

## Clinical Study

## Risk factors for surgically treated cervical spondylosis in male construction workers: a 20-year prospective study

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## Abstract

**BACKGROUND CONTEXT:** Degenerative changes due to cervical spondylosis (CS) can detrimentally affect work ability and quality of life yet understanding of how physical exposure affects disease progression is limited.**PURPOSE:** To assess the associations between occupational physical exposures and occurrence of surgically treated cervical spondylosis (ST-CS) and early exit from the labor market via disability pension.**STUDY DESIGN/SETTING:** Prospective register study with 20 years follow-up period.**PATIENT SAMPLE:** Swedish construction workers participating in a national health surveillance project conducted between 1971 and 1993.**OUTCOME MEASURES:** Surgically treated cervical spondylosis (ST-CS) and early labor market exit at a minimum rate of 25% time on disability pension.**METHODS:** Associations between occupational physical exposures (job exposure matrix) and subsequent ST-CS (National Hospital in-patient register) and early labor market exit via disability pension (Swedish Social Insurance Agency register) were assessed in a cohort of male construction workers (n=237,699).**RESULTS:** A total of 1381 ST-CS cases were present and a 20 years incidence rate of 35.1 cases per 100,000 person years (95% confidence interval (CI) 33.2–36.9). Increased relative risk (RR) for ST-CS was found for workers exposed to non-neutral (RR 1.40, 95% CI 1.15–1.69), and awkward neck postures (1.52, 1.19–1.95), working with the hands above shoulder height (1.30, 1.06–1.60), and high upper extremity loading (1.35, 1.15–1.59). Increased risk was also present for workers who reported frequent neck (3.06, 2.18–4.30) and upper back (3.84, 2.57–5.73) pain in the 12 months prior to survey. Among workers with elevated arm exposure, higher risk was seen in those who also had more frequent neck pain. ST-CS cases took early retirement more often (41.3%) and at a younger age (53 years) than the total study cohort (14.8% and 56 years of age, respectively).**CONCLUSIONS:** Occupational exposure to non-neutral neck postures, work with hands above shoulders and high loads born through the upper extremities increased the risk for ST-CS and early retirement due to disability. Decreasing postural and load exposure is salient for primary, secondary, and tertiary prevention of CS. Neck pain was shown to be a prognostic factor for ST-CS, which stresses the importance of acting early and taking preventative action to reduce workplace exposure, and the need for systematic medical check-ups within primary or occupational care to mitigate disease progression and early labour market exit due to disability. © 2022 The Authors. Published by Elsevier Inc. This is an open access article under the CC BY license<http://creativecommons.org/licenses/by/4.0/>

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## Introduction

Neck pain is a serious global public health problem. An estimated two-thirds of the world's population will experience neck pain at some point in their lives [1], with severe disability resulting for approximately 5% of those [2]. Neck pain is often persistent and is the fourth ranked global cause for years lived with disability [3]; 50%–75% of those who experience neck pain will report it again 1 to 5 years later [4]. Neck pain is a contributor to poor physical health-related quality of life [5]. Social and economic consequences include diminished quality of life, functional and activity limitations, productivity losses and direct health care expenditures [6]. Neck pain has been linked to both physical (force, posture, repetition) [1,7] and psychosocial occupational exposures (demands, decision latitude and social support) [7], as well as hand-arm vibration [8] and whole-body vibration [9,10]. Increasing population awareness regarding risk factors and preventive strategies for neck pain is warranted to reduce the future burden of this condition [1].

Cervical spondylosis (CS), a common progressive degenerative change characterized by cervical intervertebral disc degeneration and osteophyte formation [11,12], is one specific cause of neck pain which can lead to severe disease status with major consequences for the individual in terms of work ability and quality of life. CS can include herniation, radiculopathy and myelopathy [2]. Radiographic evidence of CS changes are evident in nearly 50% of people over the age of 50 and 75% of people over the age of 65, yet CS is not always symptomatic. The majority of symptomatic cervical spondylosis cases are treated non-surgically with analgesics and conservative treatments. However, for severe cases with intractable pain, progressive neurological deficits, and symptoms of spinal cord affection, surgical intervention to decompress the spinal cord and/or cervical nerve root(s) with or without fusion may be indicated [12]. The literature on cervical spondylosis is quite sparse and of uneven quality compared to neck pain [13]. Challenges to systematic review include few specific variables analyzed [14], and variability in study design, population studied, outcome measures, and length of follow-up time [2,9].

Little is known about CS risk factors other than a positive trend with age (at least up to age 50), and suggested higher risk in women and those of shorter stature [7,14–18]. One relatively large Chinese study also found higher prevalence for lower education, higher body mass, sleeping less than 7 hours/day, mental work, high housework intensity, holding the same work posture 1–3 hours/day, and commuting to work by bicycle or motor vehicle rather than walking [16]. Increased prevalence of CS has been suggested for some job titles, including interventional electrophysiologists [19], grinders [20], heavy work, dentists, meat carriers, and miners [21], and for workers exposed to heavy loads on the head [22] and neck and shoulders

[20,21], however, few studies have adequately considered occupational risk factors for CS.

The aims of this study were to address the knowledge gap regarding occupational risk factors for the incidence of surgically treated cervical spondylosis in a large cohort of male construction workers, and to investigate its consequences in the form of early exit from the labor market.

## Materials and methods

A large cohort of male construction workers was followed prospectively for 20 years (1997–2016) to examine the association of occupational physical exposures with surgically treated spondylosis of the cervical spine. The study was approved by the Regional Ethical Review Board in Umeå (2017/16–31).

### Study cohort

The study cohort was selected from a total of 389,132 Swedish construction workers who participated in health examinations as part of a national health surveillance program performed by occupational health services ('Bygghälsan') conducted from the late 1960s until 1993. While participation was voluntary, at least 80% of eligible workers completed at least one health examination [23].

### Self-reported (Q50) sub-group of study cohort

An additional questionnaire ('Q50') was collected during health examinations conducted 1989–1993 which included self-reported exposure and pain data (five response options per question) including frequency of working with hands above shoulders, vibration exposure, extent to which work is variable, and frequency of pain and/or discomfort in the previous 12 months in the neck, shoulder and upper back regions. From the total Bygghälsan cohort, 87,500 workers responded to at least one of these questions; of these, 69,875 (including 385 cases) were included in the study cohort. We used this 'Q50' sub-group of our study cohort for whom individual-level exposure assessment data were available as complementary data to the JEM-based occupational group-level exposure analyses conducted on the full study cohort, as detailed below.

### Case definition

The Swedish national hospital in-patient registry was obtained for patients with main diagnoses including spondylopathies (M45-49) and other back disorders (M50-54) from the beginning of the adoption of the ICD-10 coding system in Sweden (January 1, 1997) until December 31, 2016. Record linkage was achieved using the unique personal number assigned to each Swedish resident. Cases were defined by first surgical treatment for spondylosis of the cervical spine,

including fusion, laminectomy, decompression or discectomy (ICD-10 codes: ABC10, ABC20, ABC30, ABC50, NAG39, NAG49, NAG69, NAG79).

To investigate exit from the labor market due to early retirement via disability pension, data were obtained from the Swedish Social Insurance Agency and registry linkage was again made using personal identification numbers. In Sweden, disability pension can be part- or full-time. We defined early retirement as a minimum of 25% time on disability pension.

### Exclusions

Workers for whom no job title was recorded in any medical examination or who were classified in the “other work” group were excluded since they could not be mapped onto the JEM. We limited our analysis to men as women comprised only 5% of the population and most belonged to the “other work” group. Workers were also excluded who: were younger than 16 at their first health examination; were unusually short (<150 cm) or tall (>200 cm); were missing height or weight data; or had died, emigrated, or had record of hospitalization due to cervical disc disorder prior to the start of the observation period in 1997. To focus on aetiology in the 16–70 age range, workers who turned 70 prior to

the start of the observation period were excluded from follow-up, and any workers turning 70 during follow-up were excluded the year in which they reached 70.

The remaining 237,699 workers comprised the study cohort (Fig. 1).

### Individual factors

Worker height, weight, age, smoking status and specific trade (“job title”) data were recorded on examination. BMI was calculated and classified as underweight ( $\text{BMI} < 18.5 \text{ Kg} \cdot \text{m}^{-2}$ ), normal ( $18.5 \leq \text{BMI} < 25 \text{ Kg} \cdot \text{m}^{-2}$ ), overweight ( $25 \leq \text{BMI} < 30 \text{ Kg} \cdot \text{m}^{-2}$ ), or obese ( $\text{BMI} \geq 30 \text{ Kg} \cdot \text{m}^{-2}$ ). Workers were categorized as ever, never, and unknown smokers.

### Occupational exposure – Job exposure matrix

Occupational health service experts classified job titles into 21 occupational groups which comprised jobs with similar tasks and workers with similar background training. A group was also made for unclassifiable jobs. Full details of the job-to-group mappings were previously presented [24].

Biomechanical exposure levels were assigned to occupational groups using a job exposure matrix (JEM) developed

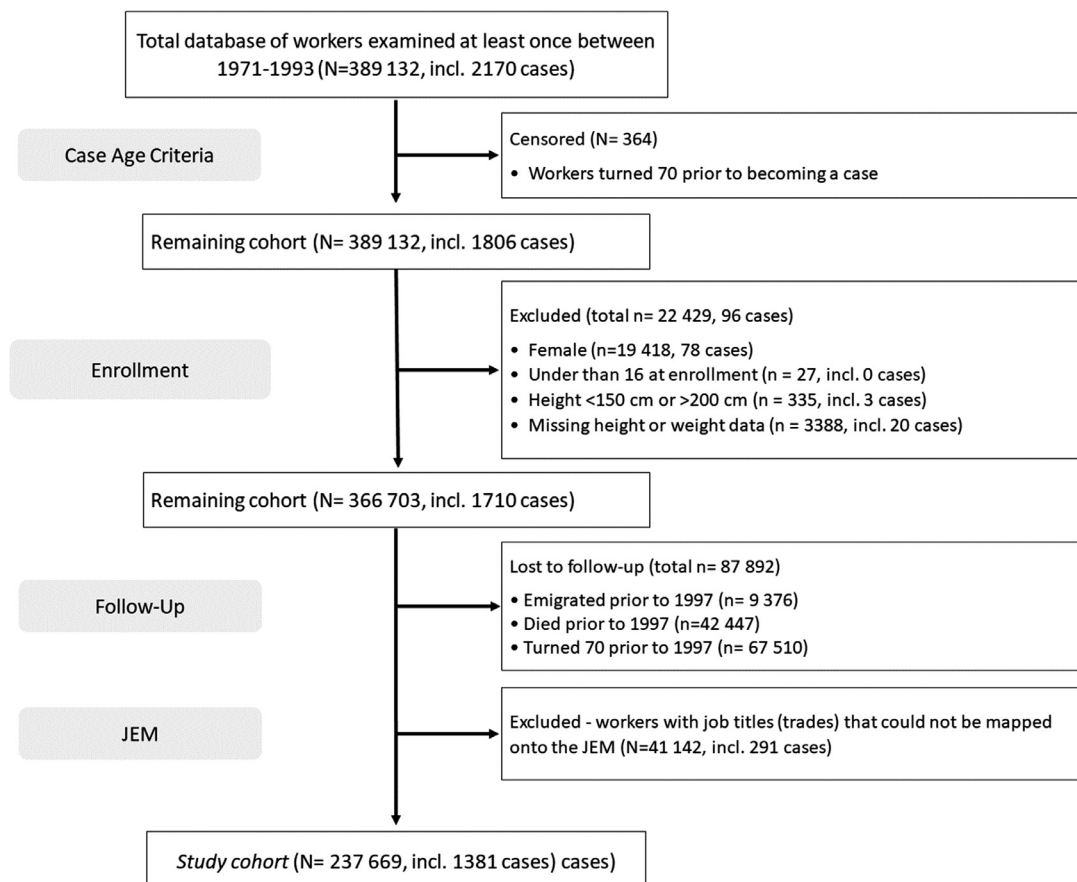


Fig. 1. Exclusion flow chart from total database to construction worker study cohort.

Table 1

Job exposure matrix for biomechanical risk factors. Assigned ratings reflect average daily exposure levels across all workers and all jobs and tasks for each occupational group

Exposure	Rating
Frequency of static non-neutral neck postures	1 – 3 <sup>a</sup>
Frequency of static extreme neck postures	1 – 3 <sup>a</sup>
Frequency of awkward neck postures	1 – 3 <sup>a</sup>
Frequency of work with arms above the shoulders	1 – 3 <sup>a</sup>
Upper extremity loading (push/pull/lift)	1 – 3 <sup>a</sup>
Hand-arm vibration exposure	1 – 3 <sup>b</sup>
Whole body vibration exposure	1 – 3 <sup>b</sup>

<sup>a</sup> 1 = low, 2 = moderate, 3 = high.

<sup>b</sup> 1 = none, 2 = acceptable, 3 = high.

for the study. The JEM contained three neck and two upper extremity exposure factors that were deemed *a priori* to be aetiologically relevant based on the available literature on cervical degeneration and disorders (Table 1). Two experts independently rated the average exposure intensity or frequency over a working day based on ergonomic assessments conducted in the 1970's for each job title (Jackson et al., 2019). All ratings were done blinded to the number of cases in each occupational group. Ratings were compared and discussed by the experts to resolve any disagreements. A single expert rated exposure to hand-arm vibration (HAV) and whole-body vibration (WBV) for all occupational groups. The two JEM experts reviewed the vibration ratings and, where necessary, disagreement was resolved through discussion with the vibration JEM rater.

Exposure estimates were assigned to each worker based on the JEM ratings for the occupational group corresponding to the job title reported at his last health examination. JEM ratings for each occupational group and biomechanical factor are presented in the appendix, Table A.1.

During health examinations conducted between 1989 and 1993, an additional questionnaire ('Q50') assessed frequency of neck, shoulder and upper back pain experienced in the 12 months prior to survey, along with self-reports on acceptability of occupational vibration (good to bad), frequency of work with hands above shoulders, and the extent of variation within work (five response options per question). A total of 87,500 workers responded to at least one of these questions; 69,402 of them (including 386 cases) were in the study cohort and were therefore included in our Q50 sub-group analyses. As this was a small proportion of the cohort, the self-reported exposures were used as complementary data but not to replace the JEM scores.

### Statistical analysis

Incidence rates of surgically treated cervical spondylosis were calculated for the study cohort over the follow-up period, 1997–2016 (Fig. 1). Person-years were summed from the start of follow up (January 1, 1997) until year of surgical treatment, or until the end of the observation period

(December 31, 2016), censoring for death, emigration, or fulfilling the 70-year age criteria. For comparison purposes, annual incidence rates for ST-CS were calculated for the general Swedish population of males aged 15–69 years, based on publicly available register data (Socialstyrelsen website, <https://www.socialstyrelsen.se/statistik-och-data/statistik/statistikdatabasen>) for the years 1998–2016 (data unavailable prior to 1998).

To account for potential confounding due to calendar time and age, the follow-up time was split into four periods of five years each. Crude associations between surgical treatment and each individual factor (age, BMI, smoking status, height) and each time period were estimated using Poisson regression. Potential interaction between age and time period was assessed in a separate Poisson regression model.

Poisson regression was then used to estimate relative risks (incidence rate ratios) and 95% confidence intervals (CIs) for the biomechanical factors, adjusted for age, BMI, smoking status, height and the four time periods. Age, BMI, and height were modelled using restricted cubic splines with three nodes at the 10th, 50th and 90th percentiles of corresponding variable. In all models, the lowest exposure rating was used as the reference category. This procedure was also repeated for the sub-set of the cohort for whom self-reports were available on pain frequency and exposure to work with hands above shoulders.

The distribution assumption of the Poisson regression models was assessed by examining outcome dispersions. All analyses were performed using R v4.0.3 [25] Poisson models were fitted using the `Glm` function in the `RMS` package [26].

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### Results

Within the study cohort (N=237,699), 3 940 034 person-years of observation were accrued. A total of 1381 individuals were treated surgically for cervical spondylosis during the follow-up period (1997–2016) (Fig. 1), for a 20-year incidence rate (IR) of 35.1 cases per 100 000 person years (95% CI 33.2–36.9). The IR rate (considered in 5 years intervals) increased across time during the follow-up period from 24.4 (1997–2001) to 49.1 (2012–2016) per 100,000 person years (Table 2); however, the distribution of cases across the age continuum was similar across all time periods (Fig. 2A), and there was no significant interaction between age groups and time periods ( $p=.21$ ).

The concurrent incidence rate for the same outcome among men aged 15–69 years in the general Swedish population was 48.0 (95% CI = 47.5–48.5). National data IR rates also increased over time, ranging from 31.1 (1998

Table 2

Individual factors (as categorical variables) and relative risk for surgically treated cervical spondylosis (N=237 669, incl. 1381 cases): crude Poisson regression models

	N	Person-years	Cases	IR	RR	95% CI
<i>Individual factors</i>						
<i>Height</i>						
180–190	79 136	1 385 959	490	35.4	1	—
150–160	569	7 708	4	51.9	1.47	0.55–3.93
160–170	25 126	372 141	123	33.1	0.94	0.77–1.14
170–180	125 637	2 041 402	729	35.7	1.01	0.90–1.13
190–201	7 201	132 824	35	26.4	0.75	0.53–1.05
<i>BMI</i>						
Normal	162 885	2 810 335	910	32.4	1	—
Underweight	3 665	69 222	15	21.7	0.67	0.40–1.11
Overweight	62 495	936 020	397	42.4	1.31	1.16–1.47
Obese	8 391	120 279	54	44.9	1.39	1.05–1.82
<i>Smoking</i>						
Never	104 114	1 829 246	465	25.4	1	—
Ever	121 416	1 918 760	839	43.7	1.72	1.54–1.93
Unknown	12 139	192 028	77	40.1	1.58	1.24–2.01
<i>Age</i>						
26–35	*	360 227	51	14.16	1	—
15–25	*	16 799	1	5.95	0.44	0.06–3.20
36–45	*	890 959	284	31.88	1.87	1.38–2.54
46–55	*	1 221 495	459	37.58	2.12	1.58–2.85
56–65	*	1 169 584	474	40.53	2.16	1.60–2.91
66–70	*	280 970	112	39.86	2.04	1.45–2.87

N, number workers; IR, incidence rate per 100,000 person-years; RR, relative risk; CI, confidence interval.

\* In assessment of age as a risk factor, workers contribute person years across all age categories in which they belong during the course of the study, thus the notion of ‘N’ as number of cases is not applicable in the same way for age as for all other factors.

–2001) to 61.6 (2012–2016). The increase was predominantly accounted for by increased rates of fusion surgeries with fixation (ICD10 surgery codes NAG 49 and NAG 79).

### Individual factors

Incidence rates of ST-CS were highest among workers in the 46–65 year age range, peaking around 55 for all decades within the follow-up period (Fig. 2A). Workers aged 46–65 had a RR of 2.1 compared with workers aged 26–35 (Table 2). There was an increased risk of ST-CS with higher BMI and having ever been a smoker (Fig. 2C

and Table 2). No clear association was evident with height (Fig. 2B and Table 2). Relative risks are presented for individual factors as categorical variables in the appendix, Table A.2.

### Occupational exposure

Increased risk of ST-CS was evident for plumbers, painters, drivers, and wood, concrete, sheet-metal, ground preparatory, asphalt and glass workers compared with the white collar and foreman workers in the reference group (RR 1.36–2.19) (Appendix – Table A.3)

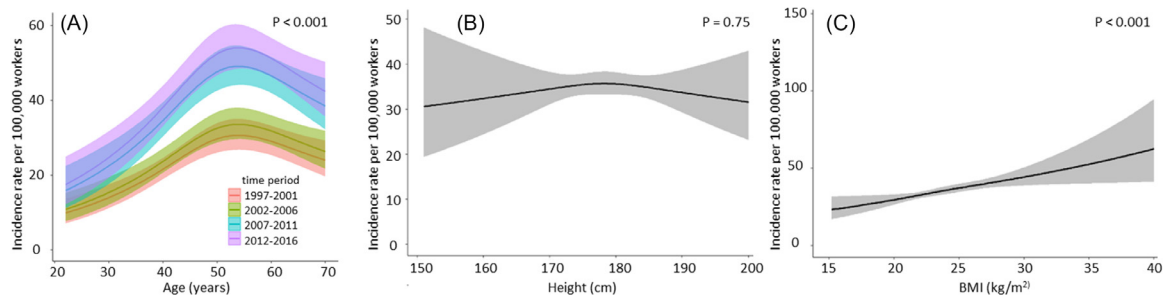


Fig. 2. Individual factors (modelled as continuous variables) and relative risk for surgery due to cervical spondylosis (n=1381) from crude models: (A) age – shown for each time period, (B) height and (C) BMI.

Table 3

Biomechanical exposure factors and relative risk for surgically treated cervical spondylosis. Poisson regression models adjusted for age, height, BMI, smoking and date of surgery. All estimates are for frequency of time spent working in the listed postures/under the listed loads, as judged by the expert JEM raters

	N	Person-years	Cases	IR	RR	95% CI
<i>Biomechanical factors</i>						
Frequency of static non-neutral neck postures						
Low	30 639	464 587	120	25.8	1	–
Moderate	153 233	2 537 447	956	37.7	1.40	1.15–1.69
High	53 797	938 000	305	32.5	1.27	1.03–1.58
Frequency of awkward neck postures						
Low	30 639	464 587	120	25.8	1	–
Moderate	185 364	3 111 745	1116	35.9	1.35	1.11–1.63
High	21 666	363 702	145	39.9	1.52	1.19–1.95
Frequency of static extreme neck postures						
Low	50 467	786 613	258	32.8	1	–
Moderate	168 150	2 826 041	992	35.1	1.07	0.93–1.23
High	19 052	327 380	131	40	1.25	1.01–1.54
Frequency of work with hands above the shoulders						
Low	64 286	1 002 793	323	32.2	1	–
Moderate	154 331	2 609 861	927	35.5	1.13	1.00–1.29
High	19 052	327 380	131	40	1.30	1.06–1.6
Upper extremity loading (push/pull/lift)						
Low	45 574	692 326	199	28.7	1	–
Moderate	101 367	1 726 115	602	34.9	1.25	1.06–1.47
High	90 728	1 521 593	580	38.1	1.35	1.15–1.59
Whole body vibration						
None	106 978	1 711 087	610	35.6	1	–
Acceptable	103 434	1 817 858	616	33.9	0.98	0.88–1.10
High	27 257	411 089	155	37.7	1.03	0.86–1.23
Hand-arm vibration						
None	213 500	3 557 290	1227	34.5	1	–
Acceptable	11 947	189 897	90	47.4	1.29	1.04–1.60
High	12 222	192 847	64	33.2	0.87	0.68–1.12

N, number workers; IR, incidence rate per 100,000 person-years; RR, relative risk; CI, confidence interval.

High exposure to any of the posture or load biomechanical factors - awkward or static extreme or non-neutral neck postures, working with hands above shoulders or having upper extremity loading - was associated with increased risk of ST-CS, with RRs in the range 1.25–1.52 (Table 3). Further, an exposure-response pattern was observed for all posture and load factors except frequency of static non-neutral neck postures. No association was found for vibration exposed workers (either hand-arm or whole body) and increased risk of ST-CS.

In the Q50 subgroup (29.4% of the cohort) from whom self-reported data were obtained, there were 385 CS cases (27.9% of the total case group); of these, 74.7% reported neck pain, and 82.5% reported neck and/or shoulder pain. The Q50 sub-group and the total study cohort had highly similar distributions of individual factors and occupational groups (Appendix tables A.4 and A.5).

The Q50 subgroup showed an exposure-response trend for frequency of work with hands over shoulder height (max RR = 1.86, 95% CI 1.30–2.67) (Table 4). Exposure-response trends were also suggested for pain in the preceding 12 months in both the neck (max RR 3.1, 95% CI 2.18–4.30), and upper back (max RR 3.8, 95% CI 2.57–5.73). Workers reporting poor working conditions

for vibration exposure also showed increased risk (IR 1.67, 95% CI 1.10–2.54). No clear association was found with variable work or shoulder pain in the preceding 12 months and ST-CS. Finally, the exposure-response trends in this subgroup produced higher risk estimates for workers with neck pain, which also increased with pain intensity (Table 5).

#### Early disability

In the entire male “Bygghälsan” construction worker cohort, 14.8% (n=35 292) took early retirement via disability pension and the mean age for start of early retirement was 56.2 years. In comparison, the ST-CS case group had a substantially higher rate of early retirement - 41.3% (n=570) - and a lower mean age at start of early retirement (53.2 years).

#### Discussion

This is the largest prospective cohort study to date to assess occupational physical risk factors for surgically treated cervical spondylosis (ST-CS: 1381 cases) and subsequent disability leave. ST-CS was associated with occupational exposure to non-neutral neck postures, working

Table 4

Self reported exposure and pain ratings and the relative risk for surgically treated cervical spondylosis in the Q50 sub-group of study cohort (N=69,402 including 386 cases) who provided self-reported exposure and pain information on health examination (1989-1995). Poisson regression models adjusted for age, height, BMI, smoking, and date of surgery

	N	Person-years	Cases	IR	RR	95% CI
<i>Self-reported exposure</i>						
<i>How often do you work with hands above shoulders?</i>						
Rarely	11 405	190 253	40	21.0	1	—
Quite rarely	5 768	100 850	25	24.8	1.21	0.73-2.00
Sometimes	15 629	272 354	91	33.4	1.66	1.14-2.41
Fairly often	18 160	321 189	120	37.4	1.86	1.30-2.67
Often	17 429	306 525	105	34.3	1.69	1.17-2.44
<i>What do you think about your current work environment in terms of vibrations?</i>						
Good	22 090	385 470	103	26.7	1	—
Fairly good	13 706	242 871	86	35.4	1.32	0.99-1.76
Acceptable	20 545	357 508	109	30.5	1.11	0.85-1.46
Pretty bad	6 207	107 034	35	32.7	1.18	0.80-1.73
Bad	3 406	57 771	28	48.5	1.67	1.10-2.54
<i>Is your work varied?</i>						
Rarely	1 835	30 706	10	32.6	1	—
Quite rarely	3 087	54 198	16	29.5	0.94	0.43-2.06
Sometimes	13 946	246 415	73	29.6	0.96	0.49-1.85
Fairly often	25 302	445 013	122	27.4	0.90	0.47-1.71
Often	24 460	418 232	157	37.5	1.22	0.64-2.31
<i>Self-reported pain/discomfort</i>						
<i>Frequency of neck pain/ache/discomfort during the last 12 months</i>						
Never	25 321	454 050	98	21.6	1	—
Rarely	12 468	220 881	62	28.1	1.29	0.94-1.77
Sometimes	17 694	305 151	90	29.5	1.32	0.99-1.76
Often	6 884	114 468	67	58.5	2.57	1.87-3.51
Very often	4 987	76 835	53	69.0	3.06	2.18-4.30
<i>Frequency of shoulder pain/ache/discomfort during the last 12 months</i>						
Rarely	1 835	30 706	10	32.6	1	—
Quite rarely	3 087	54 198	16	29.5	0.94	0.43-2.06
Sometimes	13 946	246 415	73	29.6	0.96	0.49-1.85
Fairly often	25 302	445 013	122	27.4	0.90	0.47-1.71
Often	24 460	418 232	157	37.5	1.22	0.64-2.31
<i>Frequency of upper back pain/ache/discomfort during the last 12 months</i>						
Never	33 332	592 717	141	23.8	1	—
Rarely	16 103	275 713	78	28.3	1.16	0.88-1.53
Sometimes	11 591	198 789	78	39.2	1.60	1.22-2.12
Often	3 372	57 513	30	52.2	2.09	1.41-3.10
Very often	1 874	30 296	29	95.7	3.84	2.57-5.73

N, number workers; IR, incidence rate per 100,000 person-years; RR, relative risk; CI, confidence interval.

Table 5

Self-reported ratings of neck pain and exposure to work with elevated arms and the relative risk for surgically treated cervical spondylosis in the Q50 sub-group of study cohort (N=69,402 including 386 cases). Poisson regression models adjusted for age, height, BMI, smoking and date of surgery

Neck pain in last 12 months	Frequency of work with hands above shoulders	N	Person-years	Cases	IR	RR	95% CI
Never	Rarely/quite rarely	10 965	189 824	31	16.3	1	—
	Sometimes	9 518	170 967	51	29.8	1.87	1.19-2.92
	Fairly often/often	167 88	306 028	76	24.8	1.56	1.03-2.38
Rarely/sometimes	Rarely/quite rarely	3 577	59 854	13	21.7	1.29	0.68-2.47
	Sometimes	3 713	62 711	19	30.3	1.81	1.02-3.21
	Fairly often/often	10 185	179 304	57	31.8	1.92	1.24-2.98
Often/very often	Rarely/quite rarely	2 147	33 352	18	54.0	3.10	1.73-5.56
	Sometimes	1 906	30 305	16	52.8	3.10	1.69-5.67
	Fairly often/often	7 577	124 397	85	68.3	4.05	2.68-6.12

with the hands above shoulder height, and upper extremity loading (RRs 1.25–1.52). An increased risk was also observed for workers who reported neck (RR 2.57–3.06) and upper back pain (RR = 2.09–3.84) in the 12 months prior to survey. Work with hands elevated had a higher increase in risk among those who also had more frequent neck pain. Finally, ST-CS cases took early retirement more often (41.3%) and at a younger age (53 years) than the total study cohort (14.8% and 56 years of age, respectively).

Surgical treatment was a proxy for a conclusive diagnosis. Surgery is typically reserved for cases with intractable pain, progressive neurological deficits, and indications of spinal cord involvement. The strict case definition would have under-counted the total number of construction workers with CS, as some would have avoided surgery. There could be some case misclassification in the register; this would likely be non-differential in regard to exposures and hence tending to decrease the RR estimate.

Biomechanical exposures were assessed using a cohort-specific JEM. Two raters independently evaluated historical records from ergonomists who detailed biomechanical exposures and tasks for each job title; this has been deemed the best available method for retrospective exposure assessment in cohort studies [27]. The original exposure evaluations were insufficient to facilitate comparison of specific biomechanical factors, such as specific neck postures or periods of static loading. Since the exposure factors in the JEM assess overlapping aspects, they are highly correlated. It is therefore difficult to isolate the influence of any individual factor (eg, static duration vs angle of non-neutral posture). The results must be viewed as proxies for complex exposure patterns and should not be interpreted simply as individual exposure–response associations for a given factor. The exposure factors also lack specificity for cumulative exposure or latency from first exposure to the date of surgery.

JEM ratings were made at the group level and thus did not account for any individual differences in work strategies or specific job assignments. JEM exposures were assigned using the job title reported at the first health examination, without adjustment for any potential changes in job during follow up. In Sweden, a large proportion of construction employees are skilled workers with relatively high income compared to other blue-collar workers, so they tend to stay in the industry. Still, it is likely that some workers changed jobs (trades), and also that the jobs themselves changed over time due to different work methods and technologies. No such changes were assessed or recorded, so they could not be reflected in the JEM. Further, workers who were sensitive to neck exposure or pain may have changed jobs earlier in their careers, resulting in an over-representation of non-sensitive persons – a so-called *healthy survivor* effect [28,29]. All the above limitations would tend towards an attenuated estimate of the risk. Any resulting over-estimation in person-time of observation would lead to under-estimation of disease rates. Adjustments were made in the

statistical analysis for potential confounders where data were available, but the direction and magnitude of residual confounding bias is difficult to assess.

In a highly representative subgroup of the study cohort ( $n=69,402$ ) with self-reported exposure and pain, risk of ST-CS was associated with time spent working with hands above shoulder height as measured both by JEM and self-report. The minor difference in RR magnitude could result either from JEM misclassification leading to underestimated risk or from systematic underestimation of exposures by workers leading to an inflated RR for self-reported data. Self-reported exposure to vibration, which did not distinguish between WBV and HAV, also suggested increased risk for ST-CS. This is consistent with an older report of increased risk of cervical disc herniation among professional drivers [30], although it was not confirmed by the JEM metrics where WBV and HAV were assessed separately.

The incidence rate for ST-CS was slightly lower than the concurrent national Swedish rate for males in the same age range; however, the national database includes repeated cases, while we considered only the first surgical treatment. Similar to some previous studies, we found that rates of surgically treated CS demonstrated an inverted U-shape with age [14,16,18] – showing a peak around age 55 in the present study. Workers with a history of smoking (current or former smokers at health examination) showed higher risk for ST-C which is in line with associations previously shown with smoking and neck pain [31] and smoking and cervical disc degeneration [32]. In the present, study BMI was also shown to be a risk factor for ST-CS. While consistent associations between BMI and pain have previously been demonstrated in the lumbar back region [33,34], evidence for the effect of body weight status on risk of cervical disorders or neck pain is less conclusive. Our finding of increased risk for ST-CS with increased BMI is in agreement with the positive trends [35,36] and associations [37] reported to date between obesity and cervical disc disorders and/or neck and/or shoulder pain. As obesity is a counter-indicator for surgery due to increased risk for poor post-operative outcomes [38–40], this may have led to underestimation of the risk in our cohort. Our data lend support to the notion of preventive measures aimed at reducing the incidence of overweight and obesity and support the hypothesis that obesity adds to the burden of neck pain and intervertebral disc disorders. The physiological mechanism behind the increased risk of higher BMI remains unclear. Our data did not confirm shorter stature as a risk factor [14–16,41].

Findings from the biomechanical risk factor analyses are in line with previously identified occupational risk factors for neck pain, namely, non-neutral neck postures [9,10] and heavy load in the hands [14]. In light of the very limited CS literature, our findings are notable given they identify that the same risk factors are specifically implicated

prospectively for symptomatic CS with the surgical outcome case definition.

The association between biomechanical exposure and risk of ST-CS may reflect both risk factors for the onset of CS and prognostic factors for workers who had previously developed symptoms. Decreasing non-neutral neck postures and work with hands above the shoulders is therefore salient for primary prevention as well as secondary and tertiary prevention of CS. This recommendation to reduce mechanical loading is in line with the broader ergonomic literature on preventing work-related neck disorders [42,43]. The combinatory effect of frequent work with hands above shoulder height and frequent neck pain underlined the importance of neck pain as a prognostic factor. This finding stresses the importance of systematic health assessment within primary or occupational care and early preventative action to reduce associated work place exposures to mitigate disease progression and early labour market exit due to disability.

## Conclusion

Occupational exposure to non-neutral neck postures, working with hands above shoulders and high loads born through the upper extremities were associated with increased risk for surgical treatment of cervical spondylosis and early retirement due to disability. Decreasing postural and load exposure is salient for primary, secondary, and tertiary prevention of CS. Neck pain was shown to be a prognostic factor for ST-CS, which stresses the importance of systematic health assessment within primary or occupational care and early preventative action to reduce workplace exposures to mitigate disease progression and early labor market exit.

## Data Sharing

The Bygghälsan database is managed by Umeå University and collaboration is welcomed, including sharing of deidentified participant data and data dictionary. More information and an application form for access to data are available at: <https://www.umu.se/forskning/infrastruktur/bygghalsokohorten>

## Conflict of Interests

One or more of the authors declare financial or professional relationships on ICMJE-NASSJ disclosure forms.

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## Supplementary materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1016/j.spinee.2022.08.009>.

## References

- [1] Safiri S, Kolahi AA, Hoy D, Buchbinder R, Mansournia MA, Bettampadi D, et al. Global, regional, and national burden of neck pain in the general population, 1990–2017: Systematic analysis of the Global Burden of Disease Study 2017. *BMJ* 2020;368. <https://doi.org/10.1136/bmj.m791>.
- [2] Binder AI. Cervical spondylosis and neck pain. *Br Med J* 2007;334:527–31. <https://doi.org/10.1136/bmj.39127.608299.80>.
- [3] Hoy D, March L, Woolf A, Blyth F, Brooks P, Smith E, et al. The global burden of neck pain: estimates from the global burden of disease 2010 study. *Ann Rheum Dis* 2014;73:1309–15. <https://doi.org/10.1136/annrheumdis-2013-204431>.
- [4] Carroll LJ, Hogg-Johnson S, van der Velde G, Haldeman S, Holm LW, Carragee EJ, et al. Course and prognostic factors for neck pain in the general population. results of the bone and joint decade 2000–2010 task force on neck pain and its associated disorders. *J Manipulative Physiol Ther* 2009;32:S87–96. <https://doi.org/10.1016/j.jmpt.2008.11.013>.
- [5] Nolet PS, Côté P, Kristman VL, Rezai M, Carroll LJ, Cassidy JD. Is neck pain associated with worse health-related quality of life 6 months later? A population-based cohort study. *Spine J* 2015;15:675–84. <https://doi.org/10.1016/j.spinee.2014.12.009>.
- [6] Caridi JM, Pumberger M, Hughes AP. Cervical radiculopathy: a review. *HSS J* 2011;7:265–72. <https://doi.org/10.1007/s11420-011-9218-z>.
- [7] Kim R, Wiest C, Clark K, Cook C, Horn M. Identifying risk factors for first-episode neck pain: a systematic review. *Musculoskelet Sci Pract* 2018;33:77–83. <https://doi.org/10.1016/j.msksp.2017.11.007>.
- [8] Wahlström J, Burström L, Hagberg M, Lundström R, Nilsson T. Musculoskeletal symptoms among young male workers and associations with exposure to hand - Arm vibration and ergonomic stressors. *Int Arch Occup Environ Health* 2008;81:595–602. <https://doi.org/10.1007/s00420-007-0250-8>.
- [9] Bovenzi M. A prospective cohort study of neck and shoulder pain in professional drivers. *Ergonomics* 2015;58:1103–16. <https://doi.org/10.1080/00140139.2014.935487>.
- [10] Flodin U, Rolander B, Löfgren H, Krapi B, Nyqvist F, Wåhlin C. Risk factors for neck pain among forklift truck operators: a retrospective cohort study. *BMC Musculoskelet Disord* 2018;19:1–10. <https://doi.org/10.1186/s12891-018-1956-3>.
- [11] Ferrara LA. The biomechanics of cervical spondylosis. *Adv Orthop* 2012;2012:1–5. <https://doi.org/10.1155/2012/493605>.
- [12] Theodore N. Degenerative cervical spondylosis. *N Engl J Med* 2020;383:159–68. <https://doi.org/10.1056/nejmra2003558>.
- [13] Wong JJ, Côté P, Quesnele JJ, Stern PJ, Mior SA. The course and prognostic factors of symptomatic cervical disc herniation with radiculopathy: a systematic review of the literature. *Spine J* 2014;14:1781–9. <https://doi.org/10.1016/j.spinee.2014.02.032>.
- [14] Singh S, Kumar D, Kumar S. Risk factors in cervical spondylosis. *J Clin Orthop Trauma* 2014;5:221–6. <https://doi.org/10.1016/j.jcot.2014.07.007>.
- [15] Ahmed SB, Qamar A, Imram M, Fahim MF. Comparison of neck length, relative neck length and height with incidence of cervical spondylosis. *Pakistan J Med Sci* 2020;36:219–23. <https://doi.org/10.12669/pjms.36.2.832>.
- [16] Lv Y, Tian W, Chen D, Liu Y, Wang L, Duan F. The prevalence and associated factors of symptomatic cervical Spondylosis in Chinese adults: a community-based cross-sectional study. *BMC*

- Musculoskelet Disord 2018;19:1–12. <https://doi.org/10.1186/s12891-018-2234-0>.
- [17] Schoenfeld AJ, George AA, Bader JO, Caram PM. Incidence and epidemiology of cervical radiculopathy in the United States military: 2000 to 2009. *J Spinal Disord Tech* 2012;25:17–22. <https://doi.org/10.1097/BSD.0b013e31820d77ea>.
  - [18] Wang C, Tian F, Zhou Y, He W, Cai Z. The incidence of cervical spondylosis decreases with aging in the elderly, and increases with aging in the young and adult population: a hospital-based clinical analysis. *Clin Interv Aging* 2016;11:47–53. <https://doi.org/10.2147/CIA.S93118>.
  - [19] Birnie D, Healey JS, Krahn AD, Ahmad K, Crystal E, Khaykin Y, et al. Prevalence and risk factors for cervical and lumbar spondylosis in interventional electrophysiologists. *J Cardiovasc Electrophysiol* 2011;22:957–60. <https://doi.org/10.1111/j.1540-8167.2011.02041.x>.
  - [20] Ålund M, Larsson S, Lewin T. Work-related persistent neck impairment: a study on former steelworks grinders. *Ergonomics* 1994;37:1253–60. <https://doi.org/10.1080/00140139408964903>.
  - [21] Hagberg M, Wegman DH. Prevalence rates and odds ratios of shoulder-neck diseases in different occupational groups. *Occup Environ Med* 1987;44:602–10. <https://doi.org/10.1136/oem.44.9.602>.
  - [22] Oguntona SA. Cervical spondylosis in South West Nigerian farmers and female traders. *Ann Afr Med* 2014;13:61–4. <https://doi.org/10.4103/1596-3519.129857>.
  - [23] Bergdahl IA, Torén K, Eriksson K, Hedlund U, Nilsson T, Flodin R, et al. Increased mortality in COPD among construction workers exposed to inorganic dust. *Eur Respir J* 2004;23:402–6. <https://doi.org/10.1183/09031936.04.00034304>.
  - [24] Jackson JA, Olsson D, Punnett L, Burdorf A, Järvholm B, Wahlström J. Occupational biomechanical risk factors for surgically treated ulnar nerve entrapment in a prospective study of male construction workers. *Scand J Work Environ Heal* 2019;45. <https://doi.org/10.5271/sjweh.3757>.
  - [25] R Core Team. R: A language and environment for statistical computing. R foundation for statistical computing, Vienna Austria. 2022. <https://www.R-project.org/>.
  - [26] Harrell FE Jr. rms: Regression Modeling Strategies. R package version 6.3-0. 2022. Available at: <https://cran.r-project.org/package=rms>
  - [27] T Mannetje A, Fevotte J, Fletcher T, Brennan P, Legoza J, Szeremi M, et al. Assessing exposure misclassification by expert assessment in multicenter occupational studies. *Epidemiology* 2003;14:585–92. <https://doi.org/10.1097/01.ede.0000072108.66723.0f>.
  - [28] Brown DM, Picciotto S, Costello S, Neophytou AM, Izano MA, Ferguson JM, et al. The healthy worker survivor effect: target parameters and target populations. *Curr Environ Heal Reports* 2017;4:364–72. <https://doi.org/10.1007/s40572-017-0156-x>.
  - [29] Punnett L. Adjusting for the healthy worker selection effect in cross-sectional studies. *Int J Epidemiol* 1996;25:1068–76. <https://doi.org/10.1093/ije/25.5.1068>.
  - [30] Jensen M, Tuchsén F, Orhede E. Prolapsed cervical intervertebral disc in 9 male professional drivers in Denmark, 1981–1990: a longitudinal study of 10 hospitalizations 1996:2352–5
  - [31] Hogg-Johnson S, van der Velde G, Carroll LJ, Holm LW, Cassidy JD, Guzman J, et al. The burden and determinants of neck pain in the general population. Results of the bone and joint decade 2000–2010 task force on neck pain and its associated disorders. *J Manipulative Physiol Ther* 2009;32:60–74. <https://doi.org/10.1016/j.jmpt.2008.11.010>.
  - [32] Kadow T, Sowa G, Vo N, Kang JD. Molecular basis of intervertebral disc degeneration and herniations: what are the important translational questions? *Clin Orthop Relat Res* 2015;473:1903–12. <https://doi.org/10.1007/s11999-014-3774-8>.
  - [33] Heuch I, Heuch I, Hagen K, Zwart JA. A comparison of anthropometric measures for assessing the association between body size and risk of chronic low back pain: The HUNT study. *PLoS One* 2015;10:1–15. <https://doi.org/10.1371/journal.pone.0141268>.
  - [34] Koyanagi A, Stickley A, Garin N, Miret M, Ayuso-Mateos JL, Leonardi M, et al. The association between obesity and back pain in nine countries: a cross-sectional study. *BMC Public Health* 2015;15:123. <https://doi.org/10.1186/s12889-015-1362-9>.
  - [35] Sheng B, Feng C, Zhang D, Spitler H, Shi L. Associations between obesity and spinal diseases: a medical expenditure panel study analysis. *Int J Environ Res Public Health* 2017;14:1–11. <https://doi.org/10.3390/ijerph14020183>.
  - [36] Nilsen TIL, Holtermann A, Mork PJ. Physical exercise, body mass index, and risk of chronic pain in the low back and neck/shoulders: longitudinal data from the nord-trøndelag health study. *Am J Epidemiol* 2011;174:267–73. <https://doi.org/10.1093/aje/kwr087>.
  - [37] Teraguchi M, Yoshimura N, Hashizume H, Muraki S, Yamada H, Minamide A, et al. Prevalence and distribution of intervertebral disc degeneration over the entire spine in a population-based cohort: The Wakayama Spine Study. *Osteoarthritis Cartil* 2014;22:104–10. <https://doi.org/10.1016/j.joca.2013.10.019>.
  - [38] Wilson JR, Tetreault LA, Schroeder G, Harrop JS, Prasad S, Vaccaro A, et al. Impact of elevated body mass index and obesity on long-term surgical outcomes for patients with degenerative cervical myelopathy: analysis of a combined prospective dataset. *Spine (Phila Pa 1976)* 2017;42(3):195–201. <https://doi.org/10.1097/BRS.0000000000001859>.
  - [39] Qi M, Xu C, Cao P, Tian Y, Chen H, Liu Y, et al. Does obesity affect outcomes of multilevel ACDF as a treatment for multilevel cervical spondylosis?: a retrospective study. *Clin Spine Surg* 2020;33:E460–5.
  - [40] Auffinger B, Lam S, Kraninger J, Shen J, Roitberg BZ. The impact of obesity on surgeon ratings and patient-reported outcome measures after degenerative cervical spine disease surgery. *World Neurosurg* 2014;82:e345–52. <https://doi.org/10.1016/j.wneu.2013.09.053>.
  - [41] Wang C, Tian F, Zhou Y, He W, Cai Z. The incidence of cervical spondylosis decreases with aging in the elderly, and increases with aging in the young and adult population: a hospital-based clinical analysis. *Clin Interv Aging* 2016;11:47–53.
  - [42] Da Costa BR, Vieira ER. Risk factors for work-related musculoskeletal disorders: a systematic review of recent longitudinal studies. *Am J Ind Med* 2010;53:285–323. <https://doi.org/10.1002/ajim.20750>.
  - [43] van der Molen HF, Foresti C, Daams JG, Frings-Dresen MHW, Kuijper PPFM. Work-related risk factors for specific shoulder disorders: a systematic review and meta-analysis. *Occup Environ Med* 2017 oemed-2017-104339. <https://doi.org/10.1136/oemed-2017-104339>.