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Occupational lifting, carrying, pushing, pulling loads and risk of surgery for subacromial impingement syndrome: a register-based cohort study

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ABSTRACT

Aim The aim was to examine exposure–response relations between surgery for subacromial impingement syndrome (SIS) and intensities of lifting/carrying and pushing/pulling loads during a 10-year time window.
Methods We conducted a register-based cohort study (2003–2008), comprising persons born in Denmark (1933–1977) with ≥5 years of work experience (N=2 374 403). Information on surgery for SIS was retrieved from the Danish National Patient Register (N=14 188). Occupational mechanical exposures comprising lifting/carrying loads ≥10 kg and pushing/pulling loads ≥50 kg were assessed by combining individual register-based job codes with our expert-based Shoulder job exposure matrix. We created three intensity-specific exposure duration variables by dividing the intensity for lifting/carrying and pushing/pulling loads into three categories (low, medium and high), and summed up number of years in each exposure category for a 10-year time window. The associations were analysed using logistic regression technique equivalent to discrete survival analysis.
Results The adjusted OR (OR_{adj}) increased with both exposure duration and intensity of lifting/carrying and pushing/pulling. For lifting/carrying, the OR_{adj} reached a maximum of 1.78 (95% CI 1.66 to 1.89), 2.52 (95% CI 2.32 to 2.74) and 2.96 (95% CI 2.53 to 3.47) after 10 years of exposures for the three exposure intensities. For pushing/pulling, maximum OR_{adj} was 1.44 (95% CI 1.31 to 1.58), 1.68 (95% CI 1.58 to 1.79) and 1.72 (95% CI 1.50 to 2.00), respectively.
Conclusion We found exposure–response relations for lifting/carrying and pushing/pulling across the 10-year time window. The risk was especially pronounced for lifting/carrying compared with pushing/pulling. We did not find indications of safe exposure intensities.

Key messages

What is already known about this subject?

⇒ Associations have been established between occupational mechanical exposures and subacromial impingement syndrome (SIS) in systematic reviews.
⇒ In one of our previous studies, highest risks were seen for forceful shoulder exertions.
⇒ The effect of exposure to different force activities such as lifting, carrying, pushing and pulling loads is less well studied.

What are the new findings?

⇒ The risk of surgery for SIS increased with both exposure duration and intensity of lifting/carrying and pushing/pulling loads during a 10-year time window.
⇒ The risk was highest for lifting/carrying compared with pushing/pulling loads.

How might this impact on policy or clinical practice in the foreseeable future?

⇒ Preventive efforts should focus on reducing exposure to lifting and carrying loads.

INTRODUCTION

Subacromial impingement syndrome (SIS) is considered a non-traumatic, usually unilateral disorder, in which subacromial tissues may be affected.[1] Thus, SIS encompasses a variety of disorders including tendinitis of the infraspinatus, supraspinatus and subscapularis tendons, tendinitis of the biceps tendons, subacromial bursitis and non-traumatic tears. The prevalence of SIS has been reported to be 2%–8% in general working populations, and 6%–10% in specific occupational groups with high mechanical exposures, for example, slaughterhouse workers, fish processing workers, sewing machine operators, and manufacturing and trade workers.[2–4]

Associations have been established between occupational mechanical exposures and SIS in systematic reviews.[2–6] In our systematic review, we found strong evidence of an association between combined mechanical exposures and SIS, and moderately strong evidence for forceful shoulder exertions, upper-arm elevation and repetitive shoulder movements. Limited evidence was found for hand-arm-vibrations (HAVs) and insufficient evidence for psychosocial exposures.[4]

In a recent systematic review, Seidler *et al* focused on deriving exposure–response relations.[5] Due to insufficient study numbers or different exposure measures, meta-analysis was only performed for working with upper-arm elevation, yielding a 21% (95% CI 4% to 41%) increased risk per 1000 hours of work above the shoulder. Using a newly developed analytical approach, we found safe exposure intensities for repetitive shoulder movements with a angular velocity <45°/s,[7] while two Swedish studies pointed to a threshold of 50°–60°/s.[8 9]

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In our previous study comparing the effect of forceful shoulder exertions, upper-arm elevation, repetitive shoulder movements and HAVs, the highest risk of surgery for SIS was found for force with a maximum adjusted OR (OR_{adj}) of 2.39 (95% CI 2.12 to 2.70) after 10 years with high force intensity.[7] In our study, we distilled out the effect of prolonged durations of different intensities of forceful shoulder exertions, while controlling for cumulative effects of other mechanical exposures (ie, upper-arm elevation, repetitive shoulder movements and HAVs). We were unable to identify safe levels of force intensities, which could be endured for up to 10 years without increasing the risk of SIS surgery.

In our study, we defined forceful shoulder exertion as mean shoulder force requirement for the entire workday, which includes several underlying activities such as lifting, carrying, pushing and pulling loads.[10 11] Few studies have evaluated the association between exposure to lifting and carrying loads and SIS.[12–17] In general, studies have found a tendency towards an association for exposure to lifting/carrying loads with OR_{adj} between 1.1 and 2.0. However, the results are difficult to compare due to methodological difference, for example, definition and assessment of exposure and outcome. In the systematic review of Hoozemans *et al*, it was concluded that there was strong evidence that pushing/pulling loads was associated with upper extremity symptoms, specifically for shoulder symptoms.[18] We are not aware of studies, which have evaluated the association between pushing/pulling loads and SIS. Further studies evaluating which specific underlying activities of forceful shoulder exertion that especially increase the risk of SIS is warranted.

The aim of the study was to examine exposure–response relations between surgery for SIS and intensities of lifting/carrying and pushing/pulling loads during a 10-year time window. The intention was further to provide insight into safe exposure intensities that even after prolonged exposure duration do not increase the risk of surgery for SIS.

METHODS

Study design and population

We conducted a register-based cohort study comprising all persons born in Denmark (excluding Greenland) from 1 January 1933 to 31 December 1977.[10] The flow chart and study population has previously been presented.[10] In brief, all study participants had to be alive and living in Denmark on 31 December 2002 according to Danish Civil Registration System,[19] with a minimum of 5 years full-time employment between 1 January 1993 and 31 December 2007. Employment information was retrieved from the Danish Supplementary Pension Fund Register.[20] We excluded all persons with previous shoulder surgery before 31 December 2002 according to the Danish National Patient Register (NPR).[21] The total study population comprised 2 374 403 persons. During follow-up from 1 January 2003 to 31 December 2008, 14 118 events of first time surgery for SIS were registered in NPR.[10] End of follow-up was defined as first occurrence of either surgery for SIS or other shoulder related surgery, emigration, disappearance, death or follow-up end date of 31 December 2008, which ever came first.

Outcome

Outcome was registered as first time surgery for SIS, classified according to International Classification of Diseases, 10th revision, with a main diagnosis within groups M19 (other and unspecified osteoarthritis) or M75.1–M75.9 (rotator cuff syndrome, bicipital tendinitis, calcific tendinitis, impingement syndrome, bursitis and other unspecific shoulder lesions) and a Danish Nordic Medico-Statistical Committee shoulder and upper arm surgery code KNBA, KNBE, KNBF (exploratory procedures, procedures on synovia and ligaments) or KNBG, KNBH, KNBK, KNBL, KNBM (acromioplasty, surgery on bursa, and tendons). We excluded persons with a subordinate diagnosis of adhesive capsulitis (M75.0).[10]

Exposures

From the Danish Employment Classification Module, we retrieved individual and year-by-year information on job codes (ie, Danish version of International Classification of Occupations from 1988 (D-ISCO 88)) in the timespan of 1993–2007. We converted the D-ISCO 88 codes into exposure intensity estimates for lifting/carrying and pushing/pulling loads by cross-tabulating the individual D-ISCO 88 codes with our general Shoulder job exposure matrix (JEM).[10 11 22 23] The Shoulder JEM includes all D-ISCO 88 codes collapsed into 172 job groups with information on mechanical exposure such as lifting/carrying loads ≥10 kg, pushing/pulling loads ≥50 kg, forceful shoulder exertions, working with upper arm-elevation, repetitive shoulder movements and HAVs.[11] For lifting/carrying loads, the Shoulder JEM includes information on number of hours with lifting/carrying activities per workday and frequency of lifting/carrying loads defined as the number of lifts or times carrying an object during 1 hour with lifting/carrying activities. For pushing/pulling loads ≥50 kg, the Shoulder JEM includes information on number of hours with pushing/pulling activities per workday and frequency of pushing/pulling loads defined as the number of push/pull during 1 hour with pushing/pulling activities.[11] The assessment of the exposure estimates was based on expert-ratings. Five occupational health physicians rated each exposure variable for each job group based on what they would expect to reach from a critical interview with a typical employee.[10 11] The mean of the five experts' ratings were included in the Shoulder JEM.

For each calendar year, we calculated the individual exposure intensity defined as the total number of lifting/carrying loads per workday by multiplying hours with lifting/carrying activity with the frequency of lifting/carrying loads per hour. For example, 2 hours with lifting/carrying activities and a frequency of 25 lifts or times carrying an object for each hour with lifting/carrying activities, provides a total number of 50 lifts or times carrying an object per workday (times/day). The exposure intensity for pushing/pulling was calculated in a similar way. The exposure intensity was adjusted according to the weekly working hours by the following proxy values: 1.00 (≥37 hours/week), 0.75 (≥28–<37 hours/week), 0.50 (≥18.5–<28 hours/week), 0.25 (≥9–<18.5 hours/week) and 0.00 (<9 hours/week)[10] as well as for years outside the labour market using data from the Employment Classification Module.[24] Missing exposure estimates for years with lacking D-ISCO 88 codes were filled out with that person's mean exposure intensity for years with available D-ISCO 88 codes.

Based on an evaluation of the exposure histogram, we created three intensity-specific exposure duration variables by dividing the intensity for lifting/carrying loads into low (>0.0–<10.0 times/day), medium (≥10.0–<50.0 times/day) and high (≥50.0 times/day) exposure to ensure large exposure groups with exposure contrast. Estimates regarding pushing/pulling loads were also divided into three intensity categories; low (>0.0–<0.5 times/day), medium (≥0.5–<2.5 times/day) and high (≥2.5 times/day). For each year during follow-up, we calculated individual exposure duration (years) by summing up the number of years in each exposure intensity category for a 10-year time window with a 1 year lag. This method of creating intensity-specific exposure duration variables has previously been described.[7]

Covariates

A priori, we decided to include register-based information on age, sex, region of residence, calendar year of follow-up and the number of the specific follow-up year as potential confounders.[7 10] Like in our previous study, we decided to use available information on socioeconomic status (SES) as a proxy for lifestyle factors.[7 10] Statistics Denmark provided information on SES, which we categorised as (1) self-employed, (2) top managers and upper level employees (top leaders in business and organisations and highly skilled white collar workers), (3) intermediate employees (white collar workers and skilled blue collar workers), (4) basic employees (unskilled blue collar workers and workers without mention of skill level) and (5) employees outside the labor-market (retired or unemployed). We also calculated 10-year cumulative occupational mechanical exposures using the pack-year concept of smoking (ie, arm-elevation years, repetition-years and force-years).[7] For example, for arm-elevation, a one arm-elevation-year was defined as working with elevated arm(s) >90° for 0.5 hours/day for 1 year.

Statistical analyses

We performed pairwise correlation analyses between the three intensity-specific exposure duration variables for lifting/carrying and pushing/pulling loads. We compared the intensity-specific exposure duration estimates during the 10-year time window of persons, who had first time surgery for SIS with the remaining persons in the cohort still at risk of first time surgery for SIS using logistic regression technique equivalent to discrete survival analysis.[25] The usage of logistic regression as survival analysis yields an OR, which can be interpreted as an HR. The statistical unit is person-years. In the crude analysis, all three intensity-specific exposure duration variables were included in the model. In the fully adjusted analysis, we additionally adjusted for age (five categories), sex, region of residence (five categories), calendar-year at start of follow-up (continuous), number of the particular follow-up year (continuous) and other cumulative occupational mechanical exposures (ie, arm-elevation-years, repetition-years and force-years).[7 10] Test for trends was performed with the three intensity-specific exposure duration variables as continuous. To test the robustness of our results, we changed the cut-off values for each of the three exposure intensity categories. For example, for the highest exposure intensity category of lifting/carrying loads, we changed the cut-off values from ≥50.0 times/day to ≥40.0 times/day, ≥45.0 times/day, ≥55.0 times/day and ≥60.0 times/day. For sensitivity analysis, we additionally adjusted for SES and restricted the study population to intermediate employees in two separate analyses. The intermediate group is the largest SES group, varies less according to lifestyle factors, and contains exposure contrast from no to high exposure. To test for potential exposure thresholds, we changed the exposure cut-off values for the low and medium exposure groups by stepwise reducing the upper limit for the low exposure group; increasing the number of observations in the medium exposure group.

RESULTS

Pairwise correlations between the three intensity-specific exposure duration variables for lifting/carrying loads ranged between −0.06 and −0.35. For pushing/pulling loads, the correlation ranged between −0.24 and −0.13. Table 1 shows the overall characteristic of the cohort participants, where sex, age, SES and pushing/pulling loads are shown in relation to lifting/carrying loads for the total of 13 322 922 person-years during follow-up (2003–2008). In the two highest exposure groups, men were over-represented and the oldest age group considerably under-represented. According to SES, top-managers and upper-level employees were most represented in the low exposure category, intermediate employees were evenly represented in low, medium and high exposure categories, and basic level employees were more represented in the high exposed category. Pushing/pulling groups were increasingly represented in high exposed category of lifting/carrying.

Table 1 Characteristics of 13 332 922 person-years (PY) of follow-up (2003–2008) according to categories of lifting/carrying intensities

	Lifting/carrying intensity (≥10 kg (times/day)) (%)				
	=0	>0.0–<10	≥10–<50	≥50	Total
	PY=6 700 690	PY=3 288 900	PY=2 816 420	PY=5 26 912	PY=13 322 922
Sex					
Male	48.3	40.6	64.7	84.6	51.3
Female	51.7	59.4	35.3	15.4	48.7
Age					
<35	11.8	17.3	18.2	18.6	14.8
≥35–45	25.9	31.7	32.8	35.1	29.1
≥45–55	23.0	30.3	28.7	27.6	26.2
≥55–65	27.7	19.5	19.5	18.2	23.6
≥65–70	11.6	1.2	0.8	0.5	6.3
Socioeconomic status					
Self-employed	1.9	2.1	3.1	1.1	2.2
Top managers and upper level employees	27.8	8.4	0.7	0.5	16.1
Intermediate employees	48.0	79.7	71.5	69.4	61.7
Basic employees	7.9	8.5	23.2	27.9	12.1
Employees outside the labour-market	14.4	1.3	1.5	1.1	7.9
Pushing/pulling≥50 kg (times/day)					
=0	100.0	15.1	12.1	8.8	56.9
>0.0–0.5	0.0	38.1	13.9	17.7	13.0
≥0.5–2.5	0.0	45.0	54.5	12.4	23.1
≥2.5	0.0	1.8	19.5	61.1	7.0

Occupational mechanical exposures were estimated using the Shoulder job exposure matrix.

figure 1 shows crude and adjusted ORs (OR_{adj}) of surgery for SIS in relation to the three intensity-specific exposure duration variables of lifting/carrying and pushing/pulling loads for the 10-year time window.

Lifting/carrying

The OR_{adj} increased with both exposure duration and intensity of lifting/carrying loads. OR_{adj} for low, medium and high exposure intensity reached a maximum after 10 years of exposure with OR_{adj} of 1.78 (95% CI 1.66 to 1.89), 2.52 (95% CI 2.32 to 2.74) and 2.96 (95% CI 2.53 to 3.47), respectively. Test for trends showed p values of 0.000 for the three intensity-specific exposure duration variables. In the robustness analysis, small changes in exposure cut-off values showed no overall change in OR_{adj}. When controlling for SES, OR_{adj} did not change much (max OR_{adj} for the highest exposure group was 2.74 (95% CI 2.33 to 3.21)), and we found similar results when restricting the population to intermediate employees (max OR_{adj} for the highest

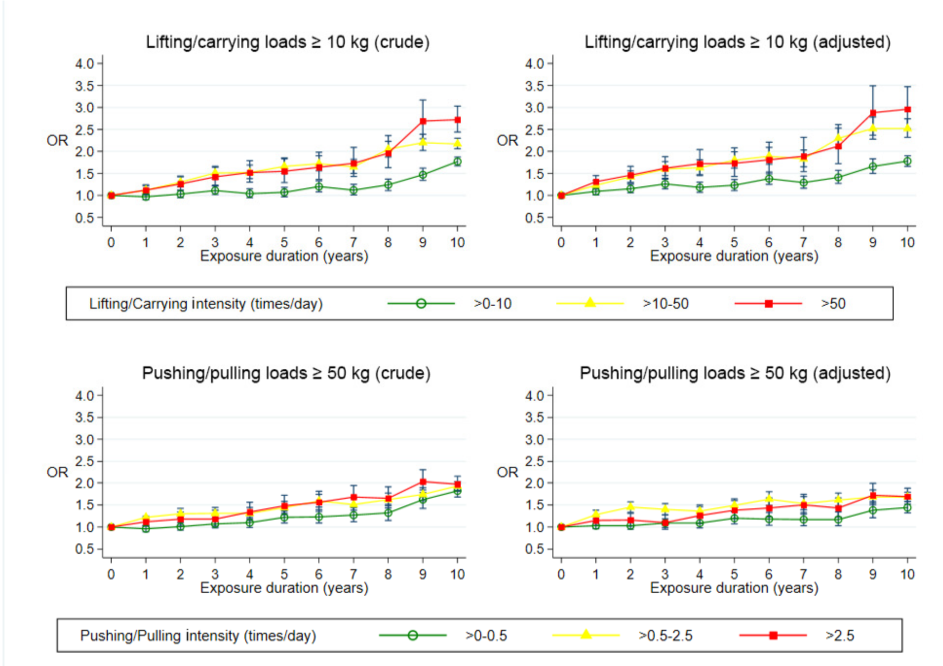

Figure 1 ORs with 95% CIs of surgery for subacromial impingement syndrome in relation to duration of exposure (years) at different exposure intensities for lifting/carrying and pushing/pulling across 10-year exposure time windows. Graphs to the left are crude ORs*, while graphs to the right are fully adjusted ORs†. *Each curve is adjusted for durations of exposure in the two other intensity categories above minimal. †Additionally, adjusted for age, sex, region of residence, calendar year at start of follow-up, the number of the particular follow-up year and cumulative effects of other occupational mechanical exposures.

exposure group was 2.51 (95% CI 2.06 to 3.04)). When testing for exposure thresholds, the cut-off values for the low exposure group was gradually reduced to >0.0–<5.0 times/day which steadily reduced the OR_{adj} to 1.49 (95% CI 1.35 to 1.64) after 10 years with low exposure intensity.

Pushing/pulling

For pushing/pulling loads, the OR_{adj} increased with exposure duration and to less extent with intensity. OR_{adj} for low, medium and high exposure intensity reached a maximum after 9–10 years of exposure with OR_{adj} of 1.44 (95% CI 1.31 to 1.58), 1.68 (95% CI 1.58 to 1.79) and 1.72 (95% CI 1.50 to 2.00), respectively. Test for trends were highly significant (p values of 0.000). In the robustness analysis, we found no overall change in OR_{adj}. When adjusting for SES and restricting the population to intermediate employees, the OR_{adj} did not change much (maximum OR_{adj} for the highest exposure group was 1.52 (95% CI 1.31 to 1.76) and 1.46 (95% CI 1.27 to 1.67), respectively). When testing for exposure thresholds, the cut-off values for the low exposure group was reduced to >0.0–<0.25 times/day which reduced OR_{adj} to 1.33 (95% CI 1.18 to 1.51) after 10 years with low exposure intensity.

DISCUSSION

We found an increased risk of surgery for SIS for both exposure duration and intensity of lifting/carrying loads ≥10 kg and pushing/pulling loads ≥50 kg. There were higher risks for lifting/carrying loads compared with pushing/pulling loads. After 10 years with high intensity of lifting/carrying loads, the risk was almost three times higher among the most exposed compared with the non-exposed. For pushing/pulling loads, there was a maximum of 72% increase in risk compared with the non-exposed. We did not find indications of safe exposure intensities across the 10-year time window.

Our study originates from a well-established high quality nationwide cohort.[7 10 26] By using data from large national registers and our Shoulder JEM, we minimised several types of methodological bias, for example, selection bias as the cohort included the entire Danish working population with almost complete follow-up and differential misclassification as both outcome and exposure were assessed without recall bias. Furthermore, socioeconomic differences in access to surgery were minimised through the Danish public healthcare system which is financed through taxes. From 2003, the NPR mandatory included surgery codes from the private healthcare. Differences in surgery for SIS in relation to place of resident and calendar year were accounted for in the analyses.[10]

Our Shoulder JEM, although expert rated, has shown good predictive validity in several studies.[7 10 22 26–28] The good predictive validity of the JEM might be explained by the large exposure contrast between job groups.[23 29] Using our JEM, higher associations for shoulder pain was found compared with other types of upper body pain indicating that the Shoulder JEM seems to reflect shoulder exposures quite specifically.[28] In a validity study comparing the expert ratings of upper-arm elevation and repetitive shoulder movements, we found good validity of the expert-rated exposures when compared with the technical measured exposures in terms of ranking and explained variance.[23] We were not able to validate the expert ratings of carrying/lifting and pushing/pulling loads due to the lack of technical measurements. There are to our knowledge no specific validation studies on carrying/lifting or pushing/pulling loads based on JEMs.

We were able to adjust for potential confounders using register information (ie, sex, age, calendar year and region of resident).

On the other hand, the register design limited the ability to adjust for lifestyles factors such as smoking and body mass index, which have been identified as risk factors of surgery for SIS.[27] To avoid confounding of lifestyle factors, we used SES as a proxy and we restricted the study population to employees with intermediate level. The analysis did not change the estimate much, indicating no high risk of confounding, which was confirmed in our previous studies.[27 30] We did not adjust for SES in the adjusted analysis due to the risk of over-adjustment.

The intensity-specific exposure duration variables were not strongly correlated, which allowed us to incorporate all of them in the statistical analyses. We were also able to adjust for the cumulative effect of other occupational mechanical exposures. For both lifting/carrying and pushing/pulling loads, we a priori decided to mutually adjust for other occupational mechanical exposures including forceful shoulder exertions to isolate the effect of the exposure of interest. We expected that exposure to forceful shoulder exertion would have some element of either lifting/carrying and/or pushing/pulling activities within the variable, which could lead to over-adjustment. However, when adjusting for forceful shoulder exertion in the analyses of both lifting/carrying and pushing/pulling loads, both measure of associations increased. This might indicate that we were able to control for other less hazardous force activities included in forceful shoulder exertion. The robustness analyses did not significantly change the exposure–response relations.

Our results support the association between lifting/carrying loads and SIS found in some of the previous studies.[12–17] In general these studies found a tendency towards an association for exposure to lifting/carrying loads with OR_{adj} between 1.1 and 2.0.[12–17] To our knowledge, no study has evaluated the association between pushing/pulling loads and SIS or compared the effect of lifting/carrying loads with pushing/pulling loads and forceful shoulder exertion using the same study population, exposure assessment and outcome definition. Compared with our previous study, higher risks were found for lifting/carrying 2.96 (95% CI 2.52 to 3.47) compared with forceful shoulder exertion (OR_{adj} of 2.5 (95% CI 2.1 to 2.9),[7] while lower risks were found for pushing/pulling 1.72 (95% CI 1.50 to 1.99). These results indicate that among the different force activities, lifting and carrying loads, in particular, should be considered hazardous.

The aim of this study was partly to identify safe exposure intensities that could be considered safe even during longer periods of exposure. This was not possible as all exposure to lifting/carrying and pushing/pulling loads above minimal lead to an increase in risk of surgery for SIS either straight away for lifting/carrying loads, or after only a few years with pushing/pulling loads. In the search for exposure thresholds, the low exposure groups (lifting/carrying loads: $>0.0–<10.0$ times/day and pushing/pulling loads: $>0.0–<0.5$ times/day) were reduced to lifting/carrying loads: $>0.0–<7.5$ and $>0.0–<5.0$ times/day and pushing/pulling loads: $>0.0–<0.35$ and $>0.0–<0.25$ times/day, which did not provide indication for safe exposure intensities.

The clinical decision to offer surgery versus conservative treatment for SIS might be influenced by the patient's physical workload, which could lead to an overestimation of the association between pushing/pulling and carrying/lifting loads and SIS surgery. However, we have performed a series of studies of surgery for SIS with different exposure metrics, which have yield similar results to studies using clinical diagnosed SIS and even self-reported shoulder pain. This might indicate that our results for lifting/carrying and pushing/pulling loads could be generalisable to clinical diagnosed SIS and perhaps shoulder pain. The results from this study could probably be extended to other countries similar to Denmark.

The assessment of ergonomic exposures for the shoulder should include lifting/carrying and pushing/pulling loads to supplement the assessment of other known harmful exposures to the shoulder such as shoulder force, repetitive shoulder movements and upper-arm elevation. In clinical practice workers with shoulder pain should be advised to avoid or at least reduce lifting/carrying and pushing/pulling loads to maybe alleviate their shoulder pain. At the work place there are several technical solutions to reduce lifting/carrying and pushing/pulling loads.

In conclusion, we found exposure–response relations for both lifting/carrying and pushing/pulling loads across the 10-year time window. The risk was especially pronounced for lifting/carrying loads compared with pushing/pulling loads. We did not find indications of safe exposure intensities.

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Patient consent for publication Not applicable.

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