbevægelser og brugen af håndarm-vibrerende værktøj, imens psykosociale eksponeringer bl.a. omfatter høje job krav, lav job kontrol og lav social støtte. I 2007 blev der udarbejdet et videnskabeligt referencedokument til belysning af om der er grundlag for at antage, at arbejds-relaterede mekaniske eksponeringer kan være årsag til SIS. I referencedokumentet blev det konkluderet, at der er en sandsynlig årsagssammenhæng mellem arbejde med armene løftet over skulderhøjde, kraftbetonede arbejdsfunktioner og SIS, imens en årsagssammenhæng synes mindre sikkert for repetitive skulderbevægelser. Endvidere blev det konkluderet at der muligvis kan være en årsagssammenhæng mellem lav social støtte i arbejdsmiljøet og risikoen for SIS. På baggrund af den foreliggende litteratur var det ikke muligt at vurdere evt. tærskelværdier. Efter udarbejdelsen af referencedokumentet i 2007 er der fremkommet nye studier på området. Arbejdsskadestyrelsen og Erhvervssygdomsudvalget har på baggrund heraf og pga. tilbagevendende drøftelser af hvilke arbejdsrelaterede eksponeringer, der kræves for at anerkende SIS som en erhvervssygdom, vurderet, at der er behov for en nærmere udredning i form af et nyt videnskabeligt referencedokument om årsagssammenhængen mellem arbejdsrelaterede eksponeringer og udvikling af SIS. Aktuelt savnes specifikt klare retningslinjer for hvilke arbejdsrelaterede eksponeringer, der kan forårsage SIS og hvornår eksponeringerne er tilstrækkelige til at medføre SIS.

Formålet med dette referencedokument er, at udarbejde et systematisk review, der skal undersøge hvilke arbejdsrelaterede mekaniske eksponeringer, som øger risikoen for SIS, samt hvornår de mekaniske eksponeringer er tilstrækkelige til at medføre SIS. Et sekundært formål er, at undersøge sammenhængen mellem arbejdsrelaterede psykosociale eksponeringer og SIS.

Materiale og metode:

Referencedokumentet blev udarbejdet som et systematisk review og registreret i PROSPERO: CRD42017079068. Der blev foretaget en systematisk litteratursøgning i samarbejde med bibliotekar Jane Kjemstrup Andersen i henholdsvis PubMed, Embase og Web of Science for videnskabelige artikler publiceret før den 26. oktober 2016. Potentielle relevante artikler omfattede epidemiologiske studier, som opfyldte a priori-definerede PECO-kriterier. I PECO blev populationen defineret som personer over den arbejdsdygtige alder. Udfald blev defineret som diagnosticeret SIS herunder rotator cuff syndrom, betændelsesreaktion i slimsækken under skulderloftet, betændelsesreaktion i den lange bicepssene og hel eller delvis ikke-traumatisk overrivning af rotator cuff-senerne og bicepssenen. Eksponeringen omfattede jobtitler og arbejdsrelaterede eksponeringer herunder både mekaniske og psykosociale eksponeringer. De arbejdsrelaterede mekaniske eksponeringer omfattede hhv. kraftbetonede arbejdsfunktioner, arm elevation, repetitive skulderbevægelser, brug af håndarm vibrerende værktøj og kombinationen af mekaniske eksponeringer, imens de psykosociale eksponeringer bl.a. omfattede krav, kontrol og støtte. Kun studier hvor en association mellem eksponering og udfald blev eller kunne estimeres blev inkluderet. Efter litteratursøgningen blev potentielle relevante artikler overført til online programmet Covidence. I Covidence blev duplikater ekskluderet, hvorefter udvælgelsen af relevante artikler blev foretaget i tre trin hhv. titel screening, abstrakt screening og gennemlæsning af hele artiklen. Denne proces blev foretaget af to af projektgruppens medlemmer, hvor uoverensstemmelse blev løst ved konsensus.

Efter udvælgelse af relevante artikler, blev oplysninger om studiernes design, population, udfald, eksponering overført til tabeller, og der blev foretaget en kvalitetsvurdering af hvert studie. Associationen mellem arbejdsrelaterede eksponeringer og SIS blev præsenteret via forrest plots og tabeller. Der blev foretaget metaanalyser, hvor studier baseret på identisk population og udfald blev ekskluderet. Publikationsbias blev undersøgt via Funnel plots og Eggers test. Graden af evidens for en årsagssammenhæng blev vurderet i forhold til Arbejdstilsynets retningslinjer.

Resultater

Den systematiske litteratursøgning resulterede i 5165 potentielle relevante artikler, hvoraf 1130 artikler var duplikater. Efter eksklusion af duplikater blev yderligere 2794 artikler ekskluderet efter gennemgang af artiklernes titel, imens hhv. 1121 og 70 artikler blev ekskluderet efter gennemlæsning af abstrakt og hele artikler. Én artikel blev inkluderet efter gennemgang af artiklernes referencelister, hvorved der i alt blev inkluderet 50 artikler i det systematiske review. De 50 artikler inkluderede 25 studier baseret på jobtitler, 22 studier baseret på arbejdsrelaterede mekaniske eksponeringer, imens 3 studier var baseret på både jobtitler og mekaniske eksponeringer.

Kraftbetonede arbejdsfunktioner: Sammenhængen mellem kraftbetonede arbejdsfunktioner og SIS blev undersøgt i 20 studier. Selv om der var forskelle mellem de enkelte studier (fx design, definition af udfald og eksponering samt eksponeringsvurdering), var der generelt enighed om, at kraftbetonede arbejdsfunktioner medfører en øget risiko for SIS. Dette understøttes af at resultater fra metaanalysen (N=14) viste en OR på 1.44 (95 % CI 1.14-1.75). Confounding af andre mekaniske eksponeringer kan ikke udelukkes, hvilket ligeledes er gældende for de øvrige mekaniske eksponeringer. Der var ingen indikation af publikationsbias. På baggrund heraf vurderes der at være nogen grad af evidens for en årsagssammenhæng (++).

Arm elevation: Sammenhængen mellem arm elevation og SIS blev undersøgt i 17 studier. Selv om der var forskelle mellem de enkelte studier, var der generelt enighed om, at arm elevation medfører en øget risiko for SIS. Resultater baseret på metaanalysen (N=11) viste en OR på 1,79 (95% CI 1,37-2,21). Der var dog tendens til publikation bias af små studier med positiv sammenhæng. På baggrund heraf vurderes der at være nogen grad af evidens for en årsagssammenhæng (++).

Repetitive skulderbevægelser: Repetitive skulderbevægelser blev undersøgt i 10 studier, hvor der var forskelle mellem de enkelte studier. Resultater baseret på metaanalysen (N=7) viste en OR på 1.72 (CI 95% 1.17-2.27), imens Funnel plot indikerede tendens til publikation bias af små studier med positiv sammenhæng. På baggrund heraf vurderes der at være nogen grad af evidens for en årsagssammenhæng (++).

Hånd-arm vibrerende værktøj: Brug af håndarm-vibrerende værktøj blev undersøgt i 8 studier. Metaanalysen (N=7) viste en OR på 1,31 (95% CI 1,00-1,62) med tendens til publikation bias af små studier med positiv sammenhæng. Graden af evidens vurderes at være begrænset (+).

Kombinerede mekaniske eksponeringer: Kombinationen af forskellige mekaniske eksponeringer blev undersøgt i 8 studier, som viste generel enighed om en sammenhæng. I kombination med resultaterne baseret på de mange undersøgelser af jobtitler understøtter denne sammenhæng. Resultater baseret på metaanalysen (N=7) viste en OR på 1,81 (95 % CI 1,37-2,24). Graden af evidens vurderes at være god (+++).

Psykosociale faktorer: De psykosociale faktorer (krav, kontrol og støtte) blev undersøgt i hhv. 11, 11 og 6 studier. Metaanalyserne viste OR mellem 0,98 og 1,14. For krav (OR=1,14) var der publikations bias af små studier med positiv association, hvorimod der for kontrol og støtte kun var en tendens hertil. Det vurderes, at der er god evidens for en manglende årsagssammenhæng (-).

Konklusion

Baseret på dette referencedokument vurderes det, at der er stærk evidens for en årsagssammenhæng mellem kombinationen af flere mekaniske eksponeringer og SIS, imens der er nogen grad af evidens for en årsagssammenhæng mellem hhv. kraftbetonede arbejdsfunktioner, arbejde med løftede arme, repetitive skulderbevægelser og SIS. Endvidere konkluderes det, at der er begrænset evidens for en årsagssammenhæng for hånd-arm vibrerende værktøj. For de psykosociale faktorer er der god evidens for en manglende årsagssammenhæng. Sikre tærskelværdier kunne ikke identificeres.

7. APPENDIX

Appendix 1: PECO

Population: Persons above working age

Exposure: Exposure includes occupational mechanical and psychosocial exposures. Occupational mechanical exposures include:

- Forceful shoulder exertion (e.g. lifting, pulling and pushing)
- Arm posture
- Repetitive shoulder movement
- Use of hand-arm vibration tool
- Combination of different mechanical exposures

Occupational psychosocial exposures include demand, control and support

Comparison: Both studies with quantitative exposure measures and studies with more crude exposure measures such as occupation/job title will be included as long as they provide measures of association (or possible to calculate). The comparison was restricted to persons in real workplace settings (no experimental studies).

Outcome: We consider subacromial impingement syndrome to comprise, broadly, disorders affecting one or more subacromial structures, or nearby structures, leading to shoulder complaints. Specific disorders include:

- Subacromial impingement syndrome
- Rotator cuff disease/syndrome
- Subacromial bursitis
- Biceps tendinitis/tendinopathy
- Tendinitis/tendinosis of the rotator cuff muscles
- Non-traumatic partial or complete tear of the long head of the biceps or rotator cuff tendons
- Primary or secondary calcifications of the rotator cuff or biceps tendons
- Osteoarthritis of the acromioclavicular joint or variations in the shape of the acromion leading to development of impingement

The diagnoses cover the ICD-10 codes: M19, M75.1-M75.9, not M75.0 (adhesive capsulitis of shoulder).

Appendix 2: Full search string for literature search in PudMed and Medline

1	shoulder.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
2	rotator cuff.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
3	rotator-cuff.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
4	supraspinatus.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
5	supra-spinatus.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
6	infraspinatus.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
7	infra-spinatus.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
8	teres minor.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
9	subscapularis.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
10	sub-scapularis.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
11	biceps tend$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
12	glenohumeral.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
13	gleno-humeral.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
14	impingement.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
15	or/1-14	
16	epidemiolo$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
17	aetiolo$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
18	etiolo$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
19	risk factor$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
20	predictive factor$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
21	risk marker$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
22	odds ratio$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
23	hazard ratio$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
24	risk ratio$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
25	rate ratio$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
26	prevalence.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
27	relative risk$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
28	incidence.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, ui]
29	or/16-28	
30	occupation$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, an, eu, pm, ui]
31	employment$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, an, eu, pm, ui]
32	job$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, an, eu, pm, ui]
33	work$.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, an, eu, pm, ui]
34	task.mp.	[mp=ti, ab, hw, tn, ot, dm, mf, dv, kw, fs, nm, kf, px, rx, an, eu, pm, ui]
35	or/30-34	
36	and/15,29,35	
37	remove duplicates from 36	
38	limit 37 to human	

Appendix 3: Study exclusion criteria

Title screening: The following exclusion criteria were used:

- No evidence of pain / disability in the neck / upper limb as an outcome measure, or
- Animal studies, children studies, reviews

At this stage, the exposure measurement in each paper was not considered.

Abstract screening: The following exclusion criteria were used:

- Explicit mention that outcome was not related to the shoulder, or
- Explicit mention that outcome comprised acute shoulder pain (not chronic shoulder pain), or
- Explicit mention that only non-occupational exposures were assessed, or
- Animal study, children study, or
- Other reasons (review, abstract only, letter to editor, not European language)

Full paper reading: The following exclusion criteria were used:

- Study outcome does not fulfill outcome definition (appendix 1), or
- Explicit mention that outcome was a traumatic or systemic disease, or
- Explicit mention that only non-occupational exposures were assessed, or
- Animal studies, children studies, or
- No measure of association between occupational exposures and outcome / or possible to calculate, or
- Other reasons (review, abstract only, letter to editor, not European languages)

Appendix 4: Methodological quality assessment. Scoring options include positive, negative, or unclear.

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 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

Appendix 5. Quality assessment of the 50 included studies

Reference	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Summary core
Dalbøge, 2014[31]	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	16
Svendsen, 2013[68]	+	+	+	+	+	-	+	+	+	+	+	+	?	+	+	+	14
Thygensen, 2016[69]	+	-	+	+	+	+	+	+	+	+	+	+	-	+	+	+	14
Bodin, 2012[28]	+	-	+	+	+	-	+	+	+	-	+	-	-	+	+	+	13
Mora, 2016[45]	+	+	+	-	+	+	+	+	?	+	+	+	-	+	+	+	13
Svendsen, 2004[67]	-	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	13
Svendsen, 2004[66]	-	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+	13
Frost, 2002[33]	-	+	+	+	+	+	+	+	+	-	+	-	-	+	+	+	12
Miranda, 2005[5]	+	+	+	+	+	+	+	+	?	-	+	-	-	+	+	+	12
Sutinen, 2006[65]	-	?	-	+	+	+	+	+	+	+	+	+	-	+	+	+	12
Silverstein, 2006[59]	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	-	12
Silverstein, 2008[60]	+	-	+	+	+	+	+	+	+	-	+	-	-	+	+	+	12
Bugajaska, 2013[29]	+	+	+	+	-	?	+	+	?	+	?	+	-	+	+	+	11
Chung, 2013[30]	+	+	+	+	-	+	+	+	?	+	-	+	+	+	-	-	11
Hansson, 2000[35]	+	+	-	+	+	+	+	+	?	-	+	-	-	+	+	+	11
Herin, 2012[37]	+	+	+	-	-	-	+	+	-	+	+	+	?	+	+	+	11
Frost, 1999[32]	+	-	+	+	+	+	+	+	-	-	+	-	-	+	+	+	11
Melchior, 2006[43]	-	+	+	+	+	+	+	+	-	-	+	-	-	+	+	+	11
Miranda, 2008[44]	-	?	+	+	+	-	-	+	?	+	+	+	+	+	+	+	11
Seidler, 2011[57]	+	-	+	+	+	-	+	+	+	-	+	-	-	+	+	+	11
Silverstein, 1998[58]	+	+	+	-	-	+	+	-	+	+	+	+	+	+	-	-	11
Stenlund, 1993[62]	+	+	-	-	+	+	+	+	+	-	+	-	-	+	+	+	11
Andersen, 1993[24]	+	?	-	-	+	+	+	+	+	-	+	-	-	+	+	+	10
Bodin, 2012[27]	+	+	+	+	+	-	+	+	?	-	-	-	-	+	+	+	10
Grzywacz, 2012[34]	+	-	+	+	+	-	+	+	?	-	+	-	-	+	+	+	10
Hsiao, 2015[38]	-	+	+	-	-	+	+	+	?	+	-	+	-	+	+	+	10

Appendix 5 (continued). Quality assessment of the 50 included studies

Reference	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Summary core**
Kaergaard, 2000[40]	-	-	-	+	+	+	+	+	+	+	+	+	+	-	-	-	10
Nordander, 2016[48]	+	?	?	+	+	+	+	+	?	-	+	-	-	+	+	+	10
Nordander, 2016[48]	+	?	?	+	+	+	+	+	?	-	+	-	-	+	+	+	10
Rosenbaum, 2013[53]	+	+	+	+	+	+	+	+	?	-	+	-	-	+	-	-	10
Sansone, 2015[56]	+	?	+	+	+	+	+	+	?	-	+	-	-	+	+	-	10
Silverstein, 2009[61]	-	-	+	+	+	+	+	+	+	-	-	-	-	+	+	+	10
Zakaria, 2004[72]	-	+	+	-	+	+	+	+	?	+	+	+	-	+	-	-	10
Arvidsson, 2016[26]	+	+	-	+	+	+	+	+	?	-	+	-	-	+	-	-	9
Jacobsson, 1992[39]	-	-	-	+	+	-	+	+	?	-	+	-	+	+	+	+	9
Kaerlev, 2008[41]	+	+	+	-	-	+	+	-	?	+	+	+	?	+	-	-	9
Nordander, 1999[46]	-	+	+	+	+	+	+	+	-	-	+	-	-	+	-	-	9
Ohlsson, 1994[50]	-	+	+	+	+	+	+	+	-	-	+	-	-	+	-	-	9
Roquelaure, 2011[52]	-	+	+	+	+	-	+	+	-	-	-	-	-	+	+	+	9
Stenlund, 1993[63]	+	+	-	-	+	-	+	+	+	-	-	-	-	+	+	+	9
Yamamoto, 2010[71]	+	+	+	-	+	-	-	+	+	-	-	-	-	+	+	+	9
Arcury, 2014[25]	-	-	-	+	+	-	+	+	?	-	+	-	-	+	+	+	8
Northover, 2007[49]	+	+	+	-	?	?	+	+	+	-	+	-	-	+	-	-	8
Rosenbaum, 2014[54]	+	-	-	-	+	-	+	+	?	-	+	-	-	+	+	+	8
Sansone, 2014[55]	+	?	-	-	-	+	+	+	?	-	+	-	-	+	+	+	8
Park, 1992[51]	-	+	+	-	-	+	-	-	+	-	+	-	+	-	+	+	8
Nordander, 2009[47]	+	?	+	-	-	+	+	+	-	-	+	-	-	+	-	-	7
Stucchi, 2016[64]	+	?	+	-	-	+	+	-	?	-	-	-	-	+	+	+	7
Luopajarvi, 1979[42]	-	+	-	-	+	+	-	-	-	-	+	-	+	+	-	-	6
Wang, 2005[70]	-	+	-	-	-	-	+	+	-	-	+	-	+	+	-	-	6
Herberts, 1981[36]	-	?	-	-	+	+	-	-	-	-	+	-	-	-	-	-	3
Total	29	30	37	33	40	38	49	49	28	25	49	27	25	58	48	48	

+ positive, - negative, ? unclear

Appendix 6: Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Force									
Arcury, 2014[25]	*Unknown dimension:* Heavy load (N=202) (not included in meta-analysis)	Age, years lived in USA, language, and exposure in analysis	No	–	–	1.00	–	–	–
			Yes	–	–	1.27	0.48–3.36	–	–
Bodin, 2012[27]	*Intensity:* High perceived physical demand (N=2622) (not included in meta-analysis)	Age, exposure categories in analysis	Borg Scale <13	1.0	–	1.0	-	–	–
			Borg Scale ≥13	2.2	1.4-3.4	1.4	0.9-2.1	–	–
Bodin, 2012[28]	*Intensity:* High perceived physical exertion (N=825)	Age, exposure categories in analysis	Borg Scale <15	1.0	–	–	–	–	–
			Borg Scale ≥15	1.6	0.8-3.2	–	–	–	–
Dalbøge, 2014[31]	*Cumulative exposure:* Forceful shoulder exertion (N=2,374,403)	Age, sex, replace of residence, calendar year at start of follow up	<5 pack/year	1.0	–	1.0	–	1.0	–
			5 pack/year	0.7	0.6-0.8	0.7	0.6-0.7	0.7	0.6-0.7
			>5-7.5 pack/year	1.1	1.1-1.2	1.1	1.1-1.2	1.2	1.1-1.2
			>7.5-10 pack/year	1.5	1.5-1.6	1.4	1.3-1.5	1.5	1.4-1.6
			>10-20 pack/year	1.7	1.6-1.8	1.9	1.7-2.1	1.7	1.6-1.8
Frost, 2002[33]	*Intensity:* Force requirements (N=2757)	Age, sex, BMI, low pressure pain threshold, leisure activity shoulder trauma, arthritis	Reference	–	–	–	–	1.0	–
			Low (<10% of MVC)	–	–	–	–	2.17	0.84–5.69
			High (≥10% of MVC)	–	–	–	–	4.21	1.71–10.40
Grzywacz, 2012[34]	*Intensity:* Heavy load (N=518)	Age, sex, language, exposure in analysis	No	–	–	–	–	1.00	–
			Yes	–	–	–	–	1.32	0.96-1.82
Herin, 2012[37]	*Intensity:* Heavy loads (N=12,714)	Age, sex, sport, BMI, social class	No	–	–	–	–	1.00	–
			Yes	–	–	–	–	1.07	0.90-1.28
	Intensity: Forceful effort (N=12,714)	Age, sex, sport, BMI, social class	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	1.24	1.04-1.47
	Intensity: Effort with tools (N=12,714)	Age, sex, sport, BMI, social class	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	0.95	0.76-1.20
Jacobsson, 1992[39]	*Intensity:* Heavy workload (N=?)	Age, sex	No	–	–	–	–	1.0	–
			Yes	–	–	–	–	5.4	3.4-8.6
Miranda, 2005[5]	*Duration:* Frequent lifting (≥5 kg >2 times/min >2 h/day) (N=8028)	BMI, smoking, sport, education, family status, region, language, comorbidity, exposure in analysis	None	1.0	–	1.0	–	1.0	–
			1–3	1.4	0.7–7.9	1.1	0.2–8.3	1.4	0.5–3.7
			4–13	0.6	0.5–4.3	3.1	1.2–7.8	1.5	0.7–3.3
			14–23	2.6	1.3–9.2	0.5	0.1–3.9	1.9	0.9–3.9
			>23	2.2	0.8–6.0	1.7	0.5–6.0	2.0	0.9–4.3
	Duration: Heavy lifting >20 kg >10 times/day (years) (N=8028)		None	1.0	–	1.0	–	1.0	–
			1–3	1.4	0.5–4.5	1.2	0.3–6.6	1.5	0.6–4.1
			4–13	1.6	0.6–4.1	6.0	2.0–12.2	3.0	1.6–5.8
			14–23	3.2	1.4–7.5	1.8	0.3–5.4	2.8	1.4–5.7
			>23	1.6	1.6–4.6	2.3	0.4–8.6	1.8	0.8–4.2

Appendix 6 (continued). Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Force									
Miranda, 2005[5] *(continued)*	*Duration:* Work requiring high hand force ≥1 h/day (years) (N=8028)	BMI, smoking, sporting activities, education, family status, region, language, comorbidity, exposure categories in analysis	None 1–3 4–13 14–23 >23	1.0 2.3 2.5 4.7 2.3	– 0.6–8.2 0.8–7.1 1.9–11.9 0.8–6.6	1.0 2.5 3.6 2.2 1.3	– 0.6–11.0 1.4–9.5 0.7–7.4 0.4–4.7	1.0 2.3 2.8 3.7 1.8	– 0.9–6.3 1.4–6.0 1.9–7.1 0.8–4.1
Miranda, 2008[44]	*Intensity:* Lifting heavy loads (N=852) (not included metaanalysis)	Age, sex, and three confounders	No Yes	1.0 1.3	- 0.6-2.9	1.0 2.3	- 1.1-5.1	1.0 2.0	- 1.2-3.4
Northover, 2007[49]	*Intensity:* Heavy manual work (N=72)	Age	No Yes	– –	– –	– –	– –	1.00 3.81	– 1.93-7.51
Roquelaure, 2011[52]	*Intensity:* High perceived workload (N=2078) (not included in meta-analysis)	Age, exposure in the analysis	<13 ≥13	1.0 2.0	– 1.3–3.1	– –	– –	– –	– –
Rosenbaum, 2014[54]	*Intensity:* Heavy load (N=286) (not included in meta-analysis)	Age, sex, language employer, work, years in poultry, education, task, organization, processing	No Yes	– –	– –	– –	– –	1.00 1.26	– 0.55-2.90
Seidler, 2011[57]	*Cumulative:* Lifting /carrying ≥ 20 kg (N=783)	Age, region, loads, work above shoulder level, HAV, sport	None >0–<9.6 h 9.6–<77 h 77–9.038 h	1.0 0.9 1.2 1.8*	– 0.5–1.7 0.6–2.1 1.0–3.2	– – – –	– – – –	– – – –	– – – –
Silverstein, 2008[60]	*Intensity:* Frequency of forceful exertions (times/min) (N=733)	Age, sex, BMI	<1 ≥1-<5 ≥5	– – –	– – –	– – –	– – –	1.00 1.35 2.02	– 0.68-2.71 1.01-4.07
Silverstein, 2009[61]	*Intensity:* Frequency of forceful exertions (times/min) (N=733) (not included in metaanalysis)	Age, BMI	<1 ≥1-<5 ≥5	1.00 1.05 1.38	– 0.41-2.71 0.54-3.52	1.00 1.75 3.35	– 0.63-4.84 1.19-9.42	– – –	– – –
Stenlund, 1993[63]	*Intensity:* Lifted load (0-709 vs >25,599) (N=207)	Age, dexterity, smoking, and sports activity	Right side Left side	1.04 1.55	0.50-2.18 0.58-4.12	– –	– –	– –	– –
Svendsen, 2004[67]	*Duration:* Lifetime shoulder force requirements (N=136)	Age	Low Medium High	1.00 1.24 0.71	– 0.48–3.18 0.30–1.65	– – –	– – –	– – –	– – –
Svendsen, 2013[68]	*Intensity:* Force score (N=29,962)	Age, sex, smoking, BMI, demand, control, and support	<1.5 points ≥1.5-<2.5 points >2.5 points	– – –	– – –	– – –	– – –	1.00 1.52 (1.40)[†] 1.74 (1.59)[†]	– 1.11-2.07 1.16-2.64
Yamamoto, 2010[71]	*Intensity:* Heaviness of labor (N=683)	Age, sex, dominant arm, history of trauma	No Yes	– –	– –	– –	– –	1.00 1.22	– 0.96-1.53

Appendix 6 (continued). Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Arm posture									
Arcury, 2014[25]	*No dimension:* Awkward posture (N=202) (not included meta-analysis)	Age, years lived in USA, language, and exposure in analysis	No	–	–	1.00	–	–	–
			Yes	–	–	1.68	0.93–3.04	–	–
Bodin, 2012[27]	*Intensity:* Sustained or repeated arm posture in abduction (≥ 2 hr/day) (N=2622) (not included meta-analysis)	Age, exposure categories in analysis	No	1.0	–	1.0	–	–	–
			>60°	1.1	0.6–2.1	1.8	1.0-3.4	–	–
			>90°	2.4	1.4-4.1	1.2	0.6-2.4	–	–
			Both	2.6	1.4-5.0	3.1	1.5-6.7	–	–
Bodin, 2012[28]	*Intensity:* Men: Repeated or sustained posture with arms above shoulder level (≥ 2 hr/day). Women: Repeated and sustained arm abduction 60-90° (N=1439)	Age, exposure categories in analysis	No	1.0	-	1.0	–	–	–
			Yes	2.2	1.0-4.7*	2.6	1.4-5.0	–	–
Dalbøge, 2014[31]	*Cumulative exposure:* Upper arm-elevation >90° (N=2,374,403)	Age, sex, replace of residence, calendar year at start of follow up	0	1.0	–	1.0	–	1.0	–
			>0-2 pack/year	1.5	1.3-1.6	1.4	1.3-1.5	1.4	1.4-1.5
			>2-5 pack/year	1.7	1.5-1.8	1.4	1.3-1.5	1.5	1.5-1.6
			>5-10 pack/year	1.9	1.8-2.1	1.8	1.7-2.0	1.8	1.7-1.9
			>10-56 pack/year	2.2	2.0-2.2	2.0	1.8-2.2	2.1	2.0-2.2
Frost, 2002[33]	*Intensity:* Micro-pauses in shoulder flexion (proportion of task cycle time with less than 2 sec between shoulder flexion) (N=2757)	Age, sex, BMI, low pressure pain threshold, leisure activity shoulder trauma, arthritis	Reference	–	–	–	–	1.0	–
			≤80% of cycle time	–	–	–	–	2.8	1.1–7.3
			>80% of cycle time	–	–	–	–	3.3	1.4–8.1
Herin, 2012[37]	*Intensity:* Posture (N=12.714)	Age, sex, sport, BMI, social class	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	1.37	1.19-1.58
Miranda, 2005[5]	*Duration:* Working with a hand above shoulder level, ≥1h/day (years) (N=8028)	BMI, smoking, sport, education, family status, region, language, comorbidity, exposure in analysis	None	1.0	–	1.0	–	1.0	–
			1–3	3.1	1.1–8.4	1.0	0.2–4.6	2.4	1.0–5.9
			4–13	3.0	1.2–7.7	2.2	0.6–7.4	3.2	1.6–6.5
			14–23	4.8	1.9–12.1	4.4	1.5–12.4	4.7	2.4–9.1
			>23	2.3	0.7–7.0	2.5	0.8–7.9	2.3	1.1–4.9
Miranda, 2008[44]	*Intensity:* Working in awkward postures (N=852) (not included in meta-analysis)	Age, sex (if not stratified), three confounders	No	1.0	–	1.0	–	1.0	–
			Yes	1.1	0.5-2.5	2.0	0.9-4.3	1.8	1.1-3.1

Appendix 6 (continued). Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Arm posture									
Northover, 2007[49]	*Intensity:* Overhead work (N=77)	Age	No Yes	– –	– –	– –	– –	1.0 3.83	- 2.15-6.84
Roquelaure, 2011[52]	*Intensity:* Sustained and repeated arm posture in abduction ≥2h/day (N=3582) (not included in meta-analysis)	Age, exposure in the analysis	No >60° >90° Both	1.0 0.9 2.3 2.0	– 0.5-1.8 1.3-3.9 1.1-3.7	1.0 1.8 1.6 3.6	– 1.0-3.2 0.8-3.1 1.8-7.3	– – – –	– – – –
Rosenbaum, 2014[54]	*Intensity:* Awkward posture (N=286)	Age, sex, years in poultry, language, processing, work education, employer, task, organization	No Yes	– –	– –	– –	– –	1.00 1.04	- 0.52-2.08
Seidler, 2011[57]	*Cumulative:* Work above shoulder level (N=783)	Age, region, lifting/carrying loads, HAV, sport	No work >0–<610 h 610–<3195 h 3195–64,057 h	1.0 1.0 1.4 2.0	– 0.6-1.8 0.8-2.4 1.1-3.5	– – – –	– – – –	– – – –	– – – –
Silverstein, 2008[60]	*Intensity:* Upper arm flexion ≥45° (% time) (N=733)	Age, sex, BMI	<18% ≥18%	– –	– –	– –	– –	1.00 2.16	– 1.22-3.83
Silverstein, 2009[61]	*Intensity:* Upper arm flexion ≥45° (% time) (N=733) (not included in meta-analysis)	Age, BMI	<18% ≥18%	1.00 1.63	– 0.76-3.51	1.00 3.12	– 1.27-7.68	– –	– –
Svendsen, 2004[66]	*Intensity:* Current upper arm elevation >90° (% of daily working hours) (N=1627; 3067 shoulders)	Unadjusted	0–3% 3–6% 6–9%	1.00 0.94 4.70	– 0.37-2.39 2.07-10.68	– – –	– – –	– – –	– – –
	Duration: Lifetime upper arm elevation >90° (N=1886)	Age, smoking	0–6 months 6–12 months 12–24 months ≥24 months	1.00 0.73 1.30 1.87	– 0.27-1.49 0.57-2.99 0.79-4.44	– – – –	– – – –	– – – –	– – – –
Svendsen, 2004[67]	*Duration:* Lifetime upper arm elevation >90° (not included in meta-analysis)	Age	0-<10 ≥10-<20 ≥20	1.00 0.95 2.33	– 0.41-2.20 0.93-5.84	– – –	– – –	– – –	– – –
Svendsen, 2013[68]	*Intensity:* Arm elevation >90° (N=29,962)	Age, sex, smoking, BMI, demand, control, and support	0 hours/day >0-<1 hours/day ≥1 hours/day	– – –	– – –	– – –	– – –	1.00 1.53 (1.19)† 1.61 (1.20)†	- 1.14-2.05 1.06-2.45

Appendix 6 (continued). Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Repetitive shoulder movements									
Bodin, 2012[27]	*Intensity:* Repetitiveness of tasks (N=1067)	Age, exposure categories in analysis	Never	–	–	1.0	-	–	–
			<2 hr/day	–	–	1.1	0.6-2.2	–	–
			≥2-4 hr/day	–	–	1.6	0.8-3.0	–	–
			≥4 hr/day	–	–	2.3	1.4-3.8	–	–
Dalbøge, 2014[31]	*Cumulative exposure:* Repetitive shoulder movements (cumulative exposure expressed as pack-years) (N=2,374,403)	Age, sex, replace of residence, calendar year at start of follow up	0 pack-years	1.0	-	1.0	-	1.0	-
			>0-1 pack-years	1.2	1.1-1.3	1.2	1.1-1.3	1.2	1.1-1.3
			>1-2 pack-years	1.6	1.5-1.8	1.5	1.3-1.6	1.5	1.5-1.6
			>2-10 pack-years	1.7	1.6-1.8	1.5	1.4-1.6	1.6	1.5-1.6
			>10-68 pack-years	2.0	1.9-2.1	1.9	1.8-2.1	1.9	1.8-2.0
Frost, 2002[33]	*Intensity:* Repetitive hand-arm movements (N=2757)	Age, sex, BMI, low pressure pain threshold, leisure activity shoulder trauma, arthritis	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	3.12	1.33-7.34
Herin, 2012[37]	*Intensity:* Repetitive work (N=12,714)	Age, sex, sport, BMI, social class	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	1.06	0.90-1.28
Miranda, 2005[5]	*Duration:* Work requiring repetitive motion hand/wrist ≥ 2/d (N=8028)	BMI, smoking, sport, education, family status, region, language, comorbidity, exposure in analysis	0 years	1.0	–	1.0	–	1.0	–
			1–3 years	2.2	0.5-10.5	0.8	0.1-6.2	1.6	0.5-5.2
			4–13 years	0.6	0.1-3.3	0.8	0.2-2.9	0.8	0.3-2.1
			14–23 years	2.5	1.0-6.6	2.0	0.8-5.0	2.4	1.3-4.3
			>23 years	3.4	1.3-9.1	1.8	0.8-4.2	2.6	1.4-4.9
Miranda, 2008[44]	*Intensity:* Work involving repetitive movements (N=852) (not included meta-analysis)	Age, (sex) and three confounders	No	1.0	-	1.0	-	1.0	-
			Yes	4.0	1.8-8.6	1.2	0.5-2.8	2.3	1.3-4.1
	Intensity: Work paced by machine (N=852) (not included meta-analysis)		No	1.0	-	1.0	-	1.0	-
			Yes	0.7	0.2-3.4	1.7	0.5-6.0	1.1	0.4-2.8
Nordander, 2016[48]	*Intensity:* Upper arm velocity, p50(N=)	Age, sex, employment time, exposure in analysis	BT					1.05	1.02-1.08
			ST					1.02	0.98-1.06
			IF					1.04	1.01-1.06
Roquelaure, 2011[52]	*Intensity:* High repetitiveness of task (N=3582) (not included meta-analysis)	Age, exposure in the analysis	<4 h/day	1.0	–	1.0	–	–	–
			≥4 h/day	1.6	1.0–2.4*	1.7	1.1–2.5	–	–
Silverstein, 2008[60]	*Intensity:* Frequency of shoulder movement (times/min) (N=733)	Age, sex, BMI	<10	–	–	–	–	1.00	-
			≥10-<20	–	–	–	–	1.76	0.83-3.71
			≥20	–	–	–	–	1.01	0.43-2.38

Appendix 6 (continued). Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Repetitive shoulder movements									
Svendsen, 2013[68]	*Intensity:* Repetitive work, moderate repetitive work (≥4-<15 movements per min), highly repetitive work (≥15 movement per min) (N=29,962)	Age, sex, smoking, BMI, demand, control, and support	Moderate repetitive work < 2 h/day			–	–	1.00	-
			Moderate repetitive work ≥2-4 h/day			–	–	1.20 (1.07)†	0.78-1.83
			Moderate repetitive work ≥ 4 h/day			–	–	1.34 (0.94)†	0.88-2.05
			Highly repetitive work ≥ 0.5 h			–	–	1.76 (1.40)†	1.05-2.96

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Hand-arm vibration									
Dalbøge, 2014[31]	Cumulative exposure: HAVs (N=2,374,403)	Age, sex, place of residence, year at follow up start	0 pack-years	1.0	-	1.0	-	1.0	-
			>0-5 pack-years	1.3	1.2-1.4	1.3	1.2-1.4	1.3	1.2-1.3
			>5-58 pack-years	1.6	1.5-1.7	1.4	1.2-1.6	1.5	1.5-1.6
Herin, 2012[37]	Intensity: Vibration (N=12,714)	Age, sex, sport, BMI, social class	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	1.05	0.87-1.27
Miranda, 2005[5]	*Duration:* Working with a vibrating tool ≥2 h/day (N=8028)	BMI, smoking, sport, education, family status, region, language, comorbidity, exposure in analysis	0 years	1.0	–	–	–	1.0	–
			1–3 years	0.8	0.1–6.1	–	–	0.6	0.1–4.6
			4–13 years	2.7	1.0–7.2	–	–	2.5	1.0–5.9
			14–23 years	4.2	1.0–9.8	–	–	3.5	1.5–7.8
			>23 years	1.8	0.6–5.1	–	–	1.4	0.5–4.4
Miranda, 2008[44]	*Intensity:* Work involving vibration (N=852) (not included meta-analysis)	Age, (sex) and up to 3 confounders	No	1.0	-	1.0	-	1.0	-
			Yes	2.3	1.0-5.3	3.0	0.6-16.6	2.5	1.2-5.2
Northover, 2007[49]	*Intensity:* Use of vibrating tools (N=44)	Age	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	1.95	0.97-3.93
Seidler, 2011[57]	*Cumulative:* Hand-arm vibration (N=783)	Age, region, sport loads, work above shoulder level	0 years	1.0	-	–	–	–	–
			>0–4.4 years	2.7	1.3-5.6	–	–	–	–
			4.4–<16 years	3.1	1.5-6.1	–	–	–	–
			16–51.6 years	3.2	1.7-5.9	–	–	–	–
Stenlund, 1993[63]	*Intensity:* Exposure to vibration (N=207)	Age, dexterity, smoking, and sports activity	Right side	1.86	1.00-3.44	–	–	–	–
			Left side	2.64	1.06-5.87	–	–	–	–
Sutinen, 2006[65]	*Cumulative:* Lifelong vibration energy ((m^2/s^4) hd) (N=52)	Age	Vibration	1.04*	1.00-1.07	–	–	–	–

Appendix 6 (continued). Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Combined exposures									
Bodin, 2012[28]	*Intensity:* High perceived physical exertion and sustained or repeated arm posture in abduction (≥2 h/day) (N=825)	Age, exposure categories in analysis	No factor	1.0	-	–	–	–	–
			One factor	2.0	1.0-3.8	–	–	–	–
			Both factors	3.3	1.3-8.4	–	–	–	–
Dalbøge, 2014[31]	*Cumulative exposure:* Combination of arm posture, repetitive shoulder movements and forceful shoulder exertion, pack-years (N=2.374.403)	Age, sex, replace of residence, calendar year at start of follow up	0 pack-years	–	–	–	–	1.0	-
			>0-5 pack-years	–	–	–	–	1.4	1.3-1.5
			>5-10 pack-years	–	–	–	–	1.7	1.6-1.7
			>10-15 pack-years	–	–	–	–	1.8	1.7-2.0
			>15-20 pack-years	–	–	–	–	2.0	1.9-2.1
Frost, 2002[33]	*Intensity:* Repetitive shoulder movements (frequency) and force (N=2757)	Age, sex, BMI, low pressure pain threshold, leisure activity shoulder trauma, arthritis	Reference			–	–	1.0	–
			Low frequency + low force			–	–	2.5	0.9–6.6
			High frequency + low force			–	–	1.7	0.6–5.3
			Low frequency + high force			–	–	2.9	0.8–10.8
			High frequency + high force			–	–	4.8	1.9–12.5
	Intensity: Repetitive shoulder movements (frequency) and lack of micro-pauses (N=2757)	Age, sex, BMI, low pressure pain threshold, leisure activity shoulder trauma, arthritis	Reference				–	1.0	–
			Low frequency, no pauses ≤80% of cycle time				–	3.1	1.2–7.9
			Low frequency, no pauses >80% of cycle time				–	2.3	0.7–8.0
			High frequency, no pauses >80% of cycle time				–	3.5	3.5–8.7
	Intensity: Force and lack of micro-pauses (% cycle time) (N=2757)	Age, sex, BMI, low pressure pain threshold, leisure activity shoulder trauma, arthritis	Reference				–	1.0	–
			Low force, no pauses ≤80% of cycle time				–	2.3	0.8–6.4
			Low force, no pauses >80% of cycle time				–	2.1	0.7–6.0
			High force, no pauses ≤80% of cycle time				–	3.5	0.9–13.2
			High force, no pauses >80% of cycle time				–	4.5	1.7–11.6
Grzywacz, 2012[34]	*Intensity:* Awkward posture and repeated movements (N=518)	Age, sex, language, exposure in analysis	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	1.31	1.07-1.69
Miranda, 2008[44]	*Intensity:* Combination of physical exposures (N=852)	Age, (sex), three confounders	None	1.0	-	1.0	-	1.0	-
			1-2 exposures	2.1	0.8-5.0	5.5	2.0-15.0	3.6	1.9-6.8
			3-5 exposures	2.9	1.1-7.9	5.3	1.4-19.8	3.9	1.8-8.5
Silverstein, 2008[60]	*Intensity:* Upper-arm flexion ≥45° and duty cycle of forceful exertions (%time) (N=733)	Age, sex, BMI	Flexion <15% and forceful exertions<9%				–	1.0	–
			Flexion ≥15% or forceful exertions ≥9%				–	2.0	0.9–4.6
			Flexion ≥15% and forceful exertions ≥9%				–	2.4	1.0–5.7
	Intensity: Upper arm flexion ≥45° and pinch grip force (%time) (N=733)	Age, sex, BMI	Flexion <15% and no pinch				–	1.0	–
			Flexion ≥15% or pinch >0%				–	1.0	0.5–2.1
			Flexion ≥15% and pinch >0%				–	2.7	1.3–5.6

Appendix 6 (continued). Association between occupational mechanical exposures and SIS

Reference	Occupational mechanical exposure	Confounders	Results						
				Men		Women		Total	
			Categories	**OR_{adj}**	**95% CI**	**OR_{adj}**	**95% CI**	**OR_{adj}**	**95% CI**
Combined exposures									
Silverstein, 2009[61]	*Intensity:* Upper arm flexion ≥45° and pinch grip force (%time) (N=733) (not included in meta-analysis)	Age, BMI	Flexion <15% and no pinch	1.00	-	1.00	-	–	–
			Flexion ≥15% or pinch >0%	0.71	0.29-1.75	2.48	0.66-9.41	–	–
			Flexion ≥15% and pinch >0%	1.44	0.53-3.94	7.06	1.94-25.66	–	–
	Intensity: Upper arm flexion or abduction ≥45° and pinch grip force (N=733) (not included in meta-analysis)	Age, BMI	Flexion or abduction <20% and no pinch grip	1.00	-	1.00	-	–	–
			Flexion or abduction >20% or pinch grip	0.62	0.26-1.48	1.25	0.43-3.63	–	–
			Flexion/abduction >20% and pinch grip	1.22	0.45-3.31	3.72	1.28-10.81	–	–
	Intensity: Vibration and pinch grip force (N=733) (not included in meta-analysis)	Age, BMI	No vibration/no pinch grip	1.00	-	1.00	-	–	–
			Vibration or pinch grip>0%	1.33	0.61-2.90	2.83	1.16-6.88	–	–
			Vibration and pinch grip>0%	1.98	0.22-8.13	4.80	0.90-25.77	–	–
Svendsen, 2013[68]	*Intensity:* Shoulder load (N=29,962)	Age, sex, smoking, BMI, demand, control, and support	Low	–	–	–	–	1.00	-
			Medium	–	–	–	–	1.64 (1.63)†	1.19-2.26
			High	–	–	–	–	1.96 (1.67)†	1.33-2.89

* Statistically significant, † Results used for metaanalysis, BMI; Body Bass Index, BT: Biceps tendinitis, HAVs; Hand-arm vibration, IT; Infraspinatus tendinitis, ST; Supraspinatus tendinitis

Appendix 7. Association between psychosocial factors and subacromial impingement syndrome

Reference	Exposure dimension	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Job demand									
Arcury, 2014[25]	Psychological demand (N=202) (not included in meta-analysis)	Age, years lived in USA, language, and exposure in analysis	Low High	– –	– –	1.00 0.91	– 0.55–1.52	– –	– –
Bodin, 2012[27]	High psychological demand (N=1555)	Age, exposure categories in analysis	No Yes	1.0 1.8	- 1.3-2.7	– –	– –	– –	– –
Bugajska, 2013[29]	Mental job demand (N=725)	Age, sex, working hours, repetitive work, force	No Yes	– –	– –	– –	– –	1.00 1.05	- 0.99-1.11
Grzywacz, 2012[34]	Psychological demand (N=518)	Age, sex, language, exposure in analysis	Seldom, never Almost always	– –	– –	– –	– –	1.00 1.30	– 1.06-1.59
Herin, 2012[37]	High psychological demand (N=12,714)	Age, sex, sport, BMI, social class	No Yes	– –	– –	– –	– –	1.00 1.23	– 1.08-1.39
Miranda, 2005	Job demand (N=8028)	BMI, smoking, sport, education, family status, region, language, comorbidity, exposure in analysis	Low High	1.0 1.6	– 0.8-3.6	1.0 1.8	– 0.8-3.8	1.0 1.7	– 1.0-3.0
Nordander, 2016[48]	Job demand (N=3141)	Age, sex, employment time, exposure in analysis	BT ST IT	–	–	–	–	1.05 1.04 1.07	0.97-1.12 0.95-1.14 1.00-1.15
Roquelaure, 2011[52]	High psychological demand (N=2078) (not included in meta-analysis)	Age, exposure in the analysis	No Yes	1.0 1.7	– 1.2-2.5	– –	– –	– –	– –
Rosenbaum, 2014[54]	Psychological demand (N=286) (not included in meta-analysis)	Age, sex, years in poultry, language, processing, work education, employer, task, organization	Low High	– –	– –	– –	– –	1.00 1.25	– 0.73-2.15
Svendsen, 2004[66]	Job demand (N=1627; 3067 shoulders)	Unadjusted	Low High	1.00 3.19	- 1.62-6.31	– –	– –	– –	– –
Svendsen, 2013[68]	Job demand (N=35,574)	Age, sex, job control, social support at work	Low High	– –	– –	– –	– –	1.00 1.13	- 0.94-1.36

Appendix 7 (continued). Association between psychosocial factors and subacromial impingement syndrome

Reference	Exposure dimension	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Job control									
Arcury, 2014[25]	Skill variety (N=202) (not included in meta-analysis)	Age, years lived in USA, language, and exposure in analysis	Yes	–	–	1.00	–	–	–
			No	–	–	1.54	0.78-3.06	–	–
	Decision latitude (N=202) (not included in meta-analysis)		Yes	–	–	1.00	–	–	–
			No	–	–	0.84	0.46-1.53	–	–
Bodin, 2012[27]	Low skill discretion (N=1555)	Age, exposure categories in analysis	No	1.0	-	–	–	–	–
			Yes	1.7	1.1-2.5	–	–	–	–
Bugajska, 2013[29]	Decision latitude (N=725)	Age, sex, working hours, repetitive work, force	Yes	–	–	–	–	1.00	–
			No	–	–	–	–	0.99	0.95-1.02
Grzywacz, 2012[34]	Job control (N=518)	Age, sex, language, exposure in analysis	Almost always	–	–	–	–	1.00	-
			Seldom, never	–	–	–	–	0.79	0.64-0.97
Herin, 2012[37]	Low decision latitude (N=12,714)	Age, sex, sport, BMI, social class	No	–	–	–	–	1.00	-
			Yes	–	–	–	–	1.21	1.04-1.41
Nordander, 2016[48]	Job control (ST) (N=3141)	Age, sex, employment time, exposure in analysis	BT	–	–	–	–	1.07	1.03-1.15
			ST					1.08	1.03-1.14
			IT					1.06	1.02-1.14
Roquelaure, 2011[52]	Low skill discretion (N=2078) (not included in meta-analysis)	Age, exposure in the analysis	No	1.0	–	–	–	–	–
			Yes	1.4	1.0-2.1	–	–	–	–
Rosenbaum, 2014[54]	Job control (N=286) (not included in meta-analysis)	Age, sex, years in poultry, language, processing, work education, employer, task, organization	High	–	–	–	–	1.00	-
			Low	–	–	–	–	2.00	0.63-1.90
Silverstein, 2008	Decision latitude (N=733)	Age, sex, BMI	High	–	–	–	–	1.00	-
			Low	–	–	–	–	1.70	0.95-3.04
Svendsen, 2004[66]	Job control (N=1627; 3067 shoulders)	Unadjusted	High	1.00	–	–	–	–	–
			Low	1.83	0.93-3.60	–	–	–	–
Svendsen, 2013[68]	Job control (N=35,574)	Age, sex, job demand, social support at work	High	–	–	–	–	1.00	-
			Low	–	–	–	–	1.22	1.00-1.50

Appendix 7 (continued). Association between psychosocial factors and subacromial impingement syndrome

Reference	Exposure dimension	Confounders	Results						
				Men		Women		Total	
			Categories	OR_{adj}	95% CI	OR_{adj}	95% CI	OR_{adj}	95% CI
Job support									
Arcury, 2014[25]	Perceived supervisor control (N=202)	Age, years lived in USA, language, and exposure in analysis	No Yes	– –	– –	1.00 0.62	– 0.24-1.60	– –	– –
Bodin, 2012[27]	Low supervisor support (N=260) (not included in meta-analysis)	Age, exposure categories in analysis	No Yes	1.0 1.3	– 0.9-1.9	1.0 1.6	– 1.1-2.4	– –	– –
Bodin, 2012[28]	Low co-worker support (N=825)	Age, exposure categories in analysis	No Yes	1.0 2.0	– 1.1-3.9	– –	– –	– –	– –
Bugajska, 2013[29]	Social support (N=725)	Age, sex, working hours, repetitive work, force	Yes No	– –	– –	– –	– –	1.00 1.00	– 0.91-1.10
Svendsen, 2004[66]	Social support (N=1627; 3067 shoulders)	Unadjusted	High Low	1.00 0.91	- 0.46-1.77	– –	– –	– –	– –
Svendsen, 2013[68]	Social support at work (N=35,574)	Age, sex, job demand, and job control	Support from leaders and colleagues Support from leaders Support from colleagues No social support			– – – –	– – – –	1.00 0.70 1.02 0.91	- 0.49-0.99 0.80-1.29 0.71-1.17

* Statistically significant, BMI; Body Bass Index, BT: Biceps tendinitis, IT; Infraspinatus tendinitis, ST; Supraspinatus tendinitis

Appendix 8. Funnel plots

Figure 10. Funnel plot of the association between forceful shoulder exertion and subacromial impingement syndrome (N=14)

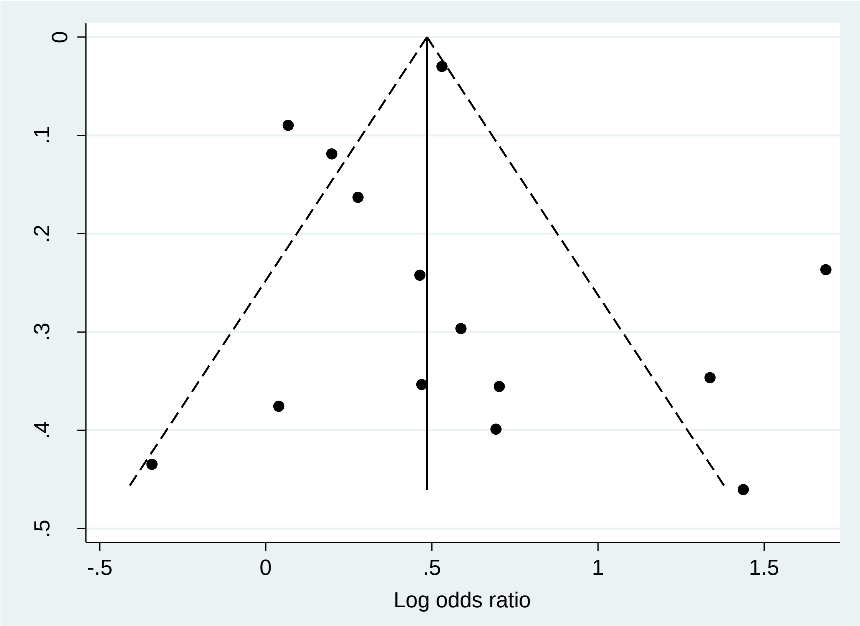
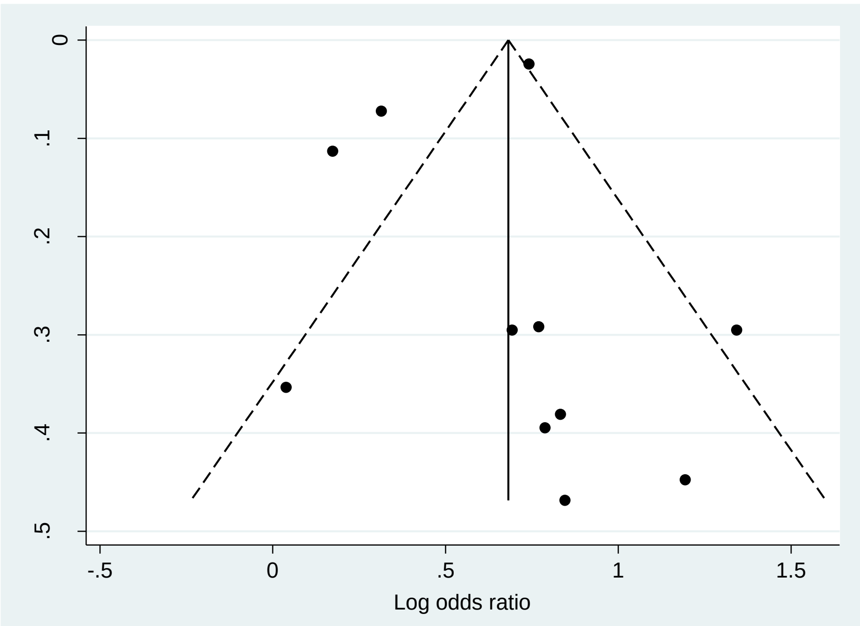


Figure 11. Funnel plot of the association between arm posture and subacromial impingement syndrome (N=11)



Appendix 8 (continued). Funnel plots

Figure 12. Funnel plot of the association between repetitive shoulder movements and subacromial impingement syndrome (N=7)

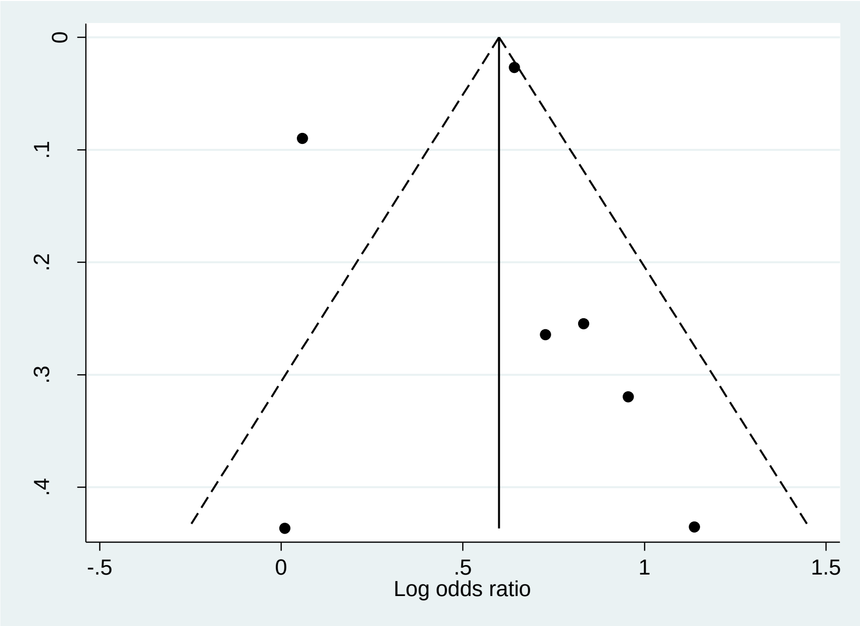
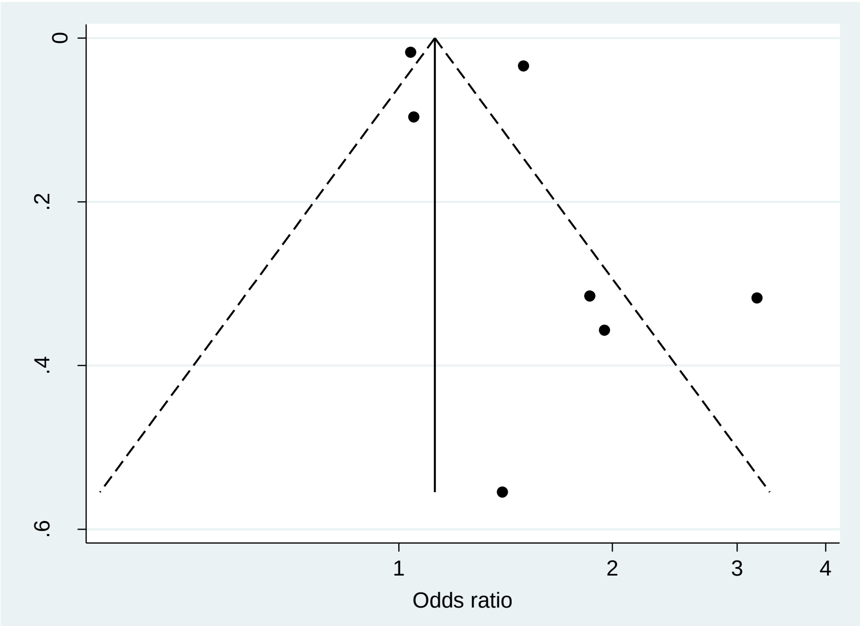


Figure 13. Funnel plot of the association between hand-arm vibration and subacromial impingement syndrome (N=7)



Appendix 8 (continued). Funnel plots

Figure 14. Funnel plot of the association between combined mechanical exposures and subacromial impingement syndrome (N=7)

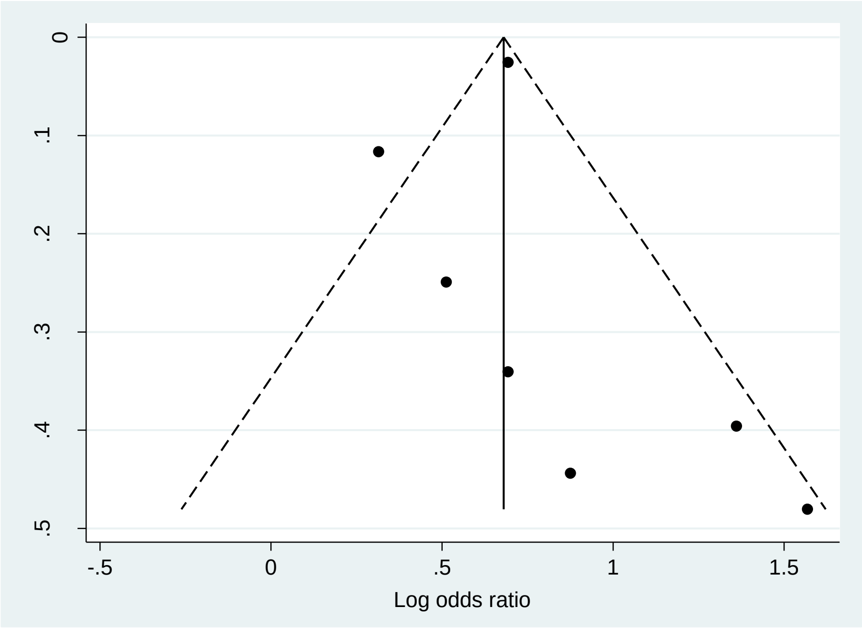
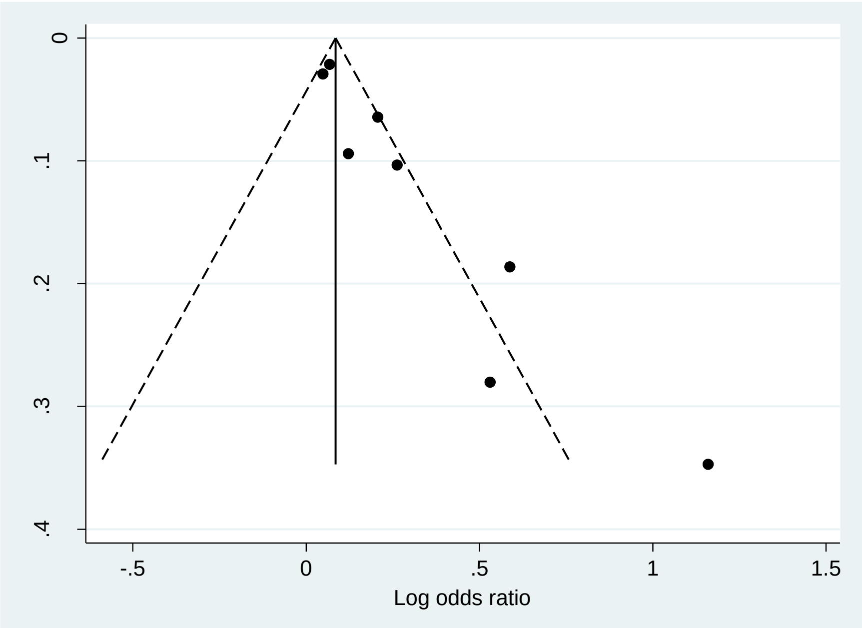


Figure 15. Funnel plot of the association between job demand and subacromial impingement syndrome (N=8)



Appendix 8 (continued). Funnel plots

Figure 16. Funnel plot of the association between job control and subacromial impingement syndrome (N=8)

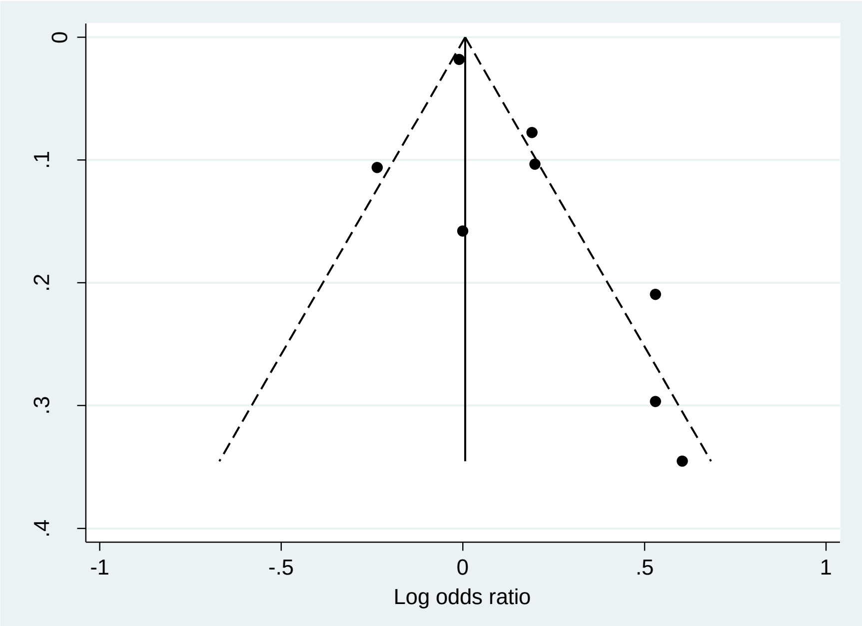
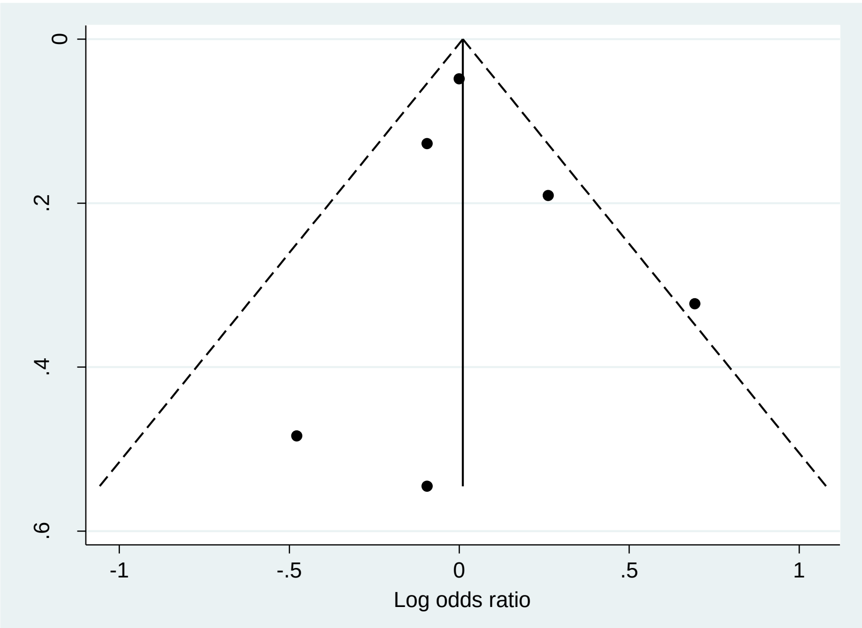


Figure 17. Funnel plot of the association between support and subacromial impingement syndrome (N=6)



Appendix 9: Degree of evidence of a causal association between an exposure to a specific risk factor and a specific outcome

The following categories are used.

+++ strong evidence of a causal association

++ moderate evidence of a causal association

+ limited evidence of a causal association

0 insufficient evidence of a causal association - evidence suggesting lack of a causal association

Strong evidence of a causal association (+++): A causal relationship is very likely. A positive relationship between exposure to the risk factor and the outcome has been observed in several epidemiological studies. It can be ruled out with reasonable confidence that this relationship is explained by chance, bias or confounding.

Moderate evidence of a causal association (++): A causal relationship is likely. A positive relationship between exposure to the risk factor and the outcome has been observed in several epidemiological studies. It cannot be ruled out with reasonable confidence that this relationship can be explained by chance, bias or confounding, although this is not a very likely explanation.

Limited evidence of a causal association (+): A causal relationship is possible. A positive relationship between exposure to the risk factor and the outcome has been observed in several epidemiological studies. It is not unlikely that this relationship can be explained by chance, bias or confounding.

Insufficient evidence of a causal association (0): The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of a causal association. Evidence suggesting lack of a causal association (-): Several studies of sufficient quality, consistency and statistical power indicate that the specific risk factor is not causally related to the specific outcome.

Comments: The classification does not include a category for which a causal relation is considered as established beyond any doubt. The key criterion is the epidemiological evidence. The likelihood that chance, bias and confounding may explain observed associations are criteria that encompass criteria such as consistency, number of 'high quality' studies, types of design etc. Biological plausibility and contributory information may add to the evidence of a causal association.

8. REFERENCE LIST

1. van der Windt DA, Koes BW, Boeke AJ, Deville W, de Jong BA, Bouter LM. Shoulder disorders in general practice: Prognostic indicators of outcome. *Br J Gen Pract*. 1996;46(0960-1643; 0960-1643; 410):519-523.

2. Ostor AJ, Richards CA, Prevost AT, Speed CA, Hazleman BL. Diagnosis and relation to general health of shoulder disorders presenting to primary care. *Rheumatology (Oxford)*. 2005;44(6):800-805.

3. Vecchio P, Kavanagh R, Hazleman BL, King RH. Shoulder pain in a community-based rheumatology clinic. *Br J Rheumatol*. 1995;34(5):440-442.

4. Roquelaure Y, Ha C, Leclerc A, et al. Epidemiologic surveillance of upper-extremity musculoskeletal disorders in the working population. *Arthritis Rheum*. 2006;55(5):765-778.

5. Miranda H, Viikari-Juntura E, Heistaro S, Heliovaara M, Riihimaki H. A population study on differences in the determinants of a specific shoulder disorder versus nonspecific shoulder pain without clinical findings. *Am J Epidemiol*. 2005;161(0002-9262; 0002-9262; 9):847-855.

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

7. Neer CS. Impingement lesions. *Clin Orthop Relat Res*. 1983(173):70-77.

8. Schellingerhout JM, Verhagen AP, Thomas S, Koes BW. Lack of uniformity in diagnostic labeling of shoulder pain: Time for a different approach. *Man Ther*. 2008;13(6):478-483.

9. Huisstede BM, Miedema HS, Verhagen AP, Koes BW, Verhaar JA. Multidisciplinary consensus on the terminology and classification of complaints of the arm, neck and/or shoulder. *Occup Environ Med*. 2007;64(1470-7926; 1351-0711; 5):313-319.

10. Bigliani LU, Levine WN. Subacromial impingement syndrome. *J Bone Joint Surg Am*. 1997;79(12):1854-1868.

11. Koester MC, George MS, Kuhn JE. Shoulder impingement syndrome. *Am J Med*. 2005;118(0002-9343; 0002-9343; 5):452-455.

12. van der Heijden GJ. Shoulder disorders: A state-of-the-art review. *Baillieres Best Pract Res Clin Rheumatol*. 1999;13(2):287-309.

13. Tyler TF, Nicholas SJ, Lee SJ, Mullaney M, McHugh MP. Correction of posterior shoulder tightness is associated with symptom resolution in patients with internal impingement. *Am J Sports Med*. 2010;38(1):114-119.

14. Ludewig PM, Borstad JD. Effects of a home exercise programme on shoulder pain and functional status in construction workers. *Occup Environ Med*. 2003;60(11):841-849.

15. McClure PW, Bialker J, Neff N, Williams G, Karduna A. Shoulder function and 3-dimensional kinematics in people with shoulder impingement syndrome before and after a 6-week exercise program. *Phys Ther*. 2004;84(9):832-848.

16. Sundhedsstyrelsen [The Danish Health and Medicines Authority]. National klinisk retningslinje for diagnostik og behandling af patienter med udvalgte skulderlidelser (national clinical guidelines for diagnosis and treatment of patients with selected shoulder disorders). *Sundhedsstyrelsen*. 2013.

17. Vitale MA, Arons RR, Hurwitz S, Ahmad CS, Levine WN. The rising incidence of acromioplasty. *J Bone Joint Surg Am*. 2010;92(9):1842-1850.

18. Judge A, Murphy RJ, Maxwell R, Arden NK, Carr AJ. Temporal trends and geographical variation in the use of subacromial decompression and rotator cuff repair of the shoulder in england. *Bone Joint J*. 2014;96-B(1):70-74.

19. Nordqvist A, Rahme H, Hovelius L, Etzner M. Axelns sjukdomar [shoulder diseases]. *Lakartidningen*. 2007;104(19):1492-1496.

20. Svendsen SW, Frost P, Jensen LD. Time trends in surgery for non-traumatic shoulder disorders and postoperative risk of permanent work disability: A nationwide cohort study. *Scand J Rheumatol*. 2012;41(1):59-65.

21. GT J, N P, El-Metwally A, GJ M, DV R, FD D. Association between work-related exposures and the occurrence of rotator cuff diseases and/or biceps tendinitis - A reference document. *The Scientific Committee of the Danish Society of Occupational and Environmental Medicine*. 2007.

22. van der Molen HF, Foresti C, Daams JG, Frings-Dresen MHW, Kuijer PPFM. Work-related risk factors for specific shoulder disorders: A systematic review and meta-analysis. *Occup Environ Med*. 2017.

23. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *Open Med*. 2009;3(3):e123-e130.

24. Andersen JH, Gaardboe O. Musculoskeletal disorders of the neck and upper limb among sewing machine operators: A clinical investigation. *Am J Ind Med*. 1993;24(6):689-700.

25. Arcury TA, Cartwright MS, Chen H, et al. Musculoskeletal and neurological injuries associated with work organization among immigrant latino women manual workers in north carolina. *Am J Ind Med*. 2014;57(4):468-475.

26. Arvidsson I, Gremark Simonsen J, Dahlqvist C, et al. Cross-sectional associations between occupational factors and musculoskeletal pain in women teachers, nurses and sonographers. *BMC Musculoskelet Disord*. 2016;17:35-016-0883-4.

27. Bodin J, Ha C, Chastang JF, et al. Comparison of risk factors for shoulder pain and rotator cuff syndrome in the working population. *Am J Ind Med*. 2012;55(7):605-615.

28. Bodin J, Ha C, Petit Le MA, et al. Risk factors for incidence of rotator cuff syndrome in a large working population. *Scand J Work Environ Health*. 2012;38(5):436-446.

29. Bugajska J, Zolnierczyk-Zreda D, Jedryka-Goral A, et al. Psychological factors at work and musculoskeletal disorders: A one year prospective study. *Rheumatol Int*. 2013;33(12):2975-2983.

30. Chung YC, Hung CT, Li SF, et al. Risk of musculoskeletal disorder among taiwanese nurses cohort: A nationwide population-based study. *BMC Musculoskelet Disord*. 2013;14:144-149.

31. Dalbøge A, Frost P, Andersen JH, Svendsen SW. Cumulative occupational shoulder exposures and surgery for subacromial impingement syndrome: A nationwide danish cohort study. *Occup Environ Med*. 2014;71(11):750-756.

32. Frost P, Andersen JH, Lundorf E. Is supraspinatus pathology as defined by magnetic resonance imaging associated with clinical sign of shoulder impingement? *J Shoulder Elbow Surg*. 1999;8(6):565-568.

33. Frost P, Bonde JP, Mikkelsen S, et al. Risk of shoulder tendinitis in relation to shoulder loads in monotonous repetitive work. *Am J Ind Med*. 2002;41(0271-3586; 0271-3586; 1):11-18.

34. Grzywacz JG, Arcury TA, Mora D, et al. Work organization and musculoskeletal health: Clinical findings from immigrant latino poultry processing and other manual workers. *J Occup Environ Med*. 2012;54(8):995-1001.

35. Hansson G, Balogh I, Ohlsson K, Palsson B, Rylander L, Skerfving S. Impact of physical exposure on neck and upper limb disorders in female workers. *Appl Ergon*. 2000;31(0003-6870; 0003-6870; 3):301-310.

36. Herberts P, Kadefors R, Andersson G, Petersen I. Shoulder pain in industry: An epidemiological study on welders. *Acta Orthop Scand*. 1981;52(0001-6470; 0001-6470; 3):299-306.

37. Herin F, Vezina M, Thaon I, Soulat JM, Paris C, ESTEV group. Predictors of chronic shoulder pain after 5 years in a working population. *Pain*. 2012;153(11):2253-2259.

38. Hsiao MS, Cameron KL, Tucker CJ, Benigni M, Blaine TA, Owens BD. Shoulder impingement in the united states military. *J Shoulder Elbow Surg*. 2015;24(9):1486-1492.

39. Jacobsson L, Lindgarde F, Manthorpe R, Ohlsson K. Effect of education, occupation and some lifestyle factors on common rheumatic complaints in a swedish group aged 50-70 years. *Ann Rheum Dis*. 1992;51(7):835-843.

40. Kaergaard A, Andersen JH. Musculoskeletal disorders of the neck and shoulders in female sewing machine operators: Prevalence, incidence, and prognosis. *Occup Environ Med*. 2000;57(1351-0711; 1351-0711; 8):528-534.

41. Kaerlev L, Jensen A, Nielsen PS, Olsen J, Hannerz H, Tuchsen F. Hospital contacts for injuries and musculoskeletal diseases among seamen and fishermen: A population-based cohort study. *BMC Musculoskelet Disord*. 2008;9:8-2474-9-8.

42. Luopajarvi T, Kuorinka I, Virolainen M, Holmberg M. Prevalence of tenosynovitis and other injuries of the upper extremities in repetitive work. *Scand J Work Environ Health*. 1979;5 suppl 3:48-55.:48-55.

43. Melchior M, Roquelaure Y, Evanoff B, et al. Why are manual workers at high risk of upper limb disorders? the role of physical work factors in a random sample of workers in france (the pays de la loire study). *Occup Environ Med*. 2006;63(11):754-761.

44. Miranda H, Punnett L, Viikari-Juntura E, Heliovaara M, Knekt P. Physical work and chronic shoulder disorder. results of a prospective population-based study. *Ann Rheum Dis*. 2008;67(1468-2060; 2):218-223.

45. Mora DC, Miles CM, Chen H, Quandt SA, Summers P, Arcury TA. Prevalence of musculoskeletal disorders among immigrant latino farmworkers and non-farmworkers in north carolina. *Arch Environ Occup Health*. 2016;71(3):136-143.

46. Nordander C, Ohlsson K, Balogh I, Rylander L, Palsson B, Skerfving S. Fish processing work: The impact of two sex dependent exposure profiles on musculoskeletal health. *Occup Environ Med*. 1999;56(4):256-264.

47. Nordander C, Ohlsson K, Akesson I, et al. Risk of musculoskeletal disorders among females and males in repetitive/constrained work. *Ergonomics*. 2009;52(10):1226-1239.

48. Nordander C, Hansson GA, Ohlsson K, et al. Exposure-response relationships for work-related neck and shoulder musculoskeletal disorders - analyses of pooled uniform data sets. *Appl Ergon*. 2016;55:70-84.

49. Northover JR, Lunn P, Clark DI, Phillipson M. Risk factors for the development of rotator cuff disease. *Int J Shoulder Surg*. 2007;1:86-86.

50. Ohlsson K, Hansson GA, Balogh I, et al. Disorders of the neck and upper limbs in women in the fish processing industry. *Occup Environ Med*. 1994;51(12):826-832.

51. Park RM, Nelson NA, Silverstein MA, Mirer FE. Use of medical insurance claims for surveillance of occupational disease. an analysis of cumulative trauma in the auto industry. *J Occup Med*. 1992;34(7):731-737.

52. Roquelaure Y, Bodin J, Ha C, et al. Personal, biomechanical, and psychosocial risk factors for rotator cuff syndrome in a working population. *Scand J Work Environ Health*. 2011;37(6):502-511.

53. Rosenbaum DA, Grzywacz JG, Chen H, et al. Prevalence of epicondylitis, rotator cuff syndrome, and low back pain in latino poultry workers and manual laborers. *Am J Ind Med*. 2013;56(2):226-234.

54. Rosenbaum DA, Mora DC, Arcury TA, Chen H, Quandt SA. Employer differences in upper-body musculoskeletal disorders and pain among immigrant latino poultry processing workers. *J Agromedicine*. 2014;19(4):384-394.

55. Sansone V, Bonora C, Boria P, Meroni R. Women performing repetitive work: Is there a difference in the prevalence of shoulder pain and pathology in supermarket cashiers compared to the general female population? *Int J Occup Med Environ Health*. 2014;27(5):722-735.

56. Sansone VC, Meroni R, Boria P, Pisani S, Maiorano E. Are occupational repetitive movements of the upper arm associated with rotator cuff calcific tendinopathies? *Rheumatol Int*. 2015;35(2):273-280.

57. Seidler A, Bolm-Audorff U, Petereit-Haack G, et al. Work-related lesions of the supraspinatus tendon: A case-control study. *Int Arch Occup Environ Health*. 2011;84(4):425-433.

58. Silverstein B, Welp E, Nelson N, Kalat J. Claims incidence of work-related disorders of the upper extremities: Washington state, 1987 through 1995. *Am J Public Health*. 1998;88(0090-0036; 0090-0036; 12):1827-1833.

59. Silverstein BA, Viikari-Juntura E, Fan ZJ, Bonauto DK, Bao S, Smith C. Natural course of nontraumatic rotator cuff tendinitis and shoulder symptoms in a working population. *Scand J Work Environ Health*. 2006;32(2):99-108.

60. Silverstein BA, Bao SS, Fan ZJ, et al. Rotator cuff syndrome: Personal, work-related psychosocial and physical load factors. *J Occup Environ Med*. 2008;50(1536-5948; 1076-2752; 9):1062-1076.

61. Silverstein B, Fan ZJ, Smith CK, et al. Gender adjustment or stratification in discerning upper extremity musculoskeletal disorder risk? *Scand J Work Environ Health*. 2009;35(2):113-126.

62. Stenlund B. Shoulder tendinitis and osteoarthrosis of the acromioclavicular joint and their relation to sports. *Br J Sports Med*. 1993;27(2):125-130.

63. Stenlund B, Goldie I, Hagberg M, Hogstedt C. Shoulder tendinitis and its relation to heavy manual work and exposure to vibration. *Scand J Work Environ Health*. 1993;19(0355-3140; 0355-3140; 1):43-49.

64. Stucchi G, Battevi N, Cairoli S, Consonni D. The prevalence of musculoskeletal disorders in the retail sector: An italian cross sectional study on 3380 workers. *Med Lav*. 2016;107(4):251-262.

65. Sutinen P, Toppila E, Starck J, Brammer A, Zou J, Pyykko I. Hand-arm vibration syndrome with use of anti-vibration chain saws: 19-year follow-up study of forestry workers. *Int Arch Occup Environ Health*. 2006;79(0340-0131; 0340-0131; 8):665-671.

66. Svendsen SW, Bonde JP, Mathiassen SE, Stengaard-Pedersen K, Frich LH. Work related shoulder disorders: Quantitative exposure-response relations with reference to arm posture. *Occup Environ Med*. 2004;61(1470-7926; 1351-0711; 10):844-853.

67. Svendsen SW, Gelineck J, Mathiassen SE, et al. Work above shoulder level and degenerative alterations of the rotator cuff tendons: A magnetic resonance imaging study. *Arthritis Rheum*. 2004;50(0004-3591; 0004-3591; 10):3314-3322.

68. Svendsen SW, Dalbøge A, Andersen JH, Thomsen JF, Frost P. Risk of surgery for subacromial impingement syndrome in relation to neck-shoulder complaints and occupational biomechanical exposures: a longitudinal study. *Scand J Work Environ Health*. 2013;39(6):568-577.

69. Thygesen LC, Mikkelsen S, Pedersen EB, et al. Subacromial shoulder disorders among baggage handlers: An observational cohort study. *Int Arch Occup Environ Health*. 2016;89(5):867-876.

70. Wang LY, Pong YP, Wang HC, Su SH, Tsai CH, Leong CP. Cumulative trauma disorders in betel pepper leaf-cullers visiting a rehabilitation clinic: Experience in taitung. *Chang Gung Med J*. 2005;28(4):237-246.

71. Yamamoto N, Muraki T, Sperling JW, et al. Contact between the coracoacromial arch and the rotator cuff tendons in nonpathologic situations: A cadaveric study. *J Shoulder Elbow Surg*. 2010;19(5):681-687.

72. Zakaria D. Rates of carpal tunnel syndrome, epicondylitis, and rotator cuff claims in ontario workers during 1997. *Chronic Dis Can*. 2004;25(2):32-39.

73. Palmer KT, Harris EC, Linaker C, Cooper C, Coggon D. Optimising case definitions of upper limb disorder for aetiological research and prevention: A review. *Occup Environ Med*. 2012;69(1):71-78.

Comment on association between occupational mechanical exposures and subacromial impingement syndrome: A reference document, by Alexis Descatha (December 4, 2017)

I thank the authors for allowing me to read and comment on this excellent work to perform a systematic review that summarize the existing epidemiological evidence of the causal relationship between occupational mechanical shoulder exposures and subacromial impingement syndrome (SIS) in the working population. Of the 4035 potential relevant articles, the authors included 50 relevant articles (32 cross-sectional, 15 cohort and three case-control studies). Exposure information was based on occupations/job titles in 25 studies, occupational exposures in 22 studies, and three studies were based on both job titles and occupational exposures. High risk occupations or risk job titles were found such as exposure with a moderate evidence on causal association for most of mechanical exposure and strong evidence for combined mechanical exposure, where the occupational psychosocial exposures, the evidence suggested lack of a causal association.

Several comments have been made on this very well-documented review that has summarized the state of current knowledge in the epidemiological field on shoulder diseases.

1. Given the risks of reverse causality in cross-sectional studies, I think that the meta-analyses might have been done separately, or at least checked that results are robust if only cohorts studies (+/- case-control studies).

2. On the definition of disorder, some of them have not been found ,though it was in the list of potential disorders. For example, no study deal with calcification, because calcification (A or B in clinical classification) are not associated with occupational exposure. I suggest to focus only (or discuss) on potential occupational disorders. Some studies, moreover, do not fulfill the criteria, as for example, a French study by Herin whose diagnosis does not necessarily correspond to a specific pathology (the authors reported shoulder pain, and mobilization of the shoulder was not specific enough for SIS.

3. In terms of the inclusion of studies, it was mentioned Pubmed, and base whose research presented corresponds to a search on Medline and the flow diagram does not report the base: does not it been included?

4. It would have been interesting to discuss the homogeneity of exposure given the heterogeneity of the type of evaluation (questionnaire, job-exposure matrix, observation), and difference between men and women.

5. It is currently accepted that journals lead to levels of evidence and recommendations that can be measured according to the GRADE list. Nevertheless, it seems here, whether to do a state of the art more than a recommendation, which explains why the usual methods of evaluation of gradation and recommendation were not used. It could have been mentioned also in the discussion.

6. Finally, it would have been necessary to compare the results of the other two systematic reviews on the subject mentioned in the introduction, both of the included studies, of their quality as well as of their result.

7. Typographical details: Page 6, on the flowchart, it misses an "e" after article "article excluded"

All these comments are minor compared to the excellent work of the authors.

Prof. Alexis Descatha MD PhD (December 4, 2017)

Alexis Descatha is paid by Versailles University and Paris Hospital for being a Professor in occupational health and a practitioner, and an Editor in chief Of Les archives des maladies professionnelles et de l’environnement. Ongoing scientific project on job exposure matrix are shared with the authors, but without direct involvement on this review previously.

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December 5, 2017

To the Danish Working Environment Authority –

I am writing to respond to your invitation to review the "Association between occupational mechanical exposures and subacromial impingement syndrome: A reference document," conducted for the Danish National Board of Industrial Injuries. I believe that you and your colleagues have done an important review that adds important information to our understanding of risk factors for work-related shoulder disorders. I will describe below my evaluation of the methodology used, the analyses and conclusions, and some minor points about how the document can be made even better.

As noted in your review, chronic shoulder disorders are a large and growing cause of medical treatment and work disability in Denmark and other industrialized nations. While personal risk factors are well described in the medical literature, relatively few studies have examined the work-related mechanical and psychosocial factors that increase the incidence of chronic shoulder disorders. Recent research, including work conducted by you and your colleagues, have added new information about causation; your review is thus a timely and welcome addition to our knowledge of work-relatedness.

This reference document followed current recommendations for how to appropriately conduct a systematic review. While I am not familiar with the guidelines for preparation and quality approval used by the Danish Work Environment Fund, I note that your study used the PRISMA guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) and was registered in PROSPERO, an international prospective registry of systematic reviews. I examined the criteria your team used for inclusion of manuscripts as described in Appendix 1 and had no concerns about the methods used to define the outcome of SIS. The clinical characteristics and ICD-10 codes all seemed reasonable, with an appropriate degree of specificity. The mechanical and psychosocial exposures sought were also appropriate based on existing literature and potential new literature.

The databases searched included the three most relevant for epidemiological studies; the search strategy and exclusion criteria presented in Appendices 2 and 3 seemed reasonable and appropriate. Independent reading and scoring by two authors was used, as recommended for systematic reviews. Data extraction followed usual procedures, and I note that you used the same quality assessment tool used by two previous systematic reviews. The quality assessment measures provided in Appendices 5 and 6 are consistent with the practices used in rigorous systematic reviews. The dichotomous cutpoint used for defining the high quality studies is of necessity arbitrary, but consistent with other practice, and was tested through sensitivity analyses. Analyses followed standard Forest plots; publication bias was assessed.

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The initial search produced >4000 relevant articles, which were reduced to 50 articles which met criteria for full review. Compared to previous reviews, many more studies of high quality were available for analysis. The detailed results for each exposure type were well described, with underlying assumptions and analyses described in sufficient detail. I agree with the main results presented in section 4.1; I believe this summary accurately captures the detailed results. These results extend earlier systematic reviews, demonstrating new relationships including moderate evidence for repetitive shoulder movement and limited evidence for Hand Arm Vibration. Not surprisingly, combined exposures showed the strongest evidence for a relationship. For psychosocial exposures, no associations were found for the diagnosis of SIS; an interesting question for the future will be whether the exposures of job demand, control and support are associated with increased disability or medical treatment among those with the diagnosis.

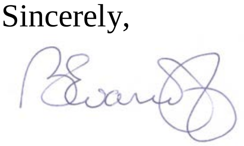
Due to heterogeneity in measures of exposure and lack of detailed quantitative exposure data I agree with your conclusion that existing data do not allow the confident definition of safe exposure intensities and durations.

I made a few suggestions on the draft for improving readability and comprehension of the presented data.

Overall, this was a very thorough and methodologically rigorous systematic review. Having been involved in two major systematic reviews, I know that this document represents a great deal of effort by you and your colleagues. The data presented are an important addition to our knowledge about causation of SIS, and points to future work. I hope that in the peer-reviewed publication that will follow you will describe the exposure durations and intensities measured in the high quality studies; although much of these data can't be pooled across studies it will give readers some idea of the exposure levels clearly associated with excess risk. Pending future data that allow determination of dose-response these data will still be of interest. You might also lay out important research questions remaining for primary and secondary prevention of SIS, given your team's current uniquely complete view of the existing literature.

Congratulations on an important contribution to our knowledge of work-related musculoskeletal disorders.

Sincerely,



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