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Physical and psychosocial work-related exposures and the occurrence of disorders of the shoulder: A systematic review update

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ABSTRACT

This review is an update of a previous systematic review and assesses the evidence for the association of work-related physical and psychosocial risk factors and specific disorders of the shoulders. Medline, Embase, Web of Science Core Collection, Cochrane Central and PsycINFO were searched and study eligibility and risk of bias assessment was performed by two independent reviewers. A total of 14 new articles were added with the majority focusing on rotator cuff syndrome (RCS) with seven studies. Nine articles reported psychosocial exposures in addition to physical exposures. The strongest evidence was found for the association between elevation, repetition, force and vibration and the occurrence of SIS and tendinosis/tendonitis. Evidence also suggests that psychosocial exposures are associated with the occurrence of RCS and tendinosis/tendonitis. Other findings were inconsistent which prevents drawing strong conclusions.

1. Introduction

Shoulder pain is frequently reported in the working population, with a year-prevalence for rotator cuff syndrome (RCS) of up to 6.6% for men and 8.5% for women (Bodin et al., 2012a). Subacromial impingement syndrome (SIS) has an incidence of 11 cases per 10,000 person-years (Dalbøge et al., 2014). Tendonitis of the shoulder has a year-prevalence of 8–13% and, similar to RCS and SIS, shows a positive association with upper arm elevation above 90° (Svendsen et al., 2004). Thoracic outlet syndrome (TOS) and shoulder bursitis have an incidence of around 2–30/1000 and their occurrence is not significantly associated to physical exposure (Citisli, 2015; Van der Windt et al., 1995). Non-specific shoulder disorders refers to shoulder pain without a detectable cause and shows a positive association with multiple physical factors, such as heavy lifting or working above shoulder level (Miranda et al., 2005).

The body of evidence for the relationship between work-related factors and shoulder complaints or disorders has been considered in several reviews (Bernard and Putz-Anderson, 1997; Larsson et al., 2007; van der Molen et al., 2017; van Rijn et al., 2010). The previous reviews all reported evidence that highly repetitive work and repeated or sustained shoulder postures with >60° flexion or abduction were associated with the occurrence of shoulder disorders. One review also reported associations between arm-hand elevation and shoulder load and the occurrence of shoulder disorders (van der Molen et al., 2017). Accordingly, in numerous countries, work-related shoulder disorders are reported as frequently occurring compensation claims or occupational diseases in various jobs and sectors of industry (Beach et al., 2012; Bodin et al., 2017; Van der Molen et al., 2016). The reviews generally identify that biomechanical factors were the most important etiological contributors, however there was also evidence that psychosocial factors may contribute to the development and occurrence of shoulder disorders

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(Bodin et al., 2017; van Rijn et al., 2010).

The aim of our study is to update a systematic review by van Rijn et al. (2010) that included 17 articles evaluating associations between type of work, physical load factors, and psychosocial work-related factors and the occurrence of the following shoulder disorders: SIS, suprascapular nerve compression, tendinitis of the biceps tendon and rotator cuff tears. This systematic review found an association with several psychical and psychosocial factors and the occurrence of SIS. They included just two articles with tendinitis of the biceps tendon as the outcome, but with inconsistent findings. They did not found any articles reporting associations between work-related risk factors and the occurrence of rotator cuff tears and suprascapular nerve compression.

Given the increasing number of new epidemiological studies and the lack of longitudinal studies in the previous review by van Rijn et al. (2010), the aim of the current review was to provide an updated review assessing the evidence for work-related physical and psychosocial risk factors for the following disorders of the shoulders: RCS, tendinosis/-tendonitis, SIS, TOS, bursitis and non-specific shoulder disorders. If the inclusion of new studies showed that these disorders were caused by work-related factors, this information would be relevant for the development of more targeted prevention and treatment strategies to better tackle these disorders in the work environment and to contribute to improved health among the working population.

2. Materials and methods

This review was part of a research project on work-related physical and psychosocial risk factors associated with the development of specific musculoskeletal disorders of the upper and lower limbs. The protocol for this project was registered on PROSPERO (CRD42020170264) (Koes et al., 2020). Reporting of this systematic review adhered to the most recent published reporting recommendations (SWiM guideline) for evidence synthesis without a meta-analysis (Campbell et al., 2020). The present systematic review focusses on shoulder disorders and is an update of a previous systematic review (van Rijn et al., 2010). In the present review, we did not reassess the studies included in the previous review, but we included a summary of the findings of the previous review (see paragraph 3.2 and supplementary table D). Results from our research project regarding other body parts have been published elsewhere (Chiarotto et al., 2023; Gerger et al., 2023, 2024).

2.1. Article selection

Medline, Embase, Web of Science Core Collection, Cochrane Central and PsycINFO were searched by combining text words and controlled vocabulary representing (1) musculoskeletal disorders of the shoulder, and (2) exposure to work-related physical and psychosocial risk factors (Supplement 1). The initial search was performed January 2020 and an updated search was performed April 2022. Our search was performed with the goal to complement the previously published article by van Rijn et al. (2010). In order to be able to identify studies which might have been missed in the previous search we did not restrict our database search to a certain time-frame. However, our goal was to present findings which add to the evidence which was presented in the previous review. Therefore, we did not include the studies which were included in the van Rijn et al. (2010) publication in our review. We do, however, present a summary of the previous findings in our results section and supplementary table D.

Title and abstracts were checked for duplicates. Two reviewers screened titles and abstracts independently against eligibility criteria. The full-texts of potentially eligible articles were then independently evaluated by two reviewers; in case of disagreements a third reviewer made the decision about eligibility.

2.2. Inclusion criteria

All included articles assess occupational physical or psychosocial exposure and evaluate the association of these exposures with the occurrence of RCS, tendinosis/tendonitis, SIS, TOS, bursitis or non-specific shoulder disorders. RCS is defined as any injury or degenerative condition affecting the rotator cuff. Tendinosis/tendinitis is defined as, respectively, a degenerative or an inflammatory injury of a tendon. SIS encompasses pathologies in the subacromial space and TOS is a group of conditions in which there is compression of the nerves or blood vessels in the thoracic aperture. Bursitis is defined as inflammation of a bursa of the shoulder. Non-specific shoulder disorder refers to shoulder pain without a detectable cause.

The definition of physical and psychosocial exposures is based on previous reviews investigating physical and psychosocial work-related factors (van Rijn et al., 2010; van der Molen et al., 2017). Physical work-related type of exposure, included: 1) force (e.g., heavy physical work, lifting, pushing or pulling), 2) awkward postures (e.g., working with hands above shoulder level), 3) vibration, 4) repetition and 5) combined exposure measures. We included exposures reported on different dimensions, including duration, intensity level, or frequency, measured with self-reported, observer-rated, or performance-based assessments. Psychosocial work-related exposures included: social support, job demands, job control, decision latitude, job satisfaction, job security, time pressure, periodic interruptions, and job-related psychosocial distress. Psychosocial exposures were typically measured with validated self-reported questionnaires but we also accepted newly-constructed study-specific survey questions. We excluded studies which reported exposures only defined on the basis of job titles (e.g., Assessment via Job Exposure Matrix – JEM). The hierarchical exclusion criteria for article screening are presented in Fig. 1.

To be eligible, a study needed to report data on the occurrence of one or more specific and non-specific shoulder disorders depending on the presence or absence of exposure or different levels of exposure. We included studies considering a naturalistic, real workplace or clinical setting. No laboratory experiments were included. Because we aimed to identify risk factors, we intended to focus our analyses and conclusions on data from longitudinal studies. However, as we expected to identify only a small number of longitudinal studies, we decided to include cross-sectional and case-control studies as well.

We included each dataset once in the review. In the case that multiple publications used the same dataset, we included the most recent publication and consulted previous publications only in the case of missing data.

2.3. Outcomes

The occurrence of disorders of the shoulder was the primary outcome, as reported by the study participants or by clinicians. The following disorders were included: RCS, tendinosis/tendonitis, SIS, TOS, bursitis and non-specific shoulder disorder.

2.4. Data extraction

From each included article, we extracted sample characteristics (e.g. mean age, sex, type of occupation), the type of risk factor, the outcome (definition of the musculoskeletal disorder), and study design details (e.g. study design, year of publication, adjustment for confounders). We extracted the number of cases and controls, and the number of study participants with and without the respective musculoskeletal disorder depending on the exposure to work-related physical or psychosocial risk factors. If the levels of exposure were not explicitly labeled in the available study report, we interpreted the lowest level of exposure as 'non-exposure'.

Odds ratios (ORs) and other effect size measures (e.g., hazard ratios, risk rations) were extracted from the included studies in addition to raw data. We extracted adjusted ORs from multiple or multivariable analyses, if no backward selection of significant predictors was applied by the authors. If only significant predictors were kept in the final multivariable model, we chose to extract data form bivariable analyses. Data extraction was performed using an Excel spreadsheet, which included descriptive details for coding study information. Data was extracted by a researcher and checked by a second senior researcher.

2.5. Risk of bias (quality) assessment

The methodological quality of the eligible studies was assessed using a list of 16 quality criteria used in previous systematic reviews on the same topic in order to allow for comparability between previous work and the planned systematic reviews (van der Molen et al., 2017; van Rijn et al., 2009a, 2009b, 2010). The list included 16 items covering five main topics: 1) study population, 2) assessment of exposure, 3) assessment of outcome, 4) study design and analysis, 5) data analysis and presentation (table B). Each item had to be rated as 'low, 'high or 'unclear', and criteria on how to score each item were a-priori defined. The content of the quality assessment tool corresponds to recently published tools for assessing the quality of observational studies (Bero et al., 2018).

In line with the most recent guidelines for systematic reviews (Higgins et al., 2019), no cut-off was used to differentiate studies of high or low quality. Two reviewers assessed risk of bias independently. Disagreements were resolved by a third reviewer.

2.6. Strategy for data synthesis

We summarized the results in tables including descriptive information about the included studies and ORs for the association between work-related physical and psychosocial risk factors and the occurrence of selected shoulder disorders. Due to the small number of included studies for each combination of disorder and exposure we did not perform meta-analyses.

3. Results

3.1. Study characteristics

Our literature search for diverse musculoskeletal disorders of the upper and lower limbs resulted in a total of 8.885 records after deduplication (Figure A). Two independent reviewers screened 1.019 full text articles and identified fourteen studies which fulfilled the inclusion criteria of this review: seven studies reported results on RCS (Applegate et al., 2017; Arcury et al., 2016; Balogh et al., 2019; Bodin et al., 2012b; Bugajska et al., 2013; Dalbøge et al., 2020; Meyers et al., 2021), four studies reported results on different forms of shoulder tendinosis/-tendonitis (Dalbøge et al., 2020; Nordander et al., 2016; Seidler et al., 2011; Stenlund et al., 1993), three studies on SIS (Chu et al., 2021; Dalbøge et al., 2020; Holm et al., 2016), two on TOS (Nordander et al., 2016; Turhan et al., 2008), one on shoulder bursitis (Dalbøge et al., 2020), and one on non-specific shoulder disorder (Walker-Bone et al., 2006) (Table A). Four of the included studies were prospective cohort studies, one was a retrospective cohort study, two were case control studies, five studies were conducted cross-sectionally, and two were individual patient data meta-analyses of cross-sectional studies. Nine included articles reported psychosocial exposures in addition to physical exposures. Table A displays relevant characteristics of the included studies. More detailed study descriptions including characteristics of physical and psychosocial exposure assessments can be found in the Supplementary materials.

3.2. Findings from previous review

The tables reporting the main results and the risk of bias assessment of the review by van Rijn et al. (2010) are presented in supplementary table D. The previous review included 17 articles: 14 cross-sectional studies, 1 case-control study and 2 cohort studies. They did not find any articles that reported associations between physical or psychosocial work-related factors and the occurrence of rotator cuff tears and suprascapular nerve compression. Only two articles reported the occurrence of tendinitis of the biceps tendon across different occupations. The remaining 15 articles reported associations with the occurrence of SIS. In contrast to our review the previous review by van Rijn et al. (2010) included exposures based on job titles. They found that shipyard welders, workers in slaughterhouse, fish processing workers and betel pepper leaf cullers were jobs with an increased occurrence of SIS, with OR ranging from 4.49 to 5.27).

With regards to exposures based on individual workers, high force requirements, heavy lifting and high hand force were associated with SIS (OR = 2.8–4.21). No associations were found for frequent lifting and lifetime shoulder force requirements. Two articles found associations between repetition and the occurrence of SIS. Repetitive motion of the hand/wrist >2 h/day (14–23 years versus none and >23 years versus none) and low and high frequency of shoulder movements during a workday were associated with SIS (OR = 2.40–3.29). No significant associations were found for repetitive motion of the hand/wrist >2 h/day for 1–3 years versus none and 4–13 years versus none. Working with a vibration tool for over 4 years versus none and lifelong vibration energy showed significant associations (OR = 1.04–3.5). Five articles described associations between posture and the occurrence of SIS, with also mainly significant associations: working above shoulder level (OR = 2.3–4.5) as well as a lack of micro pauses in shoulder flexion during cycle time (OR = 1.27–4.70) were associated with SIS. They also found a positive association between duration of exposure (8–15 years and >15 years versus 0–7 years) and the occurrence of SIS (OR = 6.32 and 8.80 respectively). Upper-arm elevation >90°(OR = 0.94–2.33) showed no significant findings with the occurrence of SIS.

Only three studies reported associations between psychosocial exposures and the occurrence of SIS. Significant associations were found between high psychosocial job demands and low job control and the occurrence of SIS (OR = 1.70–3.19). There were no significant associations between low social support, high decision altitude, high job satisfaction and high job security and the occurrence of SIS.

3.3. Risk of bias

The risk of bias of the included studies was moderate to low (Table B), with many items of our risk of bias assessment showing predominantly low risk of bias ratings. The most relevant risks of bias were due to lack of blinding in outcome and exposure assessments and lack of information regarding completers and study withdrawals (especially with regards to the comparability to the representativeness of the study completers when compared with those who initiated the study).

3.4. Association between work-related physical exposure and outcome

RCS. Results were inconsistent regarding the associations between occupational physical exposures, including force, posture, repetition, vibration, and combined physical exposure indicators and the occurrence of RCS across the seven included cross-sectional and longitudinal studies (Table C).

One study which reported exposure on more than two levels, reported significant associations with higher levels of exposure (Dalbøge et al., 2020). However, another study (Meyers et al., 2021) showed no significant associations between higher levels of exposure and the occurrence of RCS.

Three of the four prospective studies reported no significant associations between force, repetition, posture, vibration, as well as combinations and the occurrence of RCS (Arcury et al., 2016; Bugajska et al., 2013; Meyers et al., 2021). These three studies all had a low risk of bias. The fourth prospective study showed significant associations for the occurrence of RCS and high perceived physical exertion, repeated or sustained posture with arms above shoulder level for men-, and arm abduction for women (Bodin et al., 2012b). However, this study had a high risk of bias.

One retrospective cohort with a low risk of bias (Dalbøge et al., 2020) reported significant associations between measures of posture, repetitiveness, force, vibration and combined measures and risk of RCS, with ORs ranging from 1.3 to 2.4 (Table C).

The two cross-sectional studies (Applegate et al., 2017; Balogh et al., 2019) with a moderate to high risk of bias showed mainly non-significant findings, except for an association between continuous activity in the trapezius and the forearm extensors and the risk of RCS for both men and women (ORs ranging from 1.4 to 1.9) (Balogh et al., 2019).

Tendinosis/tendonitis. Four types of tendinosis/tendonitis were reported in the included studies: bicipital, supraspinatus, infraspinatus, and calcific tendinosis/tendonitis (Dalbøge et al., 2020; Nordander et al., 2016; Seidler et al., 2011; Stenlund et al., 1993). All four studies had a moderate to low risk of bias, but there were no studies of longitudinal prospective cohorts of tendinosis/tendonitis.

A retrospective cohort showed a significant association with only vibration and the occurrence of bicipital tendinosis (Dalbøge et al., 2020). It also showed a significant association with arm-elevation, repetition, force and shoulder-load and the occurrence of calcific tendinosis (table D).

One cross-sectional study (Nordander et al., 2016) showed significant association with continuous measures of activity in the trapezius and the occurrence of bicipital, supraspinatus and infraspinatus tendonitis. The other cross-sectional study (Stenlund et al., 1993) showed a significant association with vibration for the left arm and the occurrence of tendonitis of the biceps or rotator cuff muscles. The case control study (Seidler et al., 2011) showed a significant association with a higher amount of working with arms above shoulder level and the occurrence of supraspinatus tendon lesion.

SIS. Two of the three included studies (Dalbøge et al., 2020; Holm et al., 2016), one retrospective cohort and one case control, reported significant associations between higher levels of arm elevation, repetition, force, vibration, and combined physical exposures and the occurrence of SIS (Table E). This was especially evident in the retrospective cohort study (a study with low risk of bias, see Table B) (Dalbøge et al., 2020) where a dose-response trend was also shown. The third study (Chu et al., 2021), with a high risk of bias, reported mainly non-significant associations with the exception of a significant association between twisting or rotating tasks and shock and/or impact being transmitted to the body from tools or equipment and the development of SIS.

TOS. Across the two included cross-sectional studies (Nordander et al., 2016; Turhan et al., 2008), almost no significant results were found regarding associations between physical exposures and the prevalence of TOS (Table E). The only significant association was between continuous measures of activity in the trapezius and the occurrence of TOS (Nordander et al., 2016). Both studies display a high risk of bias.

Bursitis. The retrospective cohort study (Dalbøge et al., 2020), with a low risk of bias, showed a significant association between higher level of arm-elevation, repetition, force and shoulder load and the occurrence of shoulder bursitis with ORs ranging from 1.4 to 2.0 (table E). The study found no significant association between vibration and the occurrence of shoulder bursitis.

Non-specific shoulder disorder. One cross-sectional study (Walker-Bone et al., 2006), with a high risk of bias, reporting associations between non-specific shoulder disorders and physical exposures showed a significant association between dichotomous arm-elevation exposure and non-specific shoulder disorder (OR = 4.9) (table E). The study did not find a significant association between force (i.e. carrying weights on one side) and non-specific shoulder disorder (OR = 1.9).

3.5. Association between work-related psychosocial exposure and the occurrence of shoulder disorders

Nine articles reported associations between psychosocial exposures and the occurrence of shoulder disorders (Table F). Six of these studies considered RCS as the outcome (Applegate et al., 2017; Arcury et al., 2016; Balogh et al., 2019; Bodin et al., 2012b; Bugajska et al., 2013; Meyers et al., 2021) and reported significant associations between job demand, job support, job control (only significant for women) and low coworker support (only significant for men) and the occurrence of RCS. These six studies have a moderate to low risk of bias.

One study with a moderate risk of bias (Nordander et al., 2016) found significant associations between low job control and job strain and the occurrence of tendinosis/tendonitis for three kinds of tendinosis/tendonitis. No significant associations were found between high job demand and the occurrence of different diagnosis of tendinosis/tendonitis (Nordander et al., 2016).

Three studies with a high risk of bias regarding SIS, TOS and non-specific shoulder disorders as an outcome, all reported no significant associations between psychosocial exposure and the occurrence of SIS, TOS or non-specific shoulder disorder (Chu et al., 2021; Nordander et al., 2016; Walker-Bone et al., 2006).

4. Discussion

This systematic review summarizes the evidence for the association between work-related physical and psychosocial exposures and the occurrence of RCS, tendinosis/tendonitis, SIS, TOS, bursitis and nonspecific shoulder disorders. Five out of the seven studies about RCS reported no significant associations between psychical exposure and the occurrence of RCS. The strongest evidence in this systematic review was found for the association between arm elevation, repetition, force/muscle activity and vibration and an increased occurrence of SIS and tendinosis/tendonitis. There were no significant associations between physical exposures and the occurrence of TOS. The study reporting bursitis with a low risk of bias, showed a significant association between elevation, repetition, force and load and the occurrence of bursitis. A study with a high risk of bias reported only a significant association between arm elevation and the occurrence of non-specific shoulder disorders.

Nine articles reported associations between psychosocial exposures and the occurrence of shoulder disorders. Six studies reported a significant association between job demand, job support, job control and low coworker support and the occurrence of RCS. One study reported significant associations between low job control and job strain and the occurrence of different types of tendinosis/tendonitis. No significant associations were found for SIS, TOS or non-specific shoulder disorders.

We included 14 new studies which were not included in the previous review by van Rijn et al. (2010). We included 5 longitudinal studies, which in this field of research appears like a comparably small number of longitudinal studies. This limits the ability to draw strong conclusions regarding potentially causal relationships between work-related exposures and selected shoulder disorders. In our review, cross-sectional and longitudinal studies both showed inconsistent findings regarding the investigated associations. In contrast to the previous review, our review found one or more articles for each shoulder disorder. With 7 studies, the occurrence of RCS was the most frequently investigated outcome. Our results on RCS as an outcome complement the previous review, which did not find any articles which reported associations between physical an psychosocial work-related factors and rotator cuff tears and suprascapular nerve compression. The previous review only found studies with SIS as the outcome. Our results confirm mixed findings regarding most of the analyzed exposures, including significant associations between frequently handling loads with high force, highly repetitive work, hand–arm vibration, and work above shoulder level and the occurrence of SIS. The current review also showed additional significant associations with other shoulder disorders: RCS, tendinosis/tendonitis, TOS, bursitis and non-specific shoulder disorder. The addition of these other shoulder disorders, makes this review more widely applicable. However, just as the previous review, our review showed mixed findings regarding most analyzed exposures.

The number of studies for each combination of exposure type and type of disorder was relatively low. However the quality was moderate to good for most of the studies. The most common risk of bias was a lack of blinding in the assessment of exposures and outcomes, and a lack of information regarding study completers and withdrawals which can be problematic in longitudinal studies (i.e., due to the "healthy worker" effect). Of the articles included in this review, we consider the 2020 study by Dalbøge and colleagues (Dalbøge et al., 2020) to have the strongest design, research methods and best reporting. Their study demonstrated mixed associations between exposure and different types of disorders: consistently significant associations were found between higher levels of arm elevation, repetitiveness, force, vibration and a combined exposure measure and RCS and SIS. No clear associations were found for physical exposures and tendon-related disorders or bursitis.

Our review builds upon previous findings of systematic reviews assessing the association between work-related risk factors and the occurrence of shoulder disorders. They were unable to draw strong conclusions regarding causal relationships between work-related exposures and selected shoulder disorders due to the small amount of available data of the included studies and inconsistencies in findings across the included studies (van der Molen et al., 2017; van Rijn et al., 2010). Due to the differences in worker populations, work characteristics, methodologies, and exposure variables assessed, it was not possible to conduct a meta-analysis.

Our review provides insight in possible risk factors in the workplace for developing shoulder complaints. Due to inconsistent findings, unfortunately also in our updated review no strong causal conclusions are possible. Nevertheless, together with the previously published findings, our results indicate the need to improve work-place design in order to prevent the occurrence of shoulder disorders. Future research may focus on the impact of improved work-place design and other prevention and treatments strategies on the occurrence of shoulder disorders.

Our review of work-related psychosocial factors resulted in inconsistent findings, partly due to heterogeneity of the different exposures. The scarcity of strong evidence prevents the conclusion that psychosocial factors are not relevant in the development of shoulder disorders. Rather, further investigation in the form of cohort studies is required in order to clearly investigate the possible role of these factors on the development or maintenance of shoulder disorders as well as possible interactions with other (physical) work-related risk factors.

4.1. Limitations

First, data extraction was not done by two independent reviewers. However, the correctness of the extracted data was checked by a second researcher. Second, while we performed a broad systematic search in medical and psychological literature databases which returned a large number of articles for screening, we still cannot rule out that we may have missed important studies. However, we consider the risk for the occurrence of selection bias to be small. Third, we focused only on a list of predefined exposures/risk factors. If not accounted for by the authors using adequate statistical methods, we cannot rule out confounding or interactions with other risk factors which were not taken into consideration. Fourth, the included studies predominantly reported associations between exposures and the prevalence of one of the relevant disorders; only one study reported associations with the incidence of RCS. Reporting prevalence prevents the possibility to detect the natural course of disorders, i.e. the number of new cases occurring during the time of observation cannot be detected, nor is it possible to detect how many cases remitted. This limits the possibilities to draw conclusions regarding causal relationships between the observed exposures and disorders. Finally, it is important to keep in mind that due to the differences between studies in worker population, work characteristics, methodology, and outcomes, direct comparison across studies is difficult and interpretations based on such comparisons should be done with caution.

5. Conclusions

This systematic review updates a previous review with the addition of 14 new studies. The findings present compelling evidence supporting the association between elevation, repetition, force and vibration and the occurrence of SIS and tendinosis/tendonitis of the shoulder. Additionally, a potential association between psychosocial work-related risk factors and the occurrence of RCS and tendinosis/tendonitis was found. Other physical and psychosocial work-related risk factors showed inconsistent associations with the occurrence of shoulder disorders.

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Data availability statement

Not applicable.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.apergo.2024.104277.

Appendices.

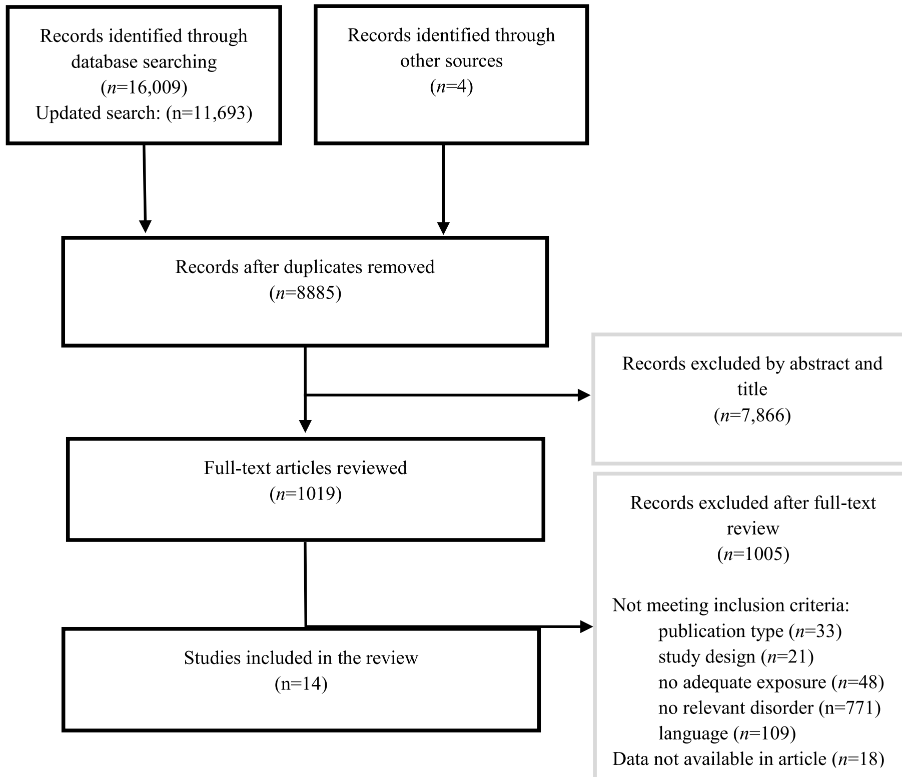

Fig. A. Flow Chart of Study Inclusion

Table A
Descriptive characteristics of the included studies.

Author Publication year Study design Country	Study population	Female/male mean age	Type of data Outcome assessment/ diagnosis	Cases/ controls	Adjusted analyses
RCS					
Arcury **2016 cohort (prospective)** **USA**	manual workers (247)	124/123 31.6	prevalence self-report & physical examination	30/NR	Baseline symptoms, gender, age, indigenous language, and industry while accounting for the stratification and clustering of sample design.
Bugajska **2013 cohort (prospective)** **Poland**	employees (725 at 1st measurement, and 542 at 2nd measurement)	t1: 558/167 t2: 417/125 t1: 42.8 t2: 43.6	prevalence self-report & physical examination	t1: 22.5%/ NR t2: 15.4%/ NR	Individual variables (age and gender), organizational and physical factors (working hours, repetitive work, force), were controlled in all analyses.
Balogh [a] **2019** **CS** **Sweden**	employees at different workplaces (5840)	4733/1107 43.62	prevalence physical examination	men: 44/ 18 women: 185/87	age
Applegate **2017** **CS** **USA**	workers (1226)	805/421 42.1	prevalence self-report & physical examination	156/1070	–
Meyers **2021** **Cohort (prospective)** **USA**	Manufacturing and healthcare workers (393)	172/221 41.6	self-report & physical examination & technical procedure	39/354	12 potential confounders were tested and each separate multivariable model included some confounders: age, education, BMI, forceful element repetition rate, site, supervisor support, years worked at employer, job strain ratio, mental demands, female, diabetes.
Bodin **2012 cohort (prospective)** **France**	workers (1456 with follow up at 5 years out of initially 3710)	617/839 43.4	incidence self-report and physical examination	96/1360	multiple regression analyses age was forced into the models). The remaining factors (P < 0.10) were entered into a final global multivariate logistic regression model and manual

(continued on next page)

Table A (*continued*)

Author Publication year Study design Country	Study population	Female/male mean age	Type of data Outcome assessment/ diagnosis	Cases/ controls	Adjusted analyses
					backward selection retained only significant variables with a P-value of 0.05. In manual backward multivariate logistic regression, if there was a change in the beta coefficients of ≥15% when a variable was deleted, this variable was considered as a confounder and was forced into the model.
Dalbøge **2020 cohort (retrospective)** **Denmark**	persons with ≥5 years of full-time employment (2,374,403)	1,156,334/1,218,069 47.3	prevalence medical records	2084/NR	sex, age, region of residency, calendar year at start of follow-up
Tendinosis/Tendonitis					
Dalbøge **2020** **cohort** **(retrospective)** **Denmark**	persons with ≥5 years of full-time employment (2,374,403) bicipital tendonitis	1,156,334/1,218,069 47.3 bicipital tendonitis	prevalence medical records	98/NR	sex, age, region of residency, calendar year at start of follow-up
Dalbøge **2020 cohort (retrospective)** **Denmark**	persons with ≥5 years of full-time employment (2,374,403) calcific tendonitis	1,156,334/1,218,069 47.3	prevalence medical records	297/NR	sex, age, region of residency, calendar year at start of follow-up
Nordander [a] **2016** **CS** **Sweden**	workers (3141) bicipital tendonitis	2324/817 NR	prevalence physical examination	NR/NR	sex
Nordander [a] **2016** **CS** **Sweden**	workers (3141) supraspinatus tendonitis	2324/817 NR	prevalence physical examination	NR/NR	sex
Nordander [a] **2016** **CS** **Sweden**	workers (3141) infraspinatus tendonitis	2324/817 NR	prevalence physical examination	NR/NR	sex
Seidler **2011** **CC** **Germany**	Cases supraspinatus tendon lesion	0/743 50.07	Prevalence technical procedure & physical examination	443/300	analyses were adjusted for age and place of residence In the "final model", they adjusted for work above shoulder level, lifting/carrying of heavy loads, and use of handheld vibrating machines in addition to age and region.
Stenlund **1993** **CS** **Sweden**	Three groups of construction workers (1: bricklayers, 2: rockblasters, 3: foremen) (207) tendonitis of the shoulder	0/207 1: 50.2 2: 41,8 3: 45,8	prevalence physical examination	35/162	multiple regression analyses: age, dexterity, smoking, sports activities
SIS					
Dalbøge **2020 cohort (retrospective)** **Denmark**	persons with ≥5 years of full-time employment (2,374,403)	1,156,334/1,218,069 47.3	prevalence medical records	8763/NR	sex, age, region of residency, calendar year at start of follow-up
Holm **2016** **CC** **Denmark**	laboratory workers (291 clinical cases out of total 362 participants with symptoms)	291/0 40	prevalence self-report & physical examination	33/NR	matching factors (age, worksite)
Chu **2021** **CS** **Taiwan**	Workers from an electronic factory	270/661 38.3 (with shoulder complaints) and 37.4 (without shoulder complaints)	prevalence mix of medical examination and self-report	284/647	–
TOS					
Nordander [a] **2016** **CS**	workers (3141)	2324/817 NR	prevalence physical examination	9/3132	sex
Turhan **2008** **CS** **Turkey**	data entry operators (173)	159/14 30.5	prevalence self-report & physical examination	21.9%/ NR	–
Bursitis					
Dalbøge **2020 cohort (retrospective)** **Denmark**	persons with ≥5 years of full-time employment (2,374,403)	1,156,334/1,218,069 47.3	prevalence medical records	NR/NR	sex, age, region of residency, calendar year at start of follow-up
Nonspecific shoulder disorder					
Walker-Bone **2006** **CS** **UK**	general population (4170)	1056/1092 NR	prevalence self-report & physical examination	37/2148	age, sex, smoking habits, SF-36 score, social class, relevant physical activities

Acronyms: CC = case control, CS = cross-sectional, NR = not reported, RCS = rotator cuff syndrome, SIS = shoulder impingement syndrome, TOS = thoracic outlet syndrome, USA = United States of Amerika, UK = United Kingdom.

[a] Studies used the datasets from several other studies with a similar design and reanalyzed them with respect to a new research question. None of the individual studies included in the pooled analysis is included in our systematic review independently.

Table B
Risk of Bias assessment of the included studies

Risk of bias domain and item	Applegate et al., 2017	Bodin et al., 2012b	Dalbøge et al., 2020	Nordander et al., 2016	Seidler et al., 2011	Stenlund et al., 1993	Arcury et al., 2016	Bugajska et al., 2013	Balogh et al., 2019	Holm et al., 2016	Walker-Bone et al., 2006	Turhan et al., 2008	Meyers et al., 2021	Chu et al., 2021
Study population														
1. Definition of study groups	low	low	low	low	low	low	low	low	low	low	low	low	low	low
2. Participation ≥70%	unclear	high	unclear	low	high	low	low	unclear	low	low	high	unclear	low	low
3. Number case ≥50	low	high	low	low	low	low	high	high	low	low	high	low	high	high
Exposure assessment														
4. Exposure measurement														
physical	low	low	low	low	low	low	low	NA	low	low	high	unclear	low	unclear
psychosocial	high	low	NA	low	NA	NA	low	low	low	NA	low	NA	NA	high
5. Dose-response														
physical	low	high	low	low	low	low	low	NA	high	low	high	high	low	unclear
psychosocial	low	high	NA	low	NA	NA	low	unclear	low	NA	high	NA	NA	low
6. Blind for outcome status														
physical	unclear	high	low	unclear	unclear	high	low	NA	low	unclear	high	unclear	low	unclear
psychosocial	high	high	NA	unclear	NA	NA	high	high	high	NA	high	NA	NA	high
Assessment of outcome														
7. Outcome definition	low	low	low	low	low	low	low	low	unclear	low	low	low	low	low
8. Assessment method	low	low	low	low	low	low	low	low	low	low	low	low	low	unclear
9. Blind for exposure status	unclear	unclear	low	unclear	low	low	unclear	unclear	low	low	low	low	unclear	unclear
Study design														
10. Longitudinal	high	low	low	high	low	high	low	low	high	low	high	high	low	high
11. Inclusion and exclusion criteria	low	low	low	unclear	low	unclear	low	low	high	low	low	high	low	low
12. Follow-up period ≥1 year	high	low	low	high	low	high	low	low	high	low	high	high	low	high
13. Info completers vs. withdrawals	unclear	unclear	unclear	unclear	unclear	unclear	unclear	low	unclear	unclear	unclear	unclear	unclear	unclear
Data analysis														
14. Data presentation	low	low	low	low	low	low	low	low	low	low	low	low	low	low
15. Consideration of confounders	low	low	low	low	low	low	low	low	low	low	low	high	low	low
16. Control for confounding	low	low	low	low	low	low	low	unclear	low	low	low	high	low	high

Table C
Occurrence of RCS Depending on the Presence of Physical Exposure.

Author Publication year Study design	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds ratio (95% CI)	p	Results (descriptive)
RCS						
Arcury **2016 cohort (prospective) prevalence**	Force	heavy load	self-report categorical (4)	0.59 (0.1–3.59)	0.57	Total N = 215
	Posture	awkward posture	self-report categorical (4)	2.1 (0.83–5.27)	0.11	Total N = 215
Bugajska **2013 cohort (prospective) prevalence**	Combined	physical job demand	self-report unclear	1.23 (0.89–1.71)	0.211	
Balogh [a] **2019** **CS** **prevalence**	Force	Trapezius (%MVE) p90	observer-report continuous	beta: *men:* **1.81 (1.13–2.9)** *women:* **1.87 (1.33–2.61)**	**men: sig** **women: sig**	Exposed: men: 920 women: 2366
	Force	forearm extensors (% MVE) p90	observer-report continuous	beta: *men*: **1.58 (1.12–2.23)** *women*: **1.36 (1.1–1.69)**	**men: sig** **women: sig**	Exposed: men: 800 women: 1437
	Posture	Upper arm elevation (°) p90	observer-report continuous	beta: *men:* 0.86 (0.44–1.69) *women:* 1.28 (0.96–1.71)	men: nonsig women: nonsig	Exposed: men: 920 women: 1878
Applegate **2017** **CS** **prevalence**	Combined	physical strain	videoanalysis unclear	1.01 (0.98–1.03)		mean (SD): RCT: 8.2 (9.2) no RCT: 7.7 (9.4) RCT/total (OR, 95% CI): 71/598 1.01 0.98–1.03
Bodin **2012 cohort (prospective) incidence**	Repetitiveness	high repetitiveness of tasks (≥ 4 h/day)	self-report dichotomous (2)		men: 0.874 women: 0.425	men: in multiple regression analysis age, repeated and sustained posture with arms above shoulder level (≥ 2 h/day) and low coworker support remained significant (p = 0.001, 0.043, and 0.033) women: in multiple regression analysis, age, work with temporary workers and repeated and sustained arm abduction remained significant (p = 0.002, 0.016, and 0.003) Exposed cases: men: no: 6.2% yes: 5.9% women: no: 6.7% yes. 8.6% Exposed total: men: no: 664 yes: 171 women: no: 445 yes: 162
	Posture	repeated and sustained posture with the arms above shoulder level (≥ 2 h/day)	self-report dichotomous (2)		men: **0.004** women:0.202	Exposed cases: men: no: 5.3% yes: 12.8% women: no: 6.9% yes: 11.3% Exposed total: men: no: 743 yes: 94 women: no: 551 yes: 62
	Posture	repeated and sustained arm abduction (60–90°)	self-report dichotomous (2)		men: 0.844 women:**0.003**	Exposed cases: men: no: 6.2% yes: 5.9% women: no: 5.5% yes. 12.7% Exposed total: men:

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Table C (*continued*)

Author Publication year Study design	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds ratio (95% CI)	p	Results (descriptive)
						no: 548 yes: 290 women: no: 457 yes: 158
	Posture	holding hand behind the trunk (≥ 2 h/day)	self-report dichotomous (2)		men: 0.429 women:0.475	Exposed cases: men: no: 6.0% yes: 9.7% women: no: 7.2% yes. 10.0% Exposed total: men: no: 806 yes: 31 women: no: 586 yes:30
	Vibration	use of vibrating hand-tools (≥ 2 h/day)	self-report dichotomous (2)		men: 0.609 women: 0.652	Exposed cases: men: no: 5.9% yes: 7.0% women: no: 7.3% yes. 10.0% Exposed total: men: no: 680 yes: 158 women: no: 592 yes: 20
	Combined	high perceived physical exertion	self-report dichotomous (2)		men: **0.030** women: 0.315	Exposed cases: men: no: 5.2% yes: 9.8% women: no: 6.8% yes. 9.4% Exposed total: men: no: 670 yes: 164 women: no: 487 yes: 128
Dalbøge 2020 cohort (retrospective) prevalence	Posture	arm-elevation years	observer-report categorical (5)	*0:* 1.0 (–) *>0–2:* **1.5 (1.3–1.7)** *>2–5:* **1.6 (1.4–1.9)** *>5–10:* **1.9 (1.7–2.2)** *>10–56:* **2.4 (2.1–2.8)**	**<0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Repetitiveness	repetition-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–1:* **1.3 (1.1–1.6)** *>1–2:* **1.6 (1.5–2.1)** *>2–10:* **1.7 (1.6–2.1)** *>10–68:* **2.2 (2.0–2.7)**	**<0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Force	force-years	observer-report categorical (5)	*<5:* 1.0 (–) *5:* 0.6 (0.5–0.7) *>5-7.5:* 1.0 (0.9–1.2) *>7.5-10:* **1.4 (1.2–1.7)** *>10–20:* **1.8 (1.5–2.2)**	**<0.002**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Vibration	HAV-years	observer-report categorical (3)	*0:* 1.0 (–) *>0–5:* **1.5 (1.3–1.7)** *>5–58:* **1.7 (1.4–1.9)**	**<0.003**	The odds ratios (ORs) can be interpreted as hazard ratios.

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Table C (*continued*)

Author Publication year Study design	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds ratio (95% CI)	p	Results (descriptive)
	Combined	shoulder load-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–5:* **1.4 (1.2–1.7)** *>5–10:* **1.8 (1.6–2.0)** *>10–15:* **2.2 (1.8–2.7)** *>15–20:* **2.2 (1.8–2.6)**	**<0.004**	The odds ratios (ORs) can be interpreted as hazard ratios.
Meyers 2021 Cohort (prospective) Incidence	Force	Peak forceful exertion – analyst rated	Video-analysis continuous	0.97 (0.46–2.04)	0.93	N = 37
	Force	TWA forceful exertion – analyst rated	Video-analysis Categorical (3)	<0.89: 1.00 (–) 0.89-<1.3: 0.93 (0.33–2.60) >1.3: 0.37 (0.09–1.59)	0.29 0.89 0.18	N = 11 N = 13 N = 13
	Force	Peak forceful exertion – worker rated	Video-analysis Continuous	0.91 (0.43–1.95)	0.81	N = 37
	Force	TWA forceful exertion – worker rated	Video-analysis Categorical (3)	<0.94: 1.00 (–) 0.94-<1.30: 1.45 (0.53–3.98) >1.30: 1.37 (0.39–4.81)	0.77 0.47 0.62	N = 12 N = 11 N = 14
	Repetition	TWA total repetition rate	Video-analysis Categorical (3)	<9.7: 1.00 (–) >9.7-<18.1: 0.88 (0.34–2.31) >18.1: 0.79 (0.31–1.98)	0.88 0.80 0.61	N = 13 N = 11 N = 13
	Repetition	TWA forceful repetition rate	Video-analysis Categorical (3)	<0.40: 1.00 (–) >0.40-<5.52: 0.41 (0.15–1.15) >5.52: 1.24 (0.42–3.61)	0.06 0.09 0.70	N = 12 N = 12 N = 13
	Combined	Total duty cycle (%time)	Video-analysis Categorical (3)	<66.0: 1.00 (–) >66.0-<84.0: 1.43 (0.54–3.80) >84.0: 0.82 (0.28–2.43)	0.55 0.48 0.72	N = 11 N = 14 N = 12
	Combined	Forceful duty cycle (% time)	Video-analysis Categorical (3)	<2.4: 1.00 (–) >2.4-<21.8: 0.82 (0.07–9.20) >21.8: 0.77 (0.06–10.20)	0.98 0.88 0.84	N = 12 N = 13 N = 12
	Vibration	Vibration	Video-analysis Dichotomous (yes/no)	0.76 (0.26–2.22)	0.61	N = 37
	Posture	Abduction >30*	Video-analysis Categorical (3)	<11.9: 1.00 (–) >11.9-<21.3: 0.73 (0.23–2.33) >21.3: 0.80 (0.31–2.10)	0.85 0.59 0.65	N = 11 N = 10 N = 14
	Posture	Flexion >45*	Video-analysis Categorical (3)	<16.7: 1.00 (–) >16.7–28.2: 1.48 (0.55–3,98) >28.2: 0.54 (0.18–1.60)	0.17 0.44 0.27	N = 11 N = 12 N = 12
	Posture	Abduction >60*	Video-analysis Categorical (2)	<4.8: 1.00 (–) >4.8: 0.53 (0.26–1.11)	0.09 0.09	N = 22 N = 13
	Posture	Flexion >90*	Video-analysis Categorical (2)	<3.5: 1.00 (–) >3.5: 0.72 (0.33–1.58)	0.41 0.41	N = 22 N = 13

Acronyms: CS = cross-sectional, RCS = rotator cuff syndrome, SD = standard deviation, OR = odds ratio, RCT = randomized controlled trial, CI = confidence intervals, MVE = maximal voluntary electric activity, TWA = time weighted average, HAV = hand–arm vibrations.

[a] The datasets from several primary studies with a similar design were used and reanalyzed with respect to a new research question. None of the individual studies included in the pooled analysis is included in our systematic review independently.

Table D
Occurrence of Tendinosis, Tendonitis, and Tendon Lesion Depending on the Presence of Physical Exposure.

Author Publication year Study design Disorder	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds ratio (95%CI)	p	Results (descriptive)
Tendinosis/Tendonitis						
Dalbøge **2020 cohort (retrospective)** **Bicipital tendinosis prevalence**	Posture	Arm-elevation years	observer-report categorical (5)	*0:* 1.0 (–) *>0–2:* 1.6 (0.9–2.8) *>2–5:* 1.3 (0.7–2.6) *>5–10:* 1.7 (0.9–3.4) *>10–56*: 1.7 (0.9–3.1)	0.11	
	Repetition	repetition-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–1:* 1.5 (0.8–2.7) *>1–2:* **1.9 (1.0–3.6)** *>2–10:* 1.3 (0.7–2.3) *>10–68:* 1.4 (0.8–3.6)	0.231	The odds ratios (ORs) can be interpreted as hazard ratios.
	Force	force-years	observer-report categorical (5)	*<5:* 1.0 (–) *5:* 1.1 (0.6–2.2) *>5-7.5:* 1.2 (0.7–2.3) *>7.5-10:* 1.2 (0.6–2.5) >10–20: 1.8 (0.9–3.6)	0.094	The odds ratios (ORs) can be interpreted as hazard ratios.
	Vibration	HAV-years	observer-report categorical (3)	*0:* 1.0 (–) *>0–5:* 1.1 (0.7–1.9) *>5–58:* **2.0 (1.2–3.5)**	**0.02**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Combined	shoulder load-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–5:* 1.2 (0.6–2.3) *>5–10:* 1.3 (0.8–2.1) *>10–15:* 1.2 (0.5–3.0) *>15–20:* 1.4 (0.7–2.7)	0.266	The odds ratios (ORs) can be interpreted as hazard ratios.
Dalbøge **2020 cohort (retrospective)** **Calcific tendinosis prevalence**	Posture	Arm-elevation years	observer-report categorical (5)	*0:* 1.0 (–) *>0–2:* 1.3 (0.9–1.7) *>2–5:* **1.5 (1.1–2.2)** *>5–10:* **1.6 (1.1–2.3)** *>10–56:* **1.6 (1.1–2.3)**	**0.005**	
	Repetition	repetition-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–1:* 1.3 (0.9–1.8) *>1–2:* 1.2 (0.8–1.9) *>2–10:* 1.2 (0.9–1.7) *>10–68:* 1.5 (1.0–2.1)	**0.036**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Force	force-years	observer-report categorical (5)	*<5:* 1.0 (–) *5:* 0.8 (0.5–1.2) *>5-7.5:* **1.3 (1.0–1.9)** *>7.5-10:* 1.2 (0.9–1.8) *>10–20:* 1.3 (0.9–2.1)	**0.028**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Vibration	HAV-years	observer-report categorical (3)	*0:* 1.0 (–) *>0–5:* 1.2 (0.9–1.6) *>5–58:* 1.1 (0.7–1.7)	0.333	The odds ratios (ORs) can be interpreted as hazard ratios.
	Combined	shoulder load-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–5:* 1.6 (1.1–2.2) *>5–10:* 1.2 (0.9–1.7) *>10–15:* 1.4 (0.8–2.5) *>15–20:* **1.8 (1.2–2.8)**	**0.006**	The odds ratios (ORs) can be interpreted as hazard ratios.
Nordander [a] **2016** **CS** **prevalence** **Bicipital tendonitis**	Combined	Trapezius muscle activity (% per %MVE) elevation & handgrip	observer continuous	*beta:* *p10:* **1.5 (0.5 - 2.4)** *p90:* **0.4 (0.1–0.6)**		reference (prevalence at 0.1% MVE): p10: women: 3, men: 2 p90: women: 2, men: 2 multivariate models: NR
Supraspinatus tendonitis	Combined	Trapezius muscle activity (% per %MVE) elevation & handgrip	observer continuous	*beta:* *p10:* **2.0 (0.9–3.1)** *p90:* **0.4 (0.1–0.6)**		reference (prevalence at 0.1% MVE): p10: women: 3, men: 3 p90: women: 2, men: 3 multivariate models: **5.4 (10.1 to -0.8)**
Infraspinatus tendonitis	Combined	Trapezius muscle activity (% per %MVE) elevation & handgrip	observer continuous	*beta:* *p10:* **1.8 (0.8–2.7)** *p90:* **0.5 (0.2–0.7)**		reference (prevalence at 0.1% MVE): p10: women: 1, men: 2 p90: women: 1, men: 2 multivariate models: **1.4 (0.8 to 2.1)**
Seidler **2011** **CC**	Force	cumulative lifting and carrying of loads ≥ 20 kg	self-report & and observer report categorical (4)	*no lifting/carrying of loads ≥ 20 kg:* 1.0 (–)		Exposed cases: no lifting/ carrying of loads ≥ 20 kg: 202 >0-<9.6 h: 52

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Table D (*continued*)

Author Publication year Study design Disorder	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds ratio (95%CI)	p	Results (descriptive)
prevalence Supraspinatus tendon lesion				*>0-<9.6 h:* 0.9 (0.5–*1.7)* *9.6-<77h:* 1.2 (0.6–2.1) *77-9.038 h:* 1.8 (1.0–3.)		9.6-<77 h: 77 77–9.038 h: 141 Exposed controls: no lifting/ carrying of loads ≥ 20 kg: 185 >0-<9.6 h: 35 9.6-<77 h: 36 77–9.038 h: 35
	Posture	cumulative work above shoulder level	self-report & and observer report categorical (4)	*no work above shoulder level:* 1.0 (–) *>0-<610 h:* 1.0 (0.6–1.8) *610-<3195 h:* 1.4 (0.8–2.4) *3195-64057 h:* **2.0 (1.1–3.5)**		Exposed cases: no work above shoulder level: 167 >0-<610 h: 52 610-<3195 h: 85 3195–64057 h: 173 Exposed controls: no work above shoulder level: 184 >0-<610 h: 36 610-<3195 h: 36 3195–64057 h: 36
Stenlund 1993 CS prevalence Tendonitis of the shoulder	Force	load lifted during a worklife	self-report categorical (3)	*right*: 1.04 (0.5–2.18) *left*: 1.55 (0.58–4.12)		
	Vibration	exposure to vibration	self-report categorical (3)	*right:* 1.86 (1.0–3.44) *left:* **2.49 (1.06–5.87)**		

Acronyms: CC = case control, CS = cross-sectional, MVE = maximal voluntary electric activity, HAV = hand–arm vibrations.
[a] The datasets from several primary studies with a similar design were used and reanalyzed with respect to a new research question. None of the individual studies included in the pooled analysis is included in our systematic review independently.

Table E
Occurrence of SIS, TOS, bursitis and Nonspecific Shoulder Disorder Depending on the Presence of Physical Exposure.

Disorder Author Publication year Study design	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds Ratio (95%CI)	p	Results (descriptive)
SIS						
Dalbøge 2020 cohort (retrospective) prevalence	Posture	arm-elevation years	observer-report categorical (5)	*0:* 1.0 (–) *>0–2:* **1.4 (1.4–1.5)** *>2–5:* **1.5 (1.4–1.6)** *>5–10:* **1.8 (1.7–2.0)** *>10–56:* **2.0 (1.9–2.2)**	**<0.001**	
	Repetition	repetition-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–1:* **1.2 (1.1–1.3)** *>1–2:* **1.6 (1.5–1.7)** *>2–10:* **1.5 (1.4–1.6)** *>10–68:* **1.9 (1.8–2.0)**	**<0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Force	force-years	observer-report categorical (5)	*<5:* 1.0 (–) *5:* 0.6 (0.7–0.8) *>5-7.5:* **1.2 (1.1–1.3)** *>7.5-10:* **1.5 (1.4–1.6)** *>10–20:* **1.7 (1.6–1.8)**	**<0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Vibration	HAV-years	observer-report categorical (3)	*0:* 1.0 (–) *>0–5:* **1.3 (1.2–1.4)** *>5–58:* **1.5 (1.4–1.6)**	**<0.01**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Combined	shoulder load-years	observer-report categorical (5)	*0:* 1.0 (–) *>0–5:* **1.4 (1.3–1.5)**	**<0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.

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Table E (*continued*)

Disorder Author Publication year Study design	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds Ratio (95%CI)	p	Results (descriptive)
				>5–10: **1.6 (1.5–1.7)** *>10–15:* **1.8 (1.6–2.0)** *>15–20:* **2.0 (1.9–2.1)**		
Holm **2016** **CC** **prevalence**	Combined	amount of pipette work	self-report & and observer report categorical (3)		**0.02**	Exposed cases: >0–2: 5 >2–5: 8 >5: 20 Exposed total: >0–2: 86 >2–5: 92 >5: 113 All exposure parameters were associated with case-control status, but cumulated amount of pipette work during the last 2 years presented the largest explanatory power in this respect, assessed by the partial correlation coefficient R. We therefore chose this as pipette exposure parameter. (cf. Table 1; the 9 "non-pipette" potential harmful lab tasks were parameterized analogously).
Chu **2021** **CS** **Prevalence**	Repetition	Repeating the same motions every few seconds	Observational Continuous	0.59 (0.22–1.61)	0.30	
	Repetition	A sequence of movements repeated more than twice per minute	Observational Continuous	0.59 (0.22–1.61)	0.30	
	Repetition	>50% of the cycle time involved performing the same sequence of motions	Observational Continuous	0.69 (0.25–1.91)	0.47	
	Posture	Large range of joint movement such as side to side or up and down	Observational Continuous	1.00 (0.29–3.42)	0.99	
	Posture	Awkward or extreme joint positions	Observational Continuous	0.76 (0.23–2.55)	0.66	
	Posture	Joints held in fixed positions	Observational Continuous	0.43 (0.15–1.17)	0.09	
	Posture	Stretching to reach items or controls	Observational Continuous	1.06 (0.38–2.91)	0.91	
	Posture	Twisting or rotating items or controls	Observational Continuous	0.2 (0.07–0.59)	**<0.01**	
	Posture	Working overhead	Observational Continuous	0.71 (0.23–2.19)	0.56	
	Force	Pushing, pulling, moving things	Observational Continuous	0.62 (0.23–1.69)	0.35	
	Force	Grasping/gripping	Observational Continuous	0.95 (0.34–2.6)	0.91	
	Force	Pinch grips i.e. holding or grasping objects between thumb and finger	Observational Continuous	1.02 (0.37–2.77)	0.97	
	Force	Steadying or supporting items or work pieces	Observational Continuous	0.4 (0.13–1.23)	0.10	
	Force	Shock and/or impact beint transmitted to the body from tools or equipment	Observational Continuous	0.29 (0.08–1.07)	**0.05**	
	Force	Objects creating localized pressure on any part of the upper limb	Observational Continuous	0.71 (0.24–2.05)	0.52	
	Vibration	Use any powered hand-held or hand-guided tools or equipment	Observational Continuous	0.71 (0.18–2.71)	0.61	
TOS						
Nordander [a] **2016** **CS** **prevalence**	Combined	Trapezius muscle activity (% per %MVE) elevation & handgrip	observer continuous	beta: p10: 0.4 (0.0–0.8) p90: **0.1 (0.0–0.2)**		reference (prevalence at 0.1%MVE): p10: 0 p90: 0 multivariate models: −0.7 (−2.1 to 0.6)
Turhan **2008** **CS** **prevalence**	Posture	awkward postures	observer-report unclear		ns	
Bursitis						

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Table E (*continued*)

Disorder Author Publication year Study design	Exposure domain	Exposure description	Exposure assessment Type of exposure data (levels of exposure)	Odds Ratio (95%CI)	p	Results (descriptive)
Dalbøge 2020 cohort (retrospective) prevalence	Posture	Arm-elevation years	observer-report categorical (5)	*0:* 1.0 (−) *>0–2:* 1.2 (0.9–1.7) *>2–5:* **1.6 (1.1–2.3)** *>5–10:* **1.6 (1.1–2.4)** *>10–56:* **1.7 (1.2–2.4)**	**<0.001**	
	Repetition	repetition-years	observer-report categorical (5)	*0:* 1.0 (−) *>0–1:* 1.1 (0.8–1.6) *>1–2:* 1.2 (0.8–1.8) *>2–10:* **1.5 (1.1–2.0)** *>10–68:* **1.6 (1.2–2.3)**	**0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Force	force-years	observer-report categorical (5)	*<5:* 1.0 (−) *5:* 0.6 (0.4–0.9) *>5-7.5:* 1.1 (0.8–1.5) *>7.5-10:* **1.5 (1.1–2.1)** *>10–20:* 1.4 (1.0–2.1)	**<0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.
	Vibration	HAV-years	observer-report categorical (3)	*0:* 1.0 (−) *>0–5:* **1.4 (1.1–1.7)** *>5–58:* 1.2 (0.8–1.8)	0.081	The odds ratios (ORs) can be interpreted as hazard ratios.
	Combined	shoulder load-years	observer-report categorical (5)	*0:* 1.0 (−) *>0–5:* 1.4 (1.0–2.0) *>5–10:* **1.6 (1.3–2.2)** *>10–15:* 1.8 (0.7–2.1) *>15–20:* **2.0 (1.4–2.9)**	**<0.001**	The odds ratios (ORs) can be interpreted as hazard ratios.
Nonspecific shoulder disorder						
Walker-Bone 2006 CS prevalence	Posture	arm-elevation (hours/day)	self-report dichotomous (2)	**4.9 (1.9–12.8)**		≤1 = reference Exposed cases: 8 Exposed controls: 158 Nonexposed cases: 28 Nonexposed controls: 1990
	Force	carrying weights on one side	self-report dichotomous (2)	1.9 (0.9–4.2)		Exposed cases: 16 Exposed controls: 645 Nonexposed cases: 20 Nonexposed controls: 1503

Acronyms: CC = case control, CS = cross-sectional, SIS = shoulder impingement syndrome, TOS = thoracic outlet syndrome, MVE = maximal voluntary electric activity, HAV = hand–arm vibrations.

[a] The datasets from several primary studies with a similar design were used and reanalyzed with respect to a new research question. None of the individual studies included in the pooled analysis is included in our systematic review independently.

Table F
Occurrence of Shoulder Disorders Depending on the Presence of Psychosocial Exposure.

Author Publication year Study designDisorder	Exposure domain	Exposure description	Exposure assessment & data type (level of exposure)	Odds Ratio (95%CI)	p	Results (descriptive)
RCS						
Arcury 2016 cohort (prospective) RCS prevalence	psychological demand	job demand	self-report categorical (4)	**3.8 (1.42–10.08)**	**0**	Total N = 215
	social support	Perceived supervisor control	self-report categorical (4)	3.45 (0.77–15.48)	0.1	Total N = 215

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Table F (*continued*)

Author Publication year Study designDisorder	Exposure domain	Exposure description	Exposure assessment & data type (level of exposure)	Odds Ratio (95%CI)	p	Results (descriptive)
	decision latitude	decision latitude	self-report categorical (4)	1.48 (0.28–3.49)	0.36	Total N = 215
	other	skill variety	self-report categorical (4)	0.78 (0.26–2.34)	0.66	Total N = 215
	other	work safety climate	self-report categorical (4)	1 (0.8–1.26)	0.96	Total N = 215
Bugajska **2013 cohort (prospective)** **RCS**	psychological demand	mental job demands	self-report unclear	1.05 (0.99–1.11)	0.092	
prevalence	social support	social support	self-report unclear	1.003 (0.91–1.10)	0.952	
	decision latitude	decision latitude	self-report unclear	0.986 (0.95–1.02)	0.386	
	job security	job insecurity	self-report unclear	1.122 (0.03–1.26)	0.233	
Balogh [a] **2019** **CS** **RCS**	psychological demand	job demand	self-report unclear	*beta:* *men:* **1.84 (1.10–3.07)** *women:* **1.48 (1.09–2.00)**	men: **sig** women: **sig**	Exposed: men: 735, women: 1878
prevalence	job control	job control	self-report unclear	*beta:* *men*: 0.65 (0.42–1.03) *women*: **0.55 (0.42–0.72)**	men: nonsig women: **sig**	Exposed: men: 754, women: 1897
	social support	job support	self-report unclear	*beta:* *men*: **0.43 (0.24–0.78)** *women*: **0.67 (0.50–0.90)**	men: **sig** women: **sig**	Exposed men: 753, women: 1884
Applegate **2017** **CS** **RCS** **prevalence**	job satisfaction	job satisfaction	self-report unclear			RCT: very satisfied: 22 (14.1%) satisfied: 77 (49.4%) neither: 41 (26.3%) dissatisfied: 15 (9.6%) very dissatisfied: 1 (0.6%) no RCT: very satisfied: 265 (24.8%) satisfied: 558 (52.2%) neither: 179 (16.7%) dissatisfied: 58 (5.4%) very dissatisfied: 10 (0.9%) RCT/total (OR, 95%CI): very satisfied: (Ref) — satisfied: 1.66 1.01–2.73 neither: 2.76 1.59–4.79 dissatisfied: 3.11 1.52–6.37 very dissatisfied: 1.21 0.15–9.85
Bodin **2012 cohort (prospective)** **RCS** **incidence**	psychological demand	high psychological demand	self-report dichotomous (2)		men: 0.091 women: 0.524	Exposed cases: men: no: 4.8% yes: 7.6% women: no: 7.9% yes. 6.5% Exposed total: men: no: 439 yes: 395 women: no: 305 yes: 308
	social support	low supervisor support	self-report dichotomous (2)		men: 0.208 women: 0.120	Exposed cases: men: no: 5.3% yes: 7.4% women: no: 6.2% yes.: 9.6% Exposed total: men: no: 511 yes: 323 women: no: 388 yes: 218

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Table F (*continued*)

Author Publication year Study designDisorder	Exposure domain	Exposure description	Exposure assessment & data type (level of exposure)	Odds Ratio (95%CI)	p	Results (descriptive)
	social support	low coworker support	self-report dichotomous (2)		men: **0.020** women: 0.301	Exposed cases: men: no: 5.2% yes: 10.3% women: no: 6.8% yes. 9.7% Exposed total: men: no: 687 yes: 145 women: no: 500 yes:103
	decision latitude	low decision authority	self-report dichotomous (2)		men: 0.444 women: 0.416	Exposed cases: men: no: 5.6% yes: 7.0% women: no: 6.7% yes: 8.4% Exposed total: men: no: 591 yes: 244 women: no: 376 yes: 238
	other	low skill discretion	self-report dichotomous (2)		men: 0.690 women: 0.537	Exposed cases men: no: 6.2% yes: 5.5% women: no: 8.2% yes: 8.4% Exposed total: men: no: 43 yes: 397 women: no: 376 yes: 236
Meyers 2021 Cohort (prospective) RCS	Decision latitude	Decision latitude	self-report Continuous	0.98 (0.95–1.02)	0.32	Beta = Hazard ratios
	Decision latitude	Decision authority	self-report continuous	0.98 (0.93–1.03)	0.48	Beta = Hazard ratios
	Decision latitude	Task control	self-report continuous	1.14 (0.75–1.75)	0.54	Beta = Hazard ratios
	Decision latitude	High vs. low decision latitude job strain category	self-report continuous	0.83 (0.42–1.66)	0.60	Beta = Hazard ratios
	Decision latitude	Task control (expanded version)	self-report continuous	1.10 (0.71–1.72)	0.67	Beta = Hazard ratios
	Social support	Coworker support	self-report continuous	1.12 (0.67–1.86)	0.67	Beta = Hazard ratios
	Job strain	Job strain categories (low strain, passive job, active job, job strain)	self-report categorical (4)	Low strain (reference group) Passive job: 1.46 (0.57–3.73) Active job: 1.74 (0.59–5.10) Job strain: 1.64 (0.59–4.52)	0.74 0.44 0.32 0.34	Beta = Hazard ratios
	Job demands	Workgroup pressure	self-report continuous			Beta = Hazard ratios
Tendinosis/Tendonitis						
Nordander [a] **2016 CS Bicipital tendonitis**	psychological demand	high job demand	Self report dichotomous (2)	beta: 0.05 (−0.03–0.13)		% per % exposed
	job control	low job control	Self report dichotomous (2)	beta: **0.07 (0.03–0.12)**		% per % exposed
	job strain	job strain	Self report dichotomous (2)	beta: **0.08 (0.02–0.14)**		% per % exposed
Nordander [a] **2016 CS Supraspinatus tendonitis**	psychological demand	high job demand	Self report dichotomous (2)	beta: 0.07 (0.00–0.14)		% per % exposed
	job control	low job control	Self report dichotomous (2)	beta: **0.06 (0.02–0.11)**		% per % exposed
	job strain	job strain	Self report dichotomous (2)	beta: **0.09 (0.03–0.14)**		% per % exposed
Nordander [a] **2016 CS**	psychological demand	high job demand	Self report dichotomous (2)	beta: 0.1 (0.0–0.2)		% per % exposed

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Table F (*continued*)

Author Publication year Study designDisorder	Exposure domain	Exposure description	Exposure assessment & data type (level of exposure)	Odds Ratio (95%CI)	p	Results (descriptive)
Infraspinatus tendonitis	job control	low job control	Self report dichotomous (2)	beta: **0.11 (0.05–0.17)**		
	job strain	job strain	Self report dichotomous (2)	beta: **0.1 (0.0–0.2)**		
SIS						
Chu 2021 CS	psychological demand	psychological stress	Self report categorical (4)	never: 1.19 (0.3–4.78) some periods: 1.45 (0.52–4.04) several periods: 0.41 (0.14–1.18) permanent: infinity	**0.02**	
	job strain	work-related physical fatigue	Self report categorical (4)	never or almost never: 0.35 (0.04–2.92) seldom: 1.24 (0.42–3.66) quite often: 0.84 (0.31–2.27) yes, nearly always: 2.34 (0.53–10.37)	0.52	
TOS						
Nordander [a] 2016 CS	psychological demand	high job demand	Self report dichotomous (2)	beta: 0.00 (−0.02–0.02)		% per % exposed
	job control	low job control	Self report dichotomous (2)	beta: 0.00 (−0.01–0.02)		% per % exposed
	job strain	job strain	Self report dichotomous (2)	beta: 0.01 (−0.01–0.03)		% per % exposed
Nonspecific shoulder disorder Walker-Bone 2006 CS	psychological demand	demands	self-report dichotomous (2)	no: 1.0 (–) yes: 1.1 (0.5–2.3)		
	job control	control	self-report dichotomous (2)	yes: 1.0 (–) no: 1.3 (0.4–4.1)		
	social support	support	self-report dichotomous (2)	yes: 1.0 (–) no: 0.4 (0.1–1.9) na: 0.8 (0.2–2.6)		

Acronyms: CC = case control, CS = cross-sectional, RCS = rotator cuff syndrome, SIS = shoulder impingement syndrome, TOS = thoracic outlet syndrome.
[a] The datasets from several primary studies with a similar design were used and reanalyzed with respect to a new research question. None of the individual studies included in the pooled analysis is included in our systematic review independently.

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