

Work-related risk factors for specific shoulder disorders: a systematic review and meta-analysis

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ABSTRACT

The objective of this systematic review and meta-analysis is to examine which work-related risk factors are associated with specific soft tissue shoulder disorders. We searched the electronic databases of Medline and Embase for articles published between 2009 and 24 March 2016 and included the references of a systematic review performed for the period before 2009. Primary cross-sectional and longitudinal studies were included when outcome data were described in terms of clinically assessed soft tissue shoulder disorders and at least two levels of work-related exposure were mentioned (exposed vs less or non-exposed). Two authors independently selected studies, extracted data and assessed study quality. For longitudinal studies, we performed meta-analyses and used GRADE (Grades of Recommendations, Assessment, Development and Evaluation) to assess the evidence for the associations between risk factors and the onset of shoulder disorders. Twenty-seven studies met the inclusion criteria. In total, 16 300 patients with specific soft tissue shoulder disorders from a population of 2 413 722 workers from Denmark, Finland, France, Germany and Poland were included in the meta-analysis of one case-control and six prospective cohort studies. This meta-analysis revealed moderate evidence for associations between shoulder disorders and arm-hand elevation (OR=1.9, 95% CI 1.47 to 2.47) and shoulder load (OR=2.0, 95% CI 1.90 to 2.10) and low to very low evidence for hand force exertion (OR=1.5, 95% CI 1.25 to 1.87), hand-arm vibration (OR=1.3, 95% CI 1.01 to 1.77), psychosocial job demands (OR=1.1, 95% CI 1.01 to 1.25) and working together with temporary workers (OR=2.2, 95% CI 1.2 to 4.2). Low-quality evidence for no associations was found for arm repetition, social support, decision latitude, job control and job security. Moderate evidence was found that arm-hand elevation and shoulder load double the risk of specific shoulder disorders. Low to very-low-quality evidence was found for an association between hand force exertion, hand-arm vibration, psychosocial job demands and working together with temporary workers and the incidence of specific shoulder disorders.

INTRODUCTION

Shoulder disorders are frequently reported in the working population, with varying prevalence rates for non-specific shoulder pain (SP) of up to 31%; for clinically assessed specific shoulder disorders such as rotator cuff syndrome (RCS) of up to 6.6% for men and 8.5% for women¹; and for incidences of surgery for subacromial impingement syndrome (SIS) of 11 per 10 000 person-years.² Moreover, in

numerous countries, work-related shoulder disorders are reported as frequently occurring compensation claims or occupational diseases in various jobs and sectors of industry.^{3–5}

Shoulder disorders represent various clinical diagnoses, varying from ICD-10 (International Classification of Diseases) codes M75.0–75.5, that is, adhesive capsulitis (M75.0), RCS—including tendinitis of the supraspinatus, infraspinatus and/or non-traumatic tears and ruptures—(M75.1), bicipital tendinitis (M75.2), calcific tendinitis (M75.3), impingement (M75.4) and bursitis (M75.5), to unspecified soft tissue disorders related to use, overuse and pressure (M70.9). Non-specific SP may be a precursor of specific shoulder disorders, but may also reflect adverse physical, psychological or psychosocial conditions.⁶ For work-related specific shoulder disorders, the biomechanical factors seem to be the most important; however, more recent research also stipulates that psychosocial factors may contribute to proximal factors such as biomechanical constraints.⁵ van Rijn *et al*⁷ concluded in their systematic review, based on cross-sectional studies, that highly repetitive work, forceful exertion in work, awkward postures and high psychosocial job demand are associated with the occurrence of SIS.

In primary clinical practice, however, the specific disease classifications of M75.1 through 75.5 are difficult to diagnose and are often assessed with the same medical interview and the physical tests. Moreover, they often present as mixed forms, for example, impingement and bursitis. In the Netherlands, a multidisciplinary guideline of the Dutch Association of Orthopaedics (2012) was recently developed for the diagnosis and treatment of subacromial pain syndrome (SAPS), including the diagnosis of M75.1–75.5,^{8,9} which is used as clinical outcome in this systematic review.

Knowledge of work-related risk factors associated with SAPS is important in order to initiate primary and secondary preventive interventions at worksites. Previous systematic reviews to determine work-related risk factors for specific soft tissue shoulder disorders^{7,10} do not include more recent studies with longitudinal study designs (eg, ref 2) that can assess work-related risk factors for the onset of specific shoulder disorders. This systematic review aimed to examine: (i) which work-related risk factors contribute to the onset of clinically assessed SAPS and (ii) to what extent these risk factors are associated with clinically assessed SAPS.



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METHODS

Protocol and registration

This review followed the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement and the study protocol was registered at PROSPERO (ID=CRD42016039059), <http://www.crd.york.ac.uk/PROSPERO>.

Study selection

Eligibility criteria

Primary cross-sectional, case-control and cohort studies were included when outcome data were described in terms of clinically assessed soft tissue shoulder disorder (present or not) and at least two levels of work-related exposure (exposed vs less or non-exposed) among a working population were reported in order to be able to retrieve or calculate a risk estimate.

Based on van Rijn *et al.*⁷ we defined six types of exposure: (1) force, (2) posture, (3) movement, (4) hand-arm vibration, (5) shoulder load as combined exposure measure and (6) psychosocial risk factors. Clinically assessed soft tissue shoulder disorders were grouped into SAPS, defined as all non-traumatic, usually unilateral, shoulder problems that cause pain, localised around the acromion, often worsening during or subsequent to lifting of the arm. The different clinical and/or radiological names, such as bursitis, tendinosis calcarea, supraspinatus tendinopathy, partial tear of the rotator cuff, biceps tendinitis (BT) or tendon cuff degeneration, are all part of SAPS.^{8,9}

All types of clinical assessments were eligible for inclusion, such as work anamnesis, physical tests, questionnaires on localised pain and imaging. Studies that described work-related risk factors in terms of job or occupation, physical workload, specific occupational activities such as repetitive arm movements, or postures such as arm elevation were eligible for inclusion. The studies had to describe workers in a real workplace setting and therefore no experimental studies were included. All types of exposure assessment were eligible for inclusion: self-reports, researcher observations or direct measurements. No additional criteria were formulated regarding latency between exposure and the presence or onset of the disorder or adjustment for confounders. The exclusion criteria concerning the outcome of clinically assessed soft tissue shoulder disorders were: nerve compressions, radiating pain from cervical spine, osteoarthritis and systemic diseases.

Data sources and search terms

We searched the electronic databases of Medline and Embase for studies between 2009 and 24 March 2016 as described in online supplementary appendix 1. Our PICO can be stated as: P=working population, I/C exposed/less or none exposed to a priori defined exposure categories, O=SAPS. To construct the search strategy (JGD, HFM) a reference set of 23 potentially eligible studies was collected. Of these, 17 studies were derived from the systematic review by van Rijn *et al.*⁷ 3 additional studies from a citation check of all these studies in Google Scholar and another 3 additional studies from an orienting (scoping) search. All 23 studies had to be retrieved to validate applied terms and concepts of the search strategy. Eligible studies before 2009 were retrieved from the systematic review by van Rijn *et al.*⁷

Data collection and analyses

Study selection process

Titles and abstracts were independently screened by two review authors (HFM, CF or PPFMK) to identify potentially

relevant studies. We used an online software tool to screen and assess references (<https://www.covidence.org>). The full texts of potentially relevant articles were assessed for eligibility against the inclusion criteria. Disagreement between review authors on the selection of studies for inclusion occurred in relation to about 5% of the references screened and was resolved by discussion.

Data extraction and management

Data were extracted by two review authors (HFM and CF) and checked by another review author (PPFMK). Data on the following were extracted from each article: author; country of study; study design (cohort, case-control or cross-sectional study); case definition of specific shoulder disorder; sources and number of participants; exposure definition; exposure assessment; exposure categories; risk estimate and adjustment for confounders.

Methodological quality assessment

Methodological quality was assessed for the studies that reported on risk factors; studies that reported on job title were analysed descriptively without quality assessment. The quality of the studies was independently assessed by two review authors (HFM, PPFMK or CF). For all study designs, the slightly adapted quality criteria (see online supplementary appendix 2) from the systematic review by van Rijn *et al.*⁷ were used. The quality criteria for exposure definition and assessment were reformulated into: (1) at least two aspects of duration, frequency and intensity of exposure; and (2) ≥ 3 exposure categories reported (in order to detect a dose-response).

In total, 16 items across five categories for quality assessment were assessed (see also online supplementary appendix 2): (1) study population, (2) assessment exposure, (3) assessment outcome, (4) study design and (5) data analysis. The criteria for each item were scored with 'positive', 'negative' or 'not clear'. There was disagreement about 19 out of 240 items, all of which were resolved by discussion. High quality was defined as ≥ 11 items scored as 'positive' out of 16 quality criteria.

Association measures between work-related risk factors or job title and SAPS

Risk estimates and the corresponding 95% CIs of the association between work-related factors and SAPS were extracted or calculated and summarised. Risk estimates concerning the association between job title and shoulder disorders were described and summarised. Three review authors (HFM, CF, PPFMK) discussed and decided on the risk estimates to be included in the meta-analysis.

Data synthesis

A descriptive analysis of all studies was performed, summarised, classified into categories of physical and psychosocial risk factors, and assessed for methodological quality.

Meta-analyses and quality of evidence

The selection of the work-related risk factors in the meta-analyses was based on: (1) sufficient contrast between reported exposure categories, that is, low versus high exposure; (2) clearly defined exposure criteria suitable for exposure assessment at worksites; and (3) effect estimates controlled for other non-work-related factors, as reported in the primary studies. Risk estimates for

both men and women were selected when the study provided only sex-specific estimates.

The meta-analysis was performed in line with the procedure described in Watanabe *et al.*¹¹: all risk estimates were transformed into a natural logarithm. The SE for a log-transformed OR was calculated based on the 95% CI for the risk estimate. A log-transformed OR and its SE were used for the meta-analysis in Review Manager (Cochrane Review Manager V5.3). For the main analysis, the main ORs and the SEs from selected studies were subjected to a random-effects model meta-analysis to estimate a pooled OR and its 95% CI.

The quality of evidence was assessed using the GRADE (Grades of Recommendations, Assessment, Development and Evaluation) framework for prognostic studies developed by Huguette *et al.*¹² The starting point for the quality of the evidence was 'high' for longitudinal studies that sought to confirm independent associations between the prognostic factor and the outcome ('Phase 2' explanatory studies). The evidence could decrease on the basis of five factors: study limitations, inconsistency, indirectness, imprecision and publication bias. Moreover, two factors: (1) study findings with moderate or large effect sizes (ie, lower limit of 95% CI, OR > 2.0) or (2) an exposure-response gradient, could lead to an upgrade of the quality of evidence. Four levels of quality were used: high, moderate, low and very low.

RESULTS

Selected studies

A PRISMA flow diagram of the study selection process is shown in figure 1. After excluding duplicates, 2744 references were retrieved from the databases and the systematic review by van Rijn *et al.*⁷ and assessed based on title and abstract. The full texts of 72 potentially eligible articles were then examined, of which 31 articles met the inclusion criteria, 4 of which contained the same study population and outcome of interest, resulting in 27 articles included in this review. Of the 27 articles, 12 described job title and sectors of industry, 13 described risk factors and 2 described both. Six diagnoses were studied: RCS or rotator cuff tendinitis, infraspinatus tendinitis, supraspinatus tendinitis, SIS, BT, SP with clinical test, all part of the SAPS case definition.

Job title and SAPS

Fourteen studies^{13–26} described the association between performing a specific job or working in a sector of industry and the occurrence of clinically assessed SAPS (including the diagnoses M75.1–75.5) (see online supplementary appendix 3). The following jobs and sectors had an increased risk of SAPS: assembly workers,¹⁴ fish processing workers,¹⁵ slaughterhouse workers,¹⁶ sewing machine operators,¹⁷ manual workers,¹⁹ fishermen,²⁰

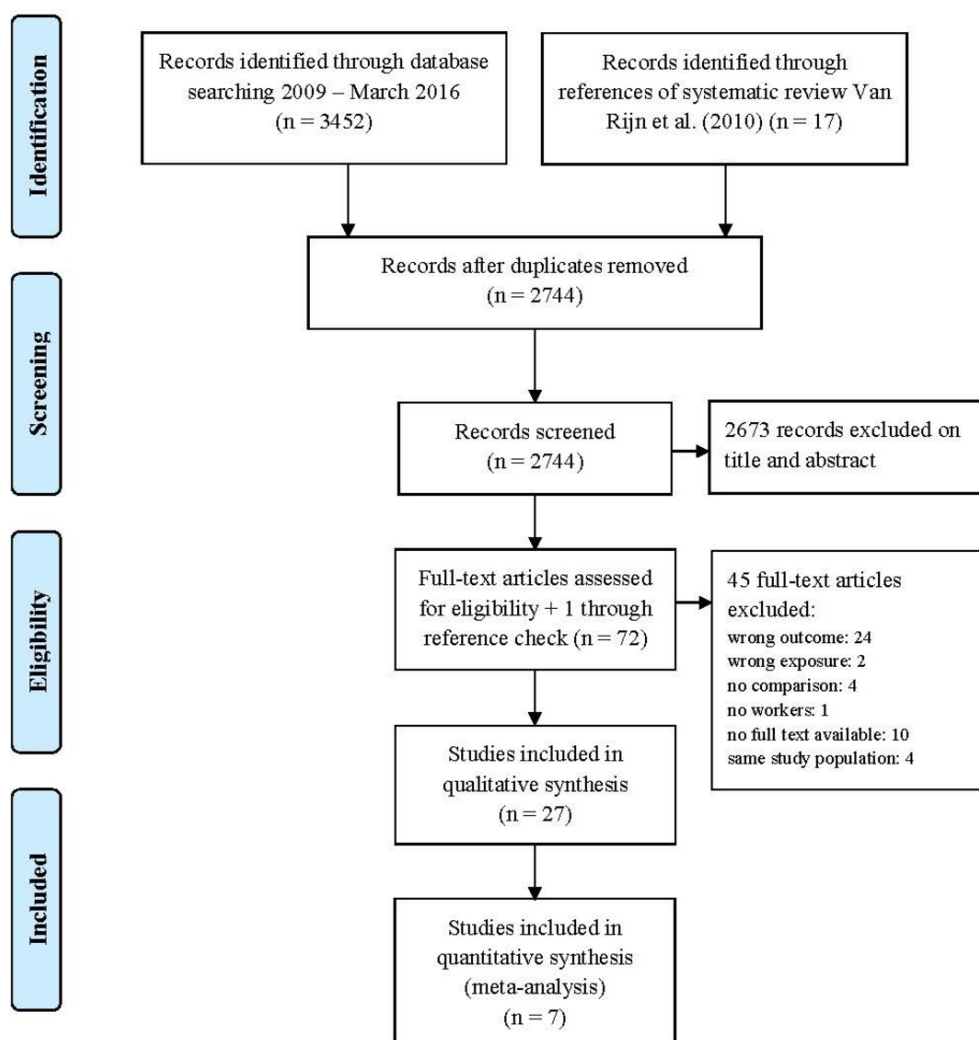


Figure 1 PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram.

construction and interior workers,²¹ metal workers,²¹ nurses,²⁴ and workers in the army, air force and marines.²⁵

Risk factors and SAPS

In total, seven longitudinal studies^{2 21 27–31} and eight cross-sectional studies^{6 22 32–37} described the association between exposure to physical and psychosocial risk factors and the occurrence of clinically assessed SAPS (see online supplementary appendix 4). The characteristics of the outcome definition (SAPS) and exposure definition (in intensity, frequency and duration) are presented in [table 1](#).

Methodological quality

The methodological quality of the studies of risk factors varied from scoring 7 out of 16 items to 16 out of 16 items (see [table 2](#)). The most frequently missing quality items were the lack of blinding for outcome status (ie, specific shoulder disorder) and the reverse, the lack of blinding for exposure status, as well as a lack of information about completers versus withdrawals from the study. All six cohort and one case-control studies met the quality level of ≥ 11 out of 16 quality criteria; among the eight cross-sectional studies five met ≥ 11 quality criteria.

Meta-analyses and assessment of evidence

In total, 16 300 patients with specific shoulder disorders from a population of 2 413 722 workers from Denmark, Finland, France, Germany and Poland were used in the meta-analysis. Two study populations were overlapping to some extent,^{2 31} therefore the risk estimates in the cohort study of Svendsen *et al*³¹ were censored by the original authors for the period from 1996 through 2002. [Figure 2](#) and additional figures in online supplementary material summarise the results of the meta-analyses, while [table 3](#) summarises the assessment of evidence concerning risk factors for specific shoulder disorders.

Arm elevation

Three cohort studies^{2 28 31} and one case-control study²¹ demonstrate that there is moderate quality evidence that arm elevation increases the incidence of SAPS, with a pooled OR of 1.91 (95% CI 1.47 to 2.47) ([table 3](#)), comparable to the pooled OR of 2.12 (95% CI 1.74 to 2.58) ([figure 2A](#)) when also including the cross-sectional studies (n=5) of sufficient quality.

Shoulder load

Two cohort studies^{2 31} demonstrate that there is moderate quality evidence that shoulder load increases the incidence of SAPS, with a pooled OR of 2.00 (95% CI 1.90 to 2.10) ([table 3](#) and [figure 2B](#)).

Hand-arm force exertion

Four cohort studies^{2 28 29 31} and one case-control study²¹ demonstrate that there is low-quality evidence that hand-arm force exertion increases the incidence of SAPS, with a pooled OR of 1.53 (95% CI 1.25 to 1.87) ([table 3](#)), comparable to the pooled OR of 1.56 (95% CI 1.26 to 1.93) (online supplementary figure 2.3) when also including the cross-sectional studies (n=3) of sufficient quality.

Arm-hand repetition

Three cohort studies^{2 29 31} demonstrate that there is low-quality evidence for no increased incidence of SAPS due to arm-hand repetition with a pooled OR of 1.42 (95% CI 0.91 to 2.22) ([table 3](#)), which is significantly lower compared with the pooled

OR of 1.70 (95% CI 1.18 to 2.46) (online supplementary figure 2.4) when also including the cross-sectional studies (n=2) of sufficient quality.

Hand-arm vibration

Three cohort studies^{2 27 29} and one case-control study²¹ demonstrate that there is low-quality evidence that hand-arm vibration increases the incidence of SAPS, with a pooled OR of 1.34 (95% CI 1.01 to 1.77) ([table 3](#)), comparable to the pooled OR of 1.34 (95% CI 1.02 to 1.76) (online supplementary figure 2.5) when also including the cross-sectional study (n=1) of sufficient quality.

Psychosocial demands

Three cohort studies^{29–31} demonstrate that there is low-quality evidence that psychosocial demands increase the incidence of SAPS, with a pooled OR of 1.12 (95% CI 1.01 to 1.25) ([table 3](#)), comparable to the pooled OR of 1.14 (95% CI 1.04 to 1.24) (online supplementary figure 2.6) when also including the cross-sectional studies (n=3) of sufficient quality.

Social support

Three cohort studies^{28 30 31} demonstrate that there is low-quality evidence for no increased incidence of SAPS due to low social support from colleagues and/or manager, with a pooled OR of 1.05 (95% CI 0.83 to 1.33) ([table 3](#)), comparable to the pooled OR of 1.02 (95% CI 0.84 to 1.24) (online supplementary figure 2.7) when also including the cross-sectional study (n=1) of sufficient quality.

Decision latitude

Two cohort studies^{29 30} demonstrate that there is low-quality evidence for no increased incidence of SAPS due to low decision latitude, with a pooled OR of 1.08 (95% CI 0.89 to 1.31) ([table 3](#)), which is comparable to the pooled OR of 1.01 (95% CI 0.81 to 1.25) (online supplementary figure 2.8) when also including the cross-sectional study (n=1) of sufficient quality.

Job control, job security and working with temporary workers

One cohort study³¹ demonstrates that there is low-quality evidence for no increased incidence of SAPS due to low job control, with an OR of 1.22 (95% CI 1.00 to 1.50). One cohort study³⁰ demonstrated that there is low-quality evidence for no increased incidence of SAPS due to low job security, with an OR of 1.12 (95% CI 0.93 to 1.36). One cohort study²⁸ demonstrated very-low-quality evidence that for female workers there is an increased incidence of SAPS when working together with temporary workers, with an OR of 2.2 (95% CI 1.2 to 4.2) ([table 3](#)).

DISCUSSION

Main findings

This systematic review, including a meta-analysis, revealed moderate evidence that arm elevation and shoulder load increase the incidence of specific shoulder disorders, with estimated pooled ORs around 2.0. Low to very-low-quality evidence was found for an association between hand force exertion, hand-arm vibration, psychosocial job demands and working together with temporary workers and the incidence of specific shoulder disorders. Low-quality evidence suggesting no associations was found for repetitive arm movements, social support, decision latitude, job control and job security.

Most longitudinal studies were controlled for the personal factors of age and sex, for non-work-related factors such as

Table 1 Definition and assessment of exposure and outcomes for studies included concerning risk factors (n=15)

Outcome (prevalence*, incidence†)		Exposure		Assessment		Assessment
Author (reference)	Definition	Definition	Definition	Assessment	Definition	
Frost <i>et al</i> ²² CS	Shoulder tendinitis: self-reported shoulder pain in combination with pain at resisted abduction, impingement pain and tenderness of the greater humeral tubercle*	Shoulder tendinitis: self-reported shoulder pain in combination with pain at resisted abduction, impingement pain and tenderness of the greater humeral tubercle*	Repetitive hand-arm movements (yes/no); frequency of shoulder movements, low: 1–14 movements/min, high: 15–36 movements/min; force requirements, low: <10% of MVC (1 on 1–5 scale), high: >10% of MVC (2–5 on 1–5 scale); micropauses in shoulder flexion (% of task), ≤80% of cycle time without pauses, >80% of cycle time without pauses	Questionnaire, physical examination	Observation by plant walk-through, video recordings, self-reported task distribution	Inclinometer measurement, torque index
Svensden <i>et al</i> ²³ CS	Supraspinatus tendinitis: increased signal intensity on T2-weighted images in two planes or focal areas of tendon discontinuity with T2 bright fluid signal or focal complete discontinuity of tendon fibres from articular to bursal surfaces or complete discontinuity of the tendon with atrophy of the muscle*	Supraspinatus tendinitis: increased signal intensity on T2-weighted images in two planes or focal areas of tendon discontinuity with T2 bright fluid signal or focal complete discontinuity of tendon fibres from articular to bursal surfaces or complete discontinuity of the tendon with atrophy of the muscle*	Lifetime upper arm elevation >90° (months), lifetime shoulder force requirements (low/medium/high)	MRI		
Svensden <i>et al</i> ²⁴ CS	Supraspinatus tendinitis: at least one sign of indirect tenderness (painful arc test positive, pain provoked by isometric abduction, Jobe's test positive) and at least one sign of direct tenderness (Hawkins's test positive, abduction internal rotation test positive)*	Supraspinatus tendinitis: at least one sign of indirect tenderness (painful arc test positive, pain provoked by isometric abduction, Jobe's test positive) and at least one sign of direct tenderness (Hawkins's test positive, abduction internal rotation test positive)*	Upper elevation above 90° (% of working hours), job demands; job control; social support	Physical examination	Inclinometer measurement, questionnaire	Interview, questionnaire
Miranda <i>et al</i> ⁶ CS	Rotator cuff tendinitis: history of pain in the rotator cuff region lasting for ≥3 months, pain during the month preceding the examination and pain in the rotator cuff region upon ≥1 resisted active movements: abduction of the arm (supraspinatus), external rotation of the arm (infraspinatus, teres minor) and internal rotation of the arm (subscapularis) or painful arc of shoulder abduction*	Rotator cuff tendinitis: history of pain in the rotator cuff region lasting for ≥3 months, pain during the month preceding the examination and pain in the rotator cuff region upon ≥1 resisted active movements: abduction of the arm (supraspinatus), external rotation of the arm (infraspinatus, teres minor) and internal rotation of the arm (subscapularis) or painful arc of shoulder abduction*	Frequent lifting, ≥5 kg, >2 times/min, >2 hours/day (year); heavy lifting, >20 kg, >10 times/day (year); working with hand above shoulder, ≥1 hour/day (year); work requiring high hand force, ≥1 hour/day (year); work requiring repetitive motion hand/wrist, ≥2 hours/day (year); working with a vibrating tool, ≥2 hours/day (year); job demands	Physical examination		
Sutinen <i>et al</i> ²⁷ Cohort	RCS: typical history of painful arch and intermittent pain and pronounced tenderness locally in the shoulder region were diagnostic or, in addition, at least one of the signs: painful arch test during elevation, pain in resisted abduction or resisted external rotation†	RCS: typical history of painful arch and intermittent pain and pronounced tenderness locally in the shoulder region were diagnostic or, in addition, at least one of the signs: painful arch test during elevation, pain in resisted abduction or resisted external rotation†	Lifelong vibration energy (m2/s4) hd	Questionnaire, physical examination	Measurements on chainsaw	Observation on-site and videotaped, questionnaire
Silverstein <i>et al</i> ³⁵ CS	RCS: shoulder pain or burning in past 12 months occurring ≥3 times or lasting >1 week, and shoulder pain or burning present in the previous 7 days, and no traumatic injury onset, and resisted shoulder abduction, external rotation, internal rotation, or a 'painful arc,' and no history of acute trauma to the shoulder or rheumatoid arthritis*	RCS: shoulder pain or burning in past 12 months occurring ≥3 times or lasting >1 week, and shoulder pain or burning present in the previous 7 days, and no traumatic injury onset, and resisted shoulder abduction, external rotation, internal rotation, or a 'painful arc,' and no history of acute trauma to the shoulder or rheumatoid arthritis*	Upper arm flexion and duty cycles of forceful exertion (%time): forceful exertion, pinch grip force ≥8.9 n (0.9 kg) or lifting objects weight, power grip or push/pull forces ≥44.1 n (4.5 kg); upper arm flexion and pinch grip force (% time); pinch grip force ≥8.9 n; decision latitude (low/high); job satisfaction (low/high); job security (low/high)	Questionnaire, physical examination		
Nordander <i>et al</i> ²⁶ CS	Supraspinatus tendinitis: shoulder pain; local tenderness over the tendon insertion; pain at resisted isometric abduction Infraspinatus tendinitis: shoulder pain; local tenderness over the tendon insertion; pain at resisted isometric outward rotation Bicipital tendinitis: 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)*	Supraspinatus tendinitis: shoulder pain; local tenderness over the tendon insertion; pain at resisted isometric abduction Infraspinatus tendinitis: shoulder pain; local tenderness over the tendon insertion; pain at resisted isometric outward rotation Bicipital tendinitis: 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)*	Head inclination (1st, 50th, 90th percentiles); head angular velocity (50th percentile); upper arm elevation (50th, 90th percentiles) and velocity (50th percentile); trapezius and forearm extensor muscles activity (10th, 90th percentiles); wrist flexion (10th, 50th, 90th percentiles) and angular velocity (50th percentiles); job demand (high/low); job control (high/low); job strain (high demand/low control); isostrain (job strain/low job support)	Questionnaire, physical examination	Direct measurement, job content questionnaire	Questionnaire
Seidler <i>et al</i> ²¹ CC	Supraspinatus lesion: shoulder pain and radiographic tear†	Supraspinatus lesion: shoulder pain and radiographic tear†	Lifting and carrying loads ≥20 kg in hours; work above shoulder level in hours; handheld vibration in years on job	Interview, MRI	Questionnaire	
Bodin <i>et al</i> ²⁸ Cohort	RCS: intermittent pain in shoulder region worsened by active elevation movement of upper arm currently or for ≥4 days during preceding 7 days and of following shoulder test positive: resisted shoulder abduction; external or internal rotation; resisted elbow flexion; painful arc on active upper arm test†	RCS: intermittent pain in shoulder region worsened by active elevation movement of upper arm currently or for ≥4 days during preceding 7 days and of following shoulder test positive: resisted shoulder abduction; external or internal rotation; resisted elbow flexion; painful arc on active upper arm test†	Perceived physical exertion (scale 6–20; high=man: ≥15, women: ≥14); repeated and sustained posture with arms above shoulder level (≥2 hours/day); coworker support (median score) JCQ; work with temporary workers; work organisation	Questionnaire, physical examination	Questionnaire	continued

Table 1 continued

Outcome (prevalence*, incidence†)		Exposure	
Author (reference)	Definition	Assessment	Assessment
Grzywacz <i>et al</i> ²² CS	RCS: pain with resisted abduction, internal rotation, external rotation or forward flexion of the shoulder, tenderness to palpation over the bicipital groove or lateral shoulder†*	Interview, physical examination	Job control (three items from 'seldom-never' coded 1 to 'almost always' coded 4); psychological demand (four items from 'seldom-never' coded 1 to 'almost always' coded 4); heavy load (12 items from 'seldom-never' coded 1 to 'almost always' coded 4); awkward posture and repeated movements (six items from 'seldom-never' coded 1 to 'almost always' coded 4); abusive supervision (three items from 'strongly disagree' coded 1 to 'strongly agree' coded 4); poor safety commitment (yes/no)
Herin <i>et al</i> ²⁹ Cohort	Incident chronic shoulder: 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	Considerable physical effort; physical effort with tools; carrying heavy loads; long, difficult working positions and awkward posture; precise movements and repetitive work; considerable vibrations and exposure to jolts; low decision latitude; high psychological demands
Bugajska <i>et al</i> ³⁰ Cohort	Rotator cuff tendinitis: positive results of at least one of the provocation tests; Nordic musculoskeletal questionnaire†	Questionnaire, physical examination	Decision latitude (no/yes); mental job demands (no/yes); job insecurity (no/yes); social support (no/yes); physical job demand (no/yes)
Svendsen <i>et al</i> ³¹ Cohort	Subacromial impingement syndrome: first-time surgery ICD-10: M19 or M75.1–M75.9†	Medical registry	Force (5-point force scale; 0=light and 4=near maximal); upper arm elevation >90°; repetitive movements (moderate: ≥4 to <15 movements of upper arm per minute, high: ≥15/min); shoulder load (high: ≥1 of force score ≥3, arm elevation >90° ≥1 hour/day, highly repetitive work ≥0.5 hour/day, moderate repetitive work ≥4 hours/day/medium: if highly repetitive work <0.5 hour/day and ≥1 of force score >1.5 <3, arm elevation >90° >0.5 to <1 hour/day, moderately repetitive work ≥2 to <4 hours/day/low: force score ≤1.5, arm elevation >90° <0.5 hour/day, moderate repetitive work <2 hours/day); job demands (high/low); job control (high/low); social support (no, from leaders and colleagues, leaders only, colleagues only)
Dalbøge <i>et al</i> ² Cohort	Subacromial impingement syndrome first-time surgery ICD-10: M19 or M75.1–M75.9†	Medical registry	Job exposure matrix assessments of years of arm elevation (>90°), repetitiveness, force and acceleration (HAV), shoulder load by five specialists in occupational medicine
Nordander <i>et al</i> ³⁷ CS	Bicipital or supraspinatus; infraspinatus*	Questionnaire, physical examination	Head inclination (1st, 50th, 90th percentiles); head angular velocity (50th percentile); upper arm elevation (50th, 90th percentiles) and velocity (50th percentile); trapezius and forearm extensor muscles activity (10th, 90th percentiles); wrist flexion (10th, 50th, 90th percentiles) and angular velocity (50th percentile); job demand (high/low), job control (high/low), job strain (high demand/low control), isostrain (job strain/low job support)

* (n=8).

† (n=7).

CC, case control; CS, cross-sectional study; HAV, hand-arm vibration; ICD, International Classification of Diseases; JCQ, Job Content Questionnaire; MVC, maximum voluntary contraction; RCS, rotator cuff syndrome.

Table 2 Methodological quality scores of 16 items for studies regarding risk factors*

Author	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Summary score
Frost <i>et al</i> ³²	+	+	+	+	+	?	+	+	+	–	–	–	–	+	+	+†	11
Svendsen <i>et al</i> ³³	+	+	+	+	+	+	+	+	+	–	+	–	?	+	+	+†	13
Svendsen <i>et al</i> ³⁴	+	+	+	+	+	+	+	+	+	–	+	–	+	+	+	+§	14
Miranda <i>et al</i> ⁶	+	+	+	+	+	–	+	+	?	–	+	–	–	+	+	+¶	11
Sutinen <i>et al</i> ²⁷	–	+	–	+	–	–	+	+	+	+	+	+	–	+	+	+**	11
Silverstein <i>et al</i> ³⁵	+	+	+	+	+	+	+	+	+	–	+	–	?	+	+	+††	13
Nordander <i>et al</i> ³⁶	+	?	+	–	–	+	+	+	–	–	+	–	–	+	–	–	7
Seidler <i>et al</i> ²¹	+	–	+	+	+	–	+	+	+	–	+	–	–	+	+	+††	11
Bodin <i>et al</i> ²⁸	+	–	+	+	+	–	+	+	?	+	+	+	+	+	+	+§§	13
Grzywacz <i>et al</i> ²²	+	+	+	–	–	–	+	+	?	–	+	–	–	+	+	+¶¶	9
Herin <i>et al</i> ²⁹	+	+	+	–	–	–	+	+	–	+	+	+	?	+	+	+***	11
Bugajska <i>et al</i> ³⁰	+	+	+	+	–	?	+	+	?	+	?	+	–	+	+	+†††	11
Svendsen <i>et al</i> ³¹	+	+	+	+	+	–	+	+	+	+	+	+	?	+	+	+†††	14
Dalbøge <i>et al</i> ²	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+§§§	16
Nordander <i>et al</i> ³⁷	+	?	?	+	+	+	+	+	?	–	+	–	–	+	+	+¶¶¶	10
Total item score	14	11	13	12	10	6	15	15	8	6	13	6	3	15	14	14	

*Criteria and scoring options for quality score for these 16 items are reported in online supplementary appendix 2.

†Adjusted for age, sex, body mass index, low pressure pain threshold, arthritis, shoulder trauma, sporting and leisure activities.

‡Adjusted for age.

§Adjusted for age, smoking.

¶Adjusted for body mass index, smoking, sporting activities, length of education, family status, region, language distribution, comorbidity, exposure categories in analyses.

**Adjusted for age.

††Adjusted for age, sex, body mass index.

‡‡Adjusted for age, region, sporting activities, exposure categories in analyses.

§§Adjusted for age, sex (separately analysed), exposure categories in analyses.

¶¶Adjusted for age, sex, indigenous language, exposure categories in analyses.

***Adjusted for age, sex, social class, body mass index, sporting activities.

†††Adjusted for age, sex, working hours, repetitive work, force.

‡‡‡Adjusted for age, sex, body mass index, smoking status, exposure categories in analyses.

§§§Adjusted for age, sex, region, calendar year at start follow-up.

¶¶¶Adjusted for age, sex, employment time, exposure categories in analyses.

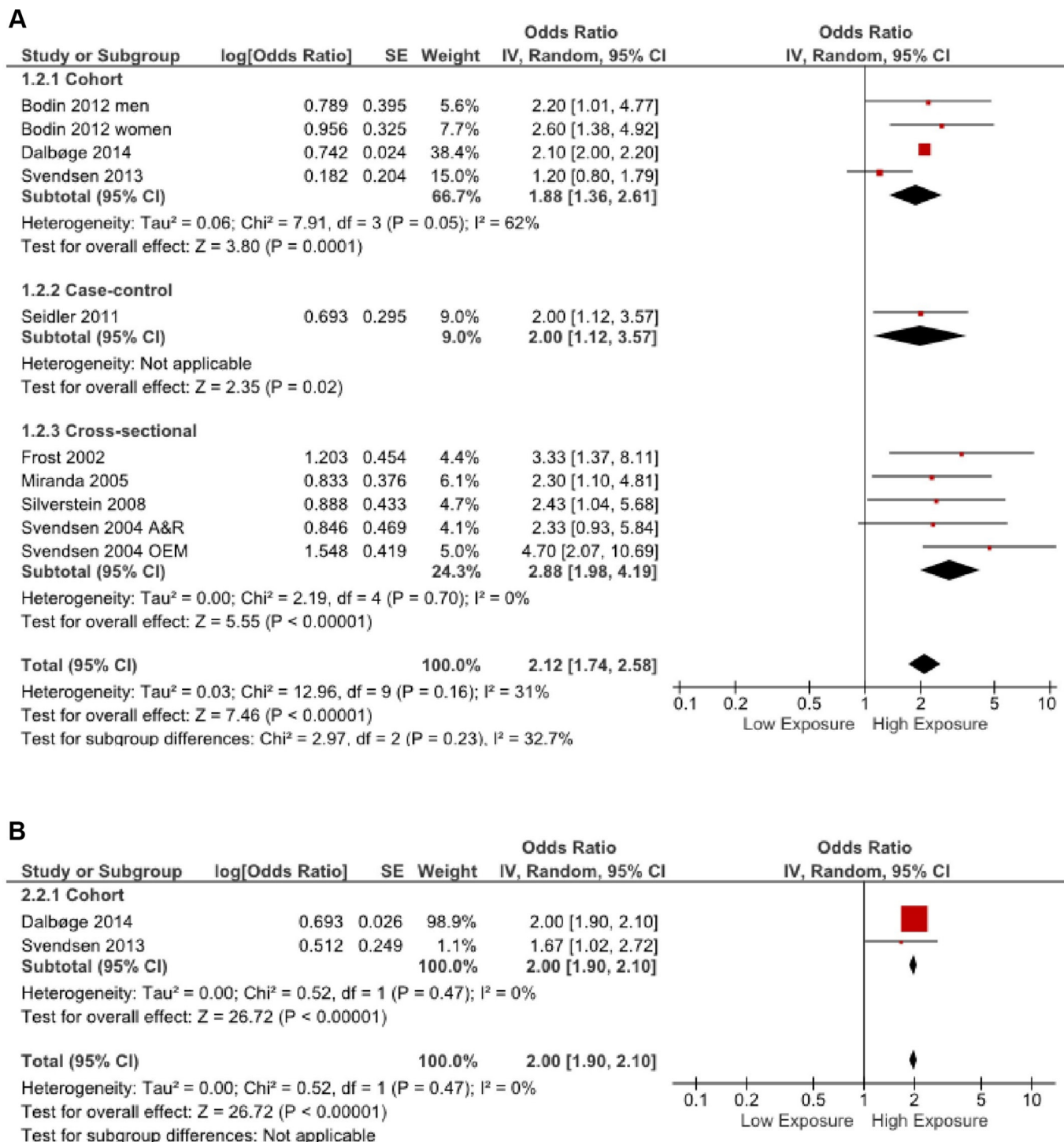


Figure 2 Forest plots. (A) Forest plot of studies regarding arm elevation and SAPS. (B) Forest plot of studies regarding shoulder load and SAPS. df, degrees of freedom; SAPS, subacromial pain syndrome.

specific leisure time or sport activities, and for other work-related factors. This could be a reason why the psychosocial factors were found to contribute little to the incidence of these specific shoulder disorders. The biological pathway for specific shoulder disorders seems to be biomechanical in nature (eg, ref³⁸), while psychosocial factors might act as more intermediating factors⁵ influencing these biomechanical factors.

This review confirmed and strengthened the evidence on risk factors as reported in the systematic review by van Rijn *et al.*⁷ Based on the more recent published prospective cohort and case-control studies used in our review, the most important

risk factors for clinically assessed soft tissue-specific shoulder disorders defined as SAPS are arm elevation and shoulder load in terms of combined physical exposures. Psychosocial factors seem to contribute to a much lesser extent in the onset of specific shoulder disorders.

Risk factors and SAPS

The exposure categories for the risk factors and the case definitions of the specific shoulder disorders varied in the included studies. Therefore, we have explicitly described all definitions

Table 3 Quality of the evidence for the relationship between risk factors and specific soft tissue shoulder disorders according to the GRADE framework

	Number of participants	Number of cases	Number of studies	Phase of investigation 1=explorative 2/3=explanatory Phase 1: ↓	Study limitations Study quality majority of studies <11/16: ↓	Inconsistency I^2 >50% or one study: ↓	Indirectness Yes: ↓	Imprecision CI effect size (<1 and >2, range >2) Yes: ↓	Publication bias Yes or unclear: ↓	Effect size OR (95% CI) Lower limit OR>2.0: ↑	Exposure-response gradient (dose effect) Majority of studies: ↑	Overall quality of evidence
Force exertion	2 412 945	16 199	5	2	Lower 'risk of bias'	66% ↓	No	No	Unclear ↓	1.53 (1.25 to 1.87)	2/5	Low
Arm elevation	2 400 231	14 844	4	2	Lower 'risk of bias'	50%	No	No	Unclear ↓	1.91 (1.47 to 2.47)	2/4	Moderate
Repetition	2 410 706	15 620	3	2	Lower 'risk of bias'	95% ↓	No	No	Unclear ↓	1.42 (0.91 to 2.22)	1/3	Low
Shoulder load	2 397 992	14 265	2	2	Lower 'risk of bias'	0%	No	No	Unclear ↓	2.00 (1.90 to 2.10)	1/2	Moderate
Hand-arm vibration	2 387 952	15 973	4	2	Lower 'risk of bias'	99% ↓	No	No	Unclear ↓	1.34 (1.01 to 1.77)	1/4	Low
Job demands	50 841	1996	3	2	Lower 'risk of bias'	62% ↓	No	No	Unclear ↓	1.12 (1.01 to 1.25)	0/3	Low
Social support	38 966	692	3	2	Lower 'risk of bias'	61% ↓	No	No	Unclear ↓	1.05 (0.83 to 1.33)	0/3	Low
Decision latitude	13 439	1439	2	2	Lower 'risk of bias'	84% ↓	No	No	Unclear ↓	1.08 (0.89 to 1.31)	0/2	Low
Job control	37 402	557	1	2	Lower 'risk of bias'	One study ↑	No	No	Unclear ↓	1.22 (1.00 to 1.50)	0/1	Low
Job security	725	84	1	2	Lower 'risk of bias'	One study ↑	No	No	Unclear ↓	1.12 (0.93 to 1.36)	0/1	Low
Work with temporary workers	614	45	1	2	Lower 'risk of bias'	One study ↓	No	Yes ↓	Unclear ↓	2.2 (1.2 to 4.2)	0/1	Very low

GRADE, Grades of Recommendations, Assessment, Development and Evaluation.

↓ signifies a downgrade of quality of the evidence; ↑ signifies an upgrade of quality of the evidence.

and assessments (see table 1) and reported outcomes (see online supplementary appendix 4). The variability in exposure categories of the retrieved risk factors, however, did not allow to combine comparable exposure levels across studies into more detail.

The variability in case definitions of specific shoulder disorders was partly due to the different clinical settings, which varied from a primary care setting to a clinical specialist. Although case definitions for the specific shoulder disorders varied, all studies in the formal and secondary meta-analyses clinically assessed these disorders using a combination of symptoms and signs in terms of diagnostic physical testing and/or imaging as recommended in the multidisciplinary guideline for diagnosis of SAPS.^{8,9} This guideline also proposes using a combination of clinical tests to increase post-test probability of a diagnosis of SAPS. Consequently, further research in the area of clinical assessment of specific shoulder disorders (eg,^{39,40} combined with more detailed exposure assessment in using intensity, duration and frequency of risk factors (eg, ref²) will contribute to a better insight into the pathogenic pathways and attributional fractions of worksite exposure.

Methodological considerations

Meta-analyses were performed to estimate pooled associations, although there was heterogeneity in the clinically assessed shoulder disorders and the assessment of exposure to risk factors in the longitudinal studies included in this review. For each risk factor we have chosen to contrast between the lowest and highest exposure category for answering our research questions whether or not an increased risk is present and to what extent. To prevent data-driven approaches, we did not select other exposures between low and high. Furthermore, a reported dose–response relation in the original studies was used in the GRADE assessment. For specific shoulder disorders we used the case definition of SAPS, although in two studies^{2,31} it was not possible to differentiate the results between SAPS diagnoses and a supposed small proportion of osteoarthritis cases.

Heterogeneity, however, was explicitly addressed through the grading of the quality of evidence. Publication bias was difficult to assess because of the small number of studies included in each risk factor. Taking cross-sectional studies into account—also including smaller study groups with and without statistically significant associations—made little difference to the estimates of the pooled ORs, with exception of repetitive arm movements. However, we treated the assessment of publication bias conservatively by downgrading the evidence in the case of lack of clarity.

In this systematic review based on a validated search in two databases, all three criteria for the establishment of work-related disorders⁴¹ were encountered, namely clinical diagnosis, exposure and evidence for causal relationships. Evidence for causal relationships was based on the meta-analyses and grading of the evidence. The choice of risk factors for the meta-analyses was transparent, and based on maximal contrast between exposure categories and feasibility of assessment for diagnosis and exposure assessment in general practice. Exploration of the formal meta-analyses (prospective cohort and case–control studies) by including cross-sectional studies yielded associations in the same direction.

Prevention

Knowledge of evidence-based work-related risk factors can stimulate primary and secondary prevention. Preventive actions to reduce arm elevation and shoulder load as combined

physical exposures, for example, hand force exertion and arm elevation, are recommended to prevent specific work-related shoulder disorders. Psychosocial demands and working together with colleagues in temporary employment were the only psychosocial factors that revealed significant associations with specific shoulder disorders in this review. It is possible that psychosocial factors play an intermediate role,^{5,38} and therefore should also be targeted in occupational preventive actions. In addition, as psychosocial factors play a more prominent role in the onset and prevalence of non-specific SP—through other biological pathways such as muscle strain from the neck and shoulder muscles—targeted interventions counteracting these factors might also be considered. There are indications that specific strength training^{42–44} or just general exercise training,⁴⁵ adjustment to furniture and equipment⁴⁶ and improving work techniques like taking more breaks and reducing work demands can reduce specific and non-specific shoulder disorders.⁴⁷

CONCLUSIONS

Arm-hand elevation and shoulder load double the risk of specific soft tissue shoulder disorders. Low to very-low-quality evidence was found for an association between hand force exertion, hand-arm vibration, psychosocial job demands and working together with temporary workers and the incidence of specific shoulder disorders.

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