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Evidence was provided for forceful hand-grip work, with and without vibration, as a risk factor for ulnar nerve entrapment (UNE) surgery in a large cohort of Swedish construction workers. Several individual biomechanical factors comprising such work were associated with increased risk of UNE, including: increased grip force, upper extremity load, frequency of hand-held tool use, and hand arm vibration.

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Key terms: biomechanical; biomechanical risk factor; construction worker; cubital tunnel syndrome; elbow; elbow extension; grip force; hand tool; hand-arm vibration; HAV; JEM; job-exposure matrix; male construction worker; neuropathy; occupational biomechanical risk factor; prospective study; repetitive; risk factor; static work; ulnar nerve entrapment; upper-arm load

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Occupational biomechanical risk factors for surgically treated ulnar nerve entrapment in a prospective study of male construction workers

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Objectives The aim of this study was to determine the association between occupational biomechanical exposures and occurrence of surgically treated ulnar nerve entrapment (UNE).

Methods A cohort of 229 689 male construction workers who participated in a national occupational health surveillance program (1971–1993) were examined prospectively over a 13-year case ascertainment period (2001–2013) for surgically treated UNE. Job title (construction trade), smoking status, height, weight and age were recorded on examination. Job titles were merged into occupational groups of workers performing similar work tasks and having similar training. Occupational biomechanical exposure estimates were assigned to each occupational group with a job exposure matrix (JEM) developed for the study. Negative binomial models were used to assess the relative risks for each biomechanical exposure and the sums of highly correlated biomechanical exposures. Surgical treatment of UNE was determined via a linkage with the Swedish Hospital Outpatient Surgery Register.

Results There were 555 cases of surgically treated UNE within the cohort. Workers exposed to forceful hand-grip factors had a 1.4-fold higher relative risk (95% CI 1.18–1.63) of undergoing surgical treatment for UNE compared to unexposed workers. Occupational groups comprising workers exposed to forceful hand-grip work showed the highest risks for UNE and included concrete workers, floor layers, ground preparatory workers, rock blasters, and sheet-metal workers.

Conclusion Forceful hand-grip work increases the risk for surgically treated ulnar nerve entrapment.

Key terms cubital tunnel syndrome; elbow; elbow extension; grip force; hand-arm vibration; hand tool; HAV; JEM; job-exposure matrix; neuropathy; repetitive; static work; upper-arm load.

Ulnar nerve entrapment (UNE) occurs due to pressure on the ulnar nerve from surrounding anatomical structures and can also arise from local friction or traction (1). The most common sites of entrapment are at or near the elbow, particularly in the cubital tunnel, which can give rise to cubital tunnel syndrome (CuTS), or in the epicondylar groove (2). Symptoms of UNE include pain at the elbow, paresthesias and change in sensation of the fourth and fifth fingers, loss of power grip, permanent atrophy and weakness of the ulnar muscles (3). Electro diagnostic examination is the current recommendation to confirm diagnosis and determine compression severity and location (4). Symptoms may be alleviated with rest, splinting, and/or rehabilitation, however cases of established compression are typically treated surgically (5).

Studies of incidence rates of physician-diagnosed UNE in the general population are scarce and have ranged from 26.6–32.7 per 100 000 person-years for men and 17.2–20.1 for women (6,7). A single study estimated incidence rates of surgically treated ulnar neuropathy to be 7.5 (95% CI 5.8–9.2) for men and 5.6 (95% CI 4.1–7.1) for women (7).

Personal risk factors for UNE include male sex (7, 8), smoking (8, 9), obesity (10, 11) and age (6–8,10,12–14).

UNE has been described in floor cleaners (15), coal miners (16), computer keyboard operators (17), occu-

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pations requiring heavy manual labor/forceful (often cyclic) work (12, 14, 18), and desk-based work involving handwriting, drawing and computing (14). Specific biomechanical exposures were considered in one prospective study (10) and one case–control study (19)- and associations between "routine use of a hand tool required to be held in position" (10) and "forceful work of the hand and arm" (19) and UNE were reported. A tendency for "using a vibrating hand tool" (10), "hand/arm vibration" (19), "using elbows for support" (10), "non-neutral postures" (19), and "repetitive work" (19) was also reportedly associated with UNE.

Sufficient evidence has not yet been provided for occupational exposure as a cause of UNE; this is required to justify preventative actions and determine occupational compensation. For example, the American Medical Association Guides state there is "insufficient evidence" for "forceful work, awkward postures, vibration or keyboard activities" as causal factors for UNE, and only "some evidence' for "force and repetition" and "force and posture" as causal factors (20). Further epidemiological consideration of specific occupational biomechanical risk factors is therefore required.

Many construction trades require forceful upper-extremity exertions, use of tools in fixed positions, and hand-arm vibration (HAV) exposure [eg, (21–26)]. A study population of construction workers would therefore facilitate further investigation into biomechanical exposure factors previously associated with UNE.

The aim of the current study was to determine the association between occupational biomechanical exposures and occurrence of UNE in a large cohort of construction workers.

Methods

Study design

A cohort of male construction workers were followed prospectively over a 13-year observation period to determine whether occupational biomechanical exposures were associated with UNE.

The Regional Ethical Review Board in Umeå approved the study (2017/16–31).

Study population

The study cohort comprised Swedish workers in the construction industry who had participated in a national occupational health surveillance program (*Bygghälsan*). The total cohort comprises 389 132 individuals who participated in ≥1 health examination between 1971 and January 1993. While participation was voluntary, ≥80% of eligible workers completed ≥1 health examination (27). Self-reported worker height, weight, age, smoking status and job title were obtained on examination.

Only male construction workers were included since females represented only 5.3% of the total population, and most belonged to the "other" work group who were excluded from the study (see below).

Workers were excluded who were <16 or >65 years at their first health examination, were unusually short (<150 cm) or tall (>200 cm), died, emigrated, retired or had record of UNE surgery prior to the start of the observation period in 2001.

Workers for whom no job title was recorded in any of the medical examinations or who were classified in the non-specific "other" work group (see below) were removed since they could not be mapped onto the job exposure matrix (JEM) (see below).

The remaining workers comprised the study cohort. A detailed description of the number of workers (including cases) excluded at each level is presented in figure 1.

Case definition

UNE case status was defined on the basis of a surgical release of UNE (code ACC53) and case data were obtained from a national registry of out-patient surgical records. The construction worker database and national surgical records were matched using the unique personal number assigned to each Swedish resident.

In Sweden, ulnaris decompression surgery is typically performed in outpatient care and fully computerized outpatient surgical data are available beginning in 2001. The period for case ascertainment was 1 January 2001–31 December 2013. No information about diagnostic procedures or non-surgical treatment was available in the database.

Personal factors

Workers were re-classified into never, ever, and unknown smoking status groups. Body mass index (BMI) was calculated from the height and weight data and characterized into two groups: normal (BMI <25 kg/m^2) and overweight (≥25 kg/m^2).

Smoking status data were extracted from the same health examination that provided job title. Due to linkage issues, height and weight data could only be obtained from the first health examination for each worker.

Biomechanical exposure factors

Biomechanical exposure estimates were assigned at the occupational group level using a job exposure matrix (JEM) developed for the study. We identified ten ergonomic (force/posture/repetition) and two vibration expo-

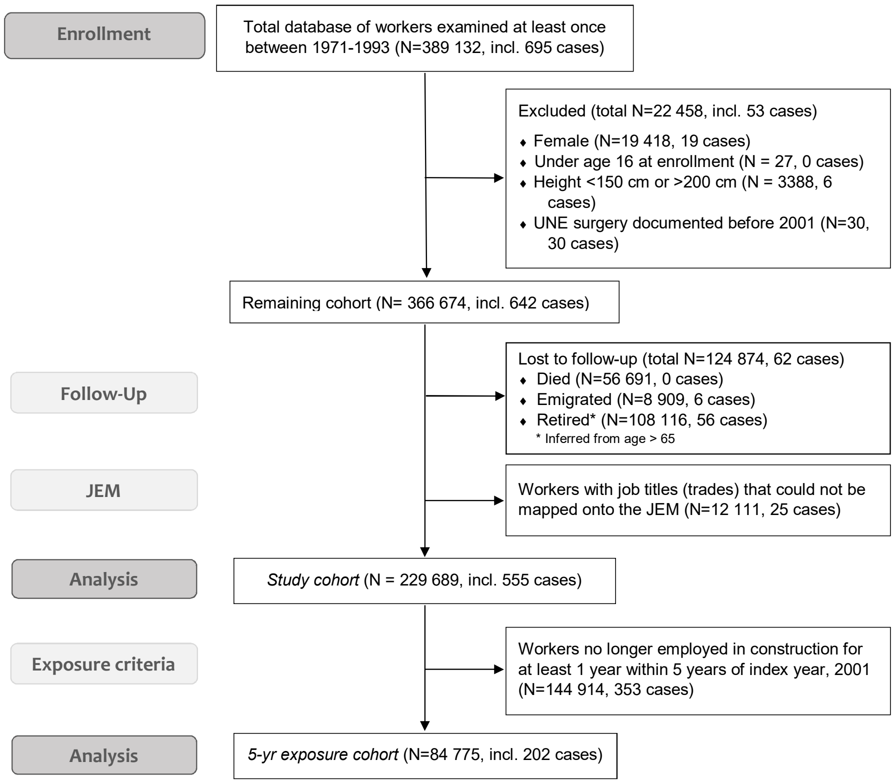

Figure 1. Flow diagram outlining construction worker cohort exclusions. A single worker may have met more than one exclusion criterion within each of the exclusion boxes.

sure factors *a priori* that we deemed potentially etiologically relevant based on the available UNE literature as well as our knowledge of elbow and upper-extremity disorders (table 1). Two experts reviewed ergonomic assessments conducted in the 1970s for each job title (figure 2) and, based on this guidance, independently determined a rating for each occupational group and exposure factor. Ratings reflected the average exposure intensity or frequency over a working day (table 1). All exposure ratings were done blinded to the number of UNE cases in each occupational group. Ratings were then compared and discussed by the experts to resolve any disagreements. A single expert rated the vibration factors for each occupational group (table 1). Exposure estimate ratings were assigned to each individual based on the JEM ratings for their occupational group. JEM ratings for each occupational group and biomechanical factor are presented in the supplementary material (table S1, www.sjweh.fi/show_abstract.php?abstract_id=3757).

Exposure scores

Spearman correlation coefficients were determined between all pairs of biomechanical exposure factors. Exposure scores were created by summing groups of highly correlated biomechanical factors (Spearman correlation coefficients >0.7).

Occupational groups

Workers reported individual job titles (construction trades) on examination according to the occupational work codes used in the Swedish construction industry at the time of the health exam. Prior to 1986, 212 individual job title codes were used, while 90 job title codes were used from 1986 onwards. For each worker,

Table 1. Biomechanical risk factors included in the job exposure matrix.

Exposure	Rating
Ergonomic factors	
Intensity of hand-grip force	1–3 [a]
Intensity of upper-extremity load	1–3 [a]
Frequency of repetitive elbow flexion and extension work	1–3 [a]
Frequency of repetitive wrist flexion and extension work	1–3 [a]
Frequency of hand-held tool use	1–3 [a]
Frequency of upper-extremity static work	1–3 [a]
Frequency of full wrist extension	1–3 [a]
Frequency of full elbow extension	1–3 [a]
Frequency of using a hand-held tool in a fixed position	1–3 [a]
Frequent leaning on the elbow	1 or 3 [b]
Vibration factors	
Magnitude of hand-arm vibration (HAV)	1–3 [c]
Frequency of impact shocks during HAV	1 or 3 [d]

[a] 1=low, 2=moderate, 3=high.
[b] 1=no, 3=yes.
[c] 1=none, 2=acceptable, 3=high.
[d] 1=rare, 3=often.

Table 2. Description of occupational groups including specific job titles mapped to each group.

Occupational group	Description and included job titles
Asphalt workers	Asphalt work, laying asphalt and asphalt insulation, driving asphalt and crushed gravel laying machine.
Brick layers	Brick laying including facades, internal walls, fireplace and chimney masonry
Concrete workers	Preparation of rebar for concrete pouring, removal of old concrete with jackhammer, drilling, spreading concrete (by hand), cleaning surfaces, concrete pouring/casting, laying concrete floors, erecting pilings (including temporary supports for concrete pouring), under ceiling/roof concrete application, asbestos removal, repair and reconstruction of concrete, assembly of pre-fab building sections, building demolition.
Crane operators	Operators of tower, mobile and other types of cranes working from inside the crane cab and/or beside the crane.
Drivers	Drivers of personal vehicles and trucks; loading and unloading of vehicles
Electricians	Electrical installation, repair, service, maintenance, elevator installation and servicing
Floor layers	Laying flooring including plastic matting, parquet and carpet and preparatory sanding work
Foremen	Overseeing of construction workers
Glaziers	Installation of windows and other glass work
Ground prep workers	Worksite clearing and preparation for building or digging, clearing trees, shaft, pipe and foundation work, grading and draining, ditch planning work, landscaping.
Heavy machinery operators	Operating engineers of caterpillar, excavator, loader, dredger, piling, grading, steamroller and dump truck, tractors and/or other heavy machinery
Insulators	Pipe, tank and cistern insulation
Painters	Wall preparatory work (including sanding and spackling, sandblasting), painting, wallpapering.
Plumbers and pipe fitters	Installation, repair and service of plumbing systems in both housing and industrial sectors.
Refrigerator technicians	Installation and repair of refrigeration systems
Repairers	Repair work carried out in workshops, outdoors, and underground on wheel loaders, road graders, concrete dumps, cross sections, trucks, and drilling equipment. In addition, on air, water and electricity wires in tunnels
Rock blasters	Preparing worksites for tunnelling projects including clearing rocks and rinsing and cleaning the ground, rock tunnel reinforcement including spraying, drilling and injection), above and underground work with explosives including drilling, covering and scraping.
Roofers	Roofing work, including laying rolls of shingle-type material
Sheet-metal workers	Metal façade work including window sill, trim and facing installation, metal roof panel assembly, ventilation assembly, sheet metal workshop work and working with sheet metal.
White-collar workers	Officials, secretaries, office workers, desk workers.
Woodworkers	Carpentry work including framing, construction of concrete pouring forms, interior carpentry including trim, mouldings, flooring, insulation work, general carpentry work, repair and remodelling of buildings, assembly of prefabricated houses.

Job title: Rockblaster

Job tools: platforms of different designs, ladders, drilling machines and scraping tools

Job description: Scraping loose pieces of rock off tunnel walls and ceiling. Work performed from the ground, platforms, and ladders.

Ergonomic assessment of occupational factors	Score				
01 Overall workload (pulse)	1	2	3	4	5
02 Upper extremity loading	1	2	3	4	5
03 Back loading	1	2	3	4	5
03 Lower extremity loading	1	2	3	4	5
04 Stone dust exposure	1	2	3	4	5
05 Noise	1	2	3	4	5
06 Vibration	1	2	3	4	5
07 Fall risk	1	2	3	4	5
08 Risk for slips or trips	1	2	3	4	5
09 Risk for falling objects	1	2	3	4	5
10 Risk for being crushed	1	2	3	4	5
11 Risk for being struck/rolled on by objects	1	2	3	4	5
12 Risk for shrapnel or being splashed	1	2	3	4	5

Additional comments:

Static muscle loading of the upper and lower extremities and back
Risk of explosive gase and/or diesel exhaust during underground work

Figure 2. Sample ergonomic assessment sheet. Document translated from the original Swedish.

job title was extracted from the last health examination record (1971–1993) for which it was reported. Job titles were merged into 22 occupational groups developed by technical experts of the industry to group workers performing similar work tasks and having similar training. The 22nd group was "other work" into which job titles with no other clear matches were placed. Table 2 outlines occupational group descriptions and mapping of specific job titles to occupational groups. Employment status (yes/no) in the construction industry from 1990–2010 was determined through a linkage of the study database with Statistics Sweden's LISA register (longitudinal integration database for health insurance and labor market studies).

Statistical analysis

Person-years were calculated from 2001 until UNE surgery or until censoring due to death, emigration, retirement (inferred from age 65) or until the end of the observation period (31 December 2013).

The annual incidence rates of UNE decompression surgery (code ACC53) for the entire Swedish male population were calculated from the National Board of Health and Welfare (*Socialstyrelsen*) website for the years 2005–2016 (data not available prior to 2005).

To obtain workers for whom the JEM scores more accurately predicted their recent occupational exposure, a five-year exposure criteria was imposed on the study cohort. This resulted in a sub-cohort comprising only workers who had worked a minimum of one year in the construction industry in the five years preceding the observation period (*5-yrExp cohort)*.

Negative binomial models with a log-link were used to estimate relative risks (RR) and 95% confidence intervals (CI) for all factors for the total study and *5-yrExp* cohorts.

When assessing RR between occupational groups, the foremen were used as the reference. For the biomechanical factors and exposure scores, the group with the lowest rating or score was used as the reference.

Results

The incidence rate (IR) of surgically treated UNE over the 13-year observation period was 19.2 cases per 100 000 person years. The IR in the study cohort were lower during the first half (2001–2006) of the observation period (16.2 cases per 100 000) compared with the second half (2008–2013, 22.3 cases per 100 000). Accordingly, a dichotomous surgical date factor was used to adjust final models.

Personal factors

Descriptive data and crude RR are presented for personal factors in table 3. Overweight workers and having ever been a smoker were associated with increased risk for UNE. Age was also related to risk, with the highest risk in the age range 45–54 years. Accordingly, all biomechanical factor and exposure score analyses were adjusted for BMI, smoking and age, as well as for the surgical date factor.

Biomechanical exposure scores

In the models run for each separate biomechanical factor, increased risk was observed for workers with higher exposure to factors relating to increased hand-grip force, including: grip force, upper-extremity load, frequency of hand-held tool use, and HAV (RR range 1.35–1.63). In addition, workers with higher frequencies of repetitive elbow flexion and extension, and static work also showed increased risks of UNE (RR 1.36 for both factors). Full results for all biomechanical factors are presented in the supplementary material, table S2, www.sjweh.fi/show_abstract.php?abstract_id=3757. All models were adjusted for age, smoking, BMI and surgical time factor, but no adjustment was made for confounding due to correlation between biomechanical factors.

Four exposure scores were created by summing biomechanical factors with Spearman correlation coefficients ≥0.7 – table 4 (for full correlation matrix see supplementary material – table S3, www.sjweh.fi/show_abstract.php?abstract_id=3757). Workers with elevated hand-grip scores (RR 1.40) showed the highest risk of surgically treated UNE (table 4). Workers exposed to static work and elbow leaning (RR 1.24) and HAV (1.18) also indicated a slightly elevated risk of UNE. Repetitive wrist and elbow flexion did not show an association with UNE.

Table 3. Personal factors and relative risk for ulnar nerve entrapment from crude models. Significant values shown in bold text. [N=number of workers; IR=incidence rate per 100 000 person-years; RR=relative risk; CI=confidence interval; BMI=body mass index.]

	Mean	N	Person-years	Cases	IR	RR	95% CI
BMI							
Healthy	22.2	167 873	2 126 982	379	17.82	1	
Overweight	28.5	61 816	769 719	176	22.87	1.28	1.07–1.54
Smoking							
Never		103 509	1 324 715	194	14.64	1	
Ever		115 025	1 433 709	335	23.37	1.60	1.34–1.91
Unknown		11 155	138 277	26	18.80	1.28	0.85–1.93
Age in 2001							
25–34		32 486	418 891	67	15.99	1	
35–44		64 123	823 469	158	19.19	1.20	0.90–1.60
45–54		73 298	927 471	198	21.35	1.34	1.01–1.76
55–64		59 782	726 870	132	18.16	1.14	0.85–1.52

Table 4. Biomechanical exposure sum scores and relative risk (RR) for ulnar nerve entrapment of exposed versus unexposed workers. Models adjusted for body mass index, smoking, age, and time of surgery. [N=number of workers; IR=incidence rate per 100 000 person-years; CI=confidence interval.]

Factor	N	Person-years	Cases	IR	RR	95% CI
Grip Score [a]						
Unexposed	48 743	612 362	89	14.53	1.00	
Exposed	180 946	2 284 339	466	20.40	1.40	1.18–1.63
Vibration Score [b]						
Unexposed	104 465	1 313 192	233	17.74	1.00	
Exposed	125 224	1 583 509	322	20.33	1.18	0.98–1.31
Repetitive Flexion & Extension Score [c]						
Low	80 999	1 018 822	194	19.04	1.00	
Exposed	148 690	1 877 879	361	19.22	1.01	0.84–1.18
Static Work & Elbow Leaning Score [d]						
Low	68 709	865 468	142	16.41	1.00	
Exposed	160 980	2 031 233	413	20.33	1.24	1.05–1.43

[a] Intensity of hand grip force + Intensity of upper extremity load + frequency of using a hand tool in a fixed posture + frequency of hand tool use.
[b] Hand-arm vibration (HAV) + frequency of impact shocks during HAV.
[c] Frequency of repetitive elbow flexion and extension work + frequency of repetitive wrist flexion and extension work.
[d] Frequency of upper extremity static work + frequency of leaning on the elbow.

Table 5. Occupational group among Swedish construction workers and relative risk (RR) for ulnar nerve entrapment in final model adjusted for body mass index, smoking, age, and surgery date. [N=number of workers; IR=incidence rate per 100 000 person-years; CI=confidence interval.]

Occupational group	N	Person-years	Cases	IR	RR	95% CI
Foremen	26 898	339 328	37	10.90	1	
Repairers	2015	25 194	3	11.91	1.05	0.32–3.44
Electricians	29 665	377 472	44	11.66	1.11	0.69–1.78
Glass workers	2142	27 037	4	14.79	1.30	0.45–3.71
Crane operators	2044	25 117	4	15.93	1.34	0.47–3.84
Painters	17 446	220 180	33	14.99	1.37	0.83–2.3
White-collar workers	9581	120 539	20	16.59	1.45	0.81–2.60
Heavy machinery operators	7476	93 211	19	20.38	1.70	0.95–3.04
Insulators	2034	25 527	5	19.59	1.71	0.66–4.42
Brick layers	6248	78 408	16	20.41	1.83	0.99–3.38
Refrigerator technicians	1120	14 152	3	21.20	1.90	0.58–6.21
Plumbers	17 065	214 763	46	21.42	1.91	1.20–3.05
Woodworkers	51 463	652 471	139	21.30	1.99	1.33–2.97
Asphalt workers	3862	48 474	11	22.69	2.01	1.01–4.03
Concrete workers	19 663	245 594	61	24.84	2.20	1.41–3.42
Drivers	2744	34 167	9	26.34	2.23	1.06–4.72
Floor layers	4388	55 473	14	25.24	2.28	1.20–4.33
Ground preparatory workers	7725	96 568	27	27.96	2.48	1.47–4.19
Rock blasters	5224	65 660	18	27.41	2.50	1.38–4.52
Sheet-metal workers	9652	121 966	35	28.70	2.55	1.55–4.18
Roofers	1234	15 400	7	45.45	3.88	1.70–8.89

Further sensitivity analyses showed no influence of birth year or age group on the reported associations between exposure and UNE.

Occupational groups

All occupational groups demonstrated higher incidence rates than the foremen (table 5). RR were significantly higher for plumbers, woodworkers, asphalt workers, concrete workers, drivers, floor layers, ground preparatory workers, rock blasters, sheet-metal workers, and roofers, and ranged from 1.91–3.88.

Recent exposure history

After imposing the five-year exposure history criteria, the resulting sub-cohort comprised 84 775 workers including 202 UNE cases (figure 1). Results for the *5yr-Exp cohort* typically mirrored those of the total study cohort, suggesting increased risk of UNE for workers with higher grip force and vibration exposures, although confidence intervals were wide, indicating less precision due to the much reduced power in these analyses. Full results are presented in the supplementary material (tables S4–S6, www.sjweh.fi/show_abstract.php?abstract_id=3757).

Discussion

This study found an association between occupational biomechanical factors and an increased risk of UNE surgery. Specifically, we found workers with forceful hand-grip work and elevated vibration exposures had an elevated risk. Occupational groups with the highest risks for UNE included concrete workers, floor layers, ground preparatory workers, rock blasters, and sheet-metal workers.

Vibration was delivered via hand-tool use, and thus we are unable to truly isolate vibration exposures from forceful hand-grip exposures in this study. In contrast, the grip score comprised workers both exposed and unexposed to HAV. The higher RR for grip score over vibration score indicates that forceful grip work (ie, increased external load applied at the hand) on its own is a key etiological aspect. Whether HAV on its own is a key factor cannot be determined from our data since operating vibrating power tools requires forceful hand-grip work to control the tool.

Most of the occupational groups at increased risk for UNE were comprised of jobs with exposure to high grip force due to external loads applied at the hand, including hand tool use (with and without vibration) and/or heavy loads carried in the hands. These occupations included: concrete, wood, sheet metal, ground preparation and floor workers, plumbers, rock blasters, and roofers. Drivers – a group not typically exposed to forceful hand-grip work – were also associated with UNE. Drivers are exposed to prolonged periods of static work and possibly elbow leaning, which was associated with UNE.

Several potential mechanisms have been proposed that could explain the link between the biomechanical risk factors and UNE, including: increased pressure on the nerve (28), which could result from forceful or prolonged muscular contractions; friction on the nerve (29), which could result from repetitive elbow flexion and extension; increased nerve tension (30), which could result with increased elbow flexion; and direct compression of the nerve (31), as could occur when leaning on the exposed nerve in the epicondylar groove (19). The findings from the present study suggest increased pressure on the nerve to forceful and/or prolonged grip muscle contractions is likely a mechanism for UNE among construction workers.

Exposure latency hypothesis

In the present study, physical exposure estimates were inherently tied to occupation as exposures were assigned using JEM scored at the occupational group level. Thus, it is a base assumption that workers maintained the same occupational group between the health evaluation at which the job title was recorded until UNE surgery, censoring due to death or immigration, or the end of the observation period. Workers leaving the construction industry during the follow-up/observation period due to change in work or retirement would likely experience different occupational exposures than those assigned based on their initial employment status, and this would not be reflected in their JEM score.

There was very little epidemiologic evidence upon which to base the judgment of latency from last exposure to occurrence of UNE. We selected the cut-off of five years prior to the index year, which had also been used by Svendsen et al (19). We hypothesized that the recent exposure history was more important than the full cumulative exposure history.

Analysis of the *5-yrExp cohort* did not produce higher risk estimates than the total study cohort; our hypothesis was not supported. These data may imply that cumulative loading is key in the etiology of UNE *and/or* may indicate that once a certain amount of exposure has occurred, damage in the affected tissue(s) is irreparably done.

Previous findings

Our exposure score findings for Grip Score and Grip + Vibration Score are in line with those of Svendsen et al (19) who found forceful work of the hand and arm was a significant predictor of UNE risk. Similarly, we also confirmed their findings of HAV as a significant risk factor in our HAV specific biomechanical factor model.

Routine use of a hand tool in a fixed position had previously been shown to be significantly associated with a 4-fold increased risk of developing UNE (10). We could not confirm hand tool in fixed position as a significant risk factor, but did find an association between several component biomechanical factors, namely: frequency of hand tool use, grip force, frequency of static work and HAV. Further the Grip Score and Grip + vibration exposure sums, both which contained the biomechanical factor, frequency of using a hand tool in a fixed posture, were significant predictors of UNE risk.

It is important to note that previous studies used different UNE definitions, including: "sensory symptoms in the ulnar nerve distribution and worsening of the symptoms as a result of compression of the cubital tunnel" (10), and "electroneurography-diagnosed UNE" (19). It is possible that case definition differences may underlie the difference in magnitude in RR between the previously published papers (RR approximately 4-fold) and the present study with UNE surgery (approximately 1.5-fold).

From the publically available national registry data (2005–2016), we calculated the mean annual crude IR of UNE surgery (ACC53) in the total Swedish population to be 12.2 per 100 000 person-years for men and 12.1 for women. To match our study cohort, we calculated the IR for only men aged 25–74 years, which was 17.9 cases per 100 000 person-years. We expected the IR in our construction cohort (19.2) to be higher given the exposure to lifting and hand tool use in construction trades, however the rates were rather similar. The average rate for surgical treatment in the general Swedish male population was also markedly higher than the general rate of surgical treatment for males in the UK (IR 7.5 (95% CI 5.8–9.2) in 2001). Given that case definition required surgical treatment, it was expected (and confirmed) that IR in both our study cohort and the general Swedish population would be lower than those previously reported for physician-diagnosed cases of UNE (26.6–32.7 per 100 000 person-years for men and 17.2–20.1 for women) (6, 7).

Personal factors

Similar to previous studies, we found smoking was a risk factor for UNE (8,9). Earlier studies documented an exposure–response effect and found no evidence of a mechanical casual effect from arm movements or static postures during smoking, leading both research teams to suggest that metabolic effects of smoking on the ulnar nerve likely underlie this relationship (8, 9).

BMI has previously been linked to increased risk of UNE in obese (BMI ≥30 kg/m^2) (10) and very obese BMI ≥38 kg/m^2 individuals (11). In the present study, we found increased risk already for the group of overweight (≥25 kg/m^2) individuals. Obesity has been frequently documented as a risk factor for carpal tunnel syndrome (CTS), and it is proposed that the risk stems from increased compression on the median nerve due to the accumulation of fat tissue inside the carpal tunnel or from an increased hydrostatic pressure in the carpal tunnel canal (32). A similar mechanism is plausible in the cubital tunnel, as postulated by Descatha et al (10). This theory is also supported by the finding that musculoskeletal complaints, including epicondylitis, were found to decrease following weight loss (33), which would presumably entail decreased adipose tissue and nerve compression.

Strengths and weaknesses

The present study is the largest prospective cohort study to date considering UNE cases and is unique in the number and detail of biomechanical exposures considered. Our use of a surgical case definition entails that all cases were carefully investigated by a medical specialist, while other studies have permitted less stringent case definitions, including self-reported sensory symptoms (10). This strict case definition can be viewed as both a strength and a weakness. Classifying workers with UNE symptoms who have not undergone surgical treatment as non-cases may have resulted in underestimation of the proportion of workers affected by UNE. It is possible that the identified biomechanical exposure factors are negative prognostic factors, and thus studies employing less stringent case definitions may show different risk estimates. Decreased exposure to grip force, vibration, and static work and leaning on elbows may therefore be important for primary as well as secondary and tertiary prevention for individuals with UNE. Our job exposure assessment was done blinded to case frequency. We examined a subpopulation with a more clear exposure history to confirm patterns seen in the total study cohort. All construction workers in the cohort had good access to occupational health care as well as general medical care, which is nearly free of charge in Sweden. Smoking and obesity are associated with socioeconomic status, however we controlled for these factors in our analyses. The construction workers in this nation-wide study lived, worked, and were treated locally. It is possible that admission standards may differ between hospitals across Sweden for UNE decompression surgery, however is seems improbably that such changes would be related to BMI, age, smoking status, or occupational group.

The main weakness of this study is the vulnerability to potential exposure misclassification, which could occur due to the lack of direct, quantitative biomechanical and HAV exposure assessment. We constructed a cohort-specific JEM based on historical ergonomic assessment reports containing estimates of awkward postures and forceful loads for each job title. The estimates in the original reports were too crude to sufficiently address the specific biomechanical factors, which have been identified more recently as etiologically relevant for common nerve entrapment syndromes, including CTS, CuTS and radial tunnel syndrome. This is often considered the best available method for retrospective exposure assessment in cohort studies (34).

Additional weaknesses include: grouping specific job titles to occupational groups such that each group contained a range of exposures; the necessary assumption that each worker's occupational group (and therefore exposure) was consistent from the time of their last examination through to the observation period; and the lack of data on potential changes in job content, methods, and technology over the 40-year study period. It seems likely that all these sources of error would lead to non-differential exposure misclassification, which would bias our RR estimates toward the null value.

There were few workers in this construction worker cohort who were likely to have been truly unexposed given the shared occupational field. The potential exposure to elbow leaning during office work meant that white-collar workers were not an ideal reference group. The foremen were deemed least exposed and used as the reference group even though they would likely have risen through the ranks of construction work, and thus would have a history of exposure to some of the same biomechanical factors under study prior to becoming foremen. This could lead to underestimated risk for the occupational groups compared to a completely unexposed group.

Concluding remark

This prospective study found forceful hand-grip work was associated with the occurrence of surgically treated ulnar nerve entrapment.

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