Original research

Occupational risk factors for work disability following carpal tunnel syndrome: a pooled prospective study

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ABSTRACT

Background Although recent studies have identified important risk factors associated with incident carpal tunnel syndrome (CTS), risk factors associated with its severity have not been well explored.
Objective To examine the associations between personal, workplace psychosocial and biomechanical factors and incident work disability among workers with CTS.
Methods Between 2001 and 2010 five research groups conducted coordinated prospective studies of CTS and related work disability among US workers from various industries. Workers with prevalent or incident CTS (N=372) were followed for up to 6.4 years. Incident work disability was measured as: (1) change in work pace or work quality, (2) lost time or (3) job change following the development of CTS. Psychosocial factors were assessed by questionnaire. Biomechanical exposures were assessed by observation and measurements and included force, repetition, duty cycle and posture. HRs were estimated using Cox models.
Results Disability incidence rates per 100 person-years were 33.2 for changes in work pace or quality, 16.3 for lost time and 20.0 for job change. There was a near doubling of risk for job change among those in the upper tertile of the Hand Activity Level Scale (HR 2.17; 95% CI 1.17 to 4.01), total repetition rate (HR 1.75; 95% CI 1.02 to 3.02), % time spent in all hand exertions (HR 2.20; 95% CI 1.21 to 4.01) and a sixfold increase for high job strain. Sensitivity analyses indicated attenuation due to inclusion of the prevalent CTS cases.
Conclusion Personal, biomechanical and psychosocial job factors predicted CTS-related disability. Results suggest that prevention of severe disability requires a reduction of both biomechanical and organisational work stressors.

Key messages

What is already known about this subject?
⇒ Although studies have shown the associations between risk factors and incident carpal tunnel syndrome (CTS), few large prospective studies using rigorous case criteria, individual-level exposure data and appropriate controls for confounding have examined associations between various types of risk factors and disability due to CTS.

What are the new findings?
⇒ Although prior analyses found that various measures of force but not repetition, per se, were strongly associated with incident CTS, measures of repetitive hand activity and duration of all (light and heavy) hand exertions were associated with increased work disability following CTS.
⇒ Furthermore, low job satisfaction and high job strain increased the rate of work disability following CTS.

How might this impact on policy or clinical practice in the foreseeable future?
⇒ Understanding risk factors associated with work disability is important to developing effective intervention strategies for preventing disability once someone develops CTS. These observations suggest that tertiary prevention strategies may be most effective when they reduce both biomechanical exposures and work psychosocial stress.

INTRODUCTION
Carpal tunnel syndrome (CTS) is an important occupational health problem due to its considerable incidence rate (IR) and associated disability.[1] Recent large prospective studies with diverse worker risk groups in the USA[2] (this consortium's data) and Italy[3 4] have reported CTS IR of 2.3 per 100 person-years (pyrs) and 5.4 per 100 pyrs, respectively. Additionally, the median lost work time following CTS is 25 days, making CTS an important driver of overall workers compensation costs.[1 5] Consequently, a better understanding of CTS-associated disability is key to minimising the adverse impact of the disorder on workers and employers.

Primary, secondary and tertiary prevention are commonly defined as: (1) prevention of any physiological change that may lead to injury or disease, (2) prevention of the occurrence of disease once some pathophysiological change has occurred, and (3) prevention of disability and recurrence once the injury or disease has occurred. Since it has been shown in other body regions, such as the low back, that aetiologic (cause of injury) and prognostic (chance of recovery) factors can be different,[6] assessing both etiologic and prognostic factors for MSDs like CTS is warranted.

Previously, we pooled six prospective cohort studies with individualised exposure assessments and reported the personal, work psychosocial

and biomechanical factors associated with the development of incident cases of CTS.[7–9] However, no large-scale studies have assessed the risk of work disability among workers with CTS using individual-level biomechanical exposure assessments. Understanding who is at the highest risk for disability once CTS develops is extremely useful for tertiary prevention efforts. Therefore, the goal of these analyses was to explore the personal, biomechanical and work psychosocial factors associated with severity of CTS as measured by three measures of work disability among those with CTS. We hypothesised that the effect estimates of the associations between covariates, physical exposures, psychosocial factors and outcome measures would get higher with increasing severity levels of work disability.

METHODS
Study design
This consortium consists of six research groups which conducted coordinated multi-year, prospective studies of upper extremity musculoskeletal disorders (UEMSDs) among 4321 US workers from 54 different workplaces across 10 different states between 2001 and 2010.[2 10] Jobs ranged in physical demand; individual-level exposure and health outcome information (including symptoms, physical examination findings, nerve conduction measures and functional outcome assessments) were collected. Similarities in study design allowed pooling of raw study data.[2 10] Workers meeting the case definition of CTS were assessed through repeated annual or biannual questionnaires for up to 6.4 years (average 2.4 years). This current report had requisite data collected by four research groups that also collected information on work disability representing workers from nine US states (AL, AR, CA, NV, ME, WA, WI, IL, UT).

Participants
This study's analyses relied on the 372 baseline prevalent or incident CTS cases (figure 1). Electrodiagnostic testing (EDS) of the median and ulnar nerves were performed at baseline and at regular intervals during the follow-up periods. A detailed questionnaire was administered at baseline to assess work history, demographics, psychosocial factors, medical history, musculoskeletal symptoms and work disability. Periodic surveys were administered to trigger physical exams, electrodiagnostic studies and assess work-related pain and disability.

The case definition of CTS required positive symptoms (numbness, tingling, burning or pain in one or more of the first three digits) AND positive temperature-adjusted latency criteria for
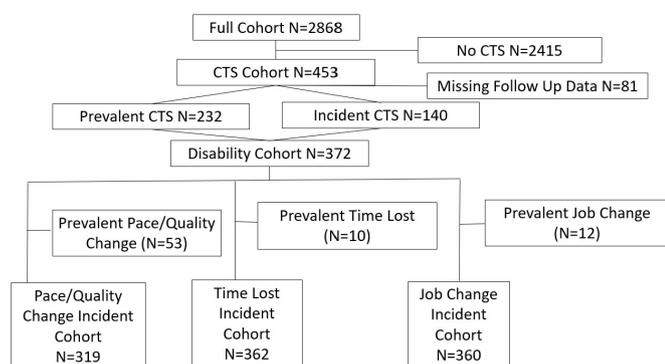

Figure 1 Subject flow chart of the cohort included in the analyses for pace/quality of work change, time lost and job change among those with CTS. Includes both incident and prevalent cases (see attached). CTS, carpal tunnel syndrome.

Table 1 Sociodemographic characteristics and baseline health of the carpal tunnel syndrome (CTS) disability cohort including those having CTS at baseline and those developing an incident case of CTS (n=372)*

Demographics (n (%))	Total N=372
Gender	
Male	126 (34%)
Female	246 (66%)
Age (years)	
<30 years of age	45 (12%)
≥30 and <40 years of age	79 (21%)
≥40 and <50 years of age	138 (37%)
≥50 years of age	110 (30%)
Race/ethnicity	
Caucasian	213 (57%)
Hispanic/Latino	44 (12%)
Black/African American	37 (10%)
Asian	17 (5%)
Other	15 (4%)
Education	
Some high school or less	52 (14%)
High school graduate or above	315 (85%)
Handedness	
Left handed	35 (9%)
Right handed	337 (91%)
Body mass index (kg/m²)	
<25	71 (19%)
≥25 and <30 (overweight)	115 (31%)
≥30 (obese)	184 (50%)
General health	
Very good or excellent	142 (38%)
Good	161 (43%)
Fair or poor	53 (14%)
Medical condition	
No medical condition	309 (83%)
Current medical condition	63 (17%)
Diabetes mellitus	24 (7%)
Rheumatoid arthritis	17 (5%)
Thyroid disease (hyper/hypo)	31 (8%)
Pregnancy	0 (0%)
Previous Distal Upper Extremity Musculoskeletal Disorder (UEMSD)	
No previous distal UEMSD	204 (55%)
Previous distal UEMSD	77 (21%)
Smoking status	
Never smoked	188 (51%)
Currently smokes	96 (26%)
Previously smoked	85 (23%)
Non-occupational weekly aerobic non-hand activity	
≤3 hours/week	91 (25%)
>3 hours/week	114 (31%)
Non-occupational weekly hand intensive activity	
≤3 hours/week	74 (20%)
>3 hours/week	206 (55%)
Summary of workplace factors	
Years worked at enrolment	
≤1 year	35 (10%)
>1 year and ≤ 3 years	53 (15%)
>3 years and ≤ 7 years	95 (26%)
>7 years and ≤12 years	104 (29%)
>12 years	73 (20%)
Job satisfaction	
Very satisfied	106 (29%)
Satisfied	187 (50%)
Not satisfied (includes neutral, dissatisfied, very dissatisfied)	67 (18%)

*Remaining percentages represent missing data.

median mononeuropathy at the wrist.[2 11] Participants with symptoms consistent with CTS and concurrent abnormal median and ulnar nerve EDS were classified as possible polyneuropathy and were censored at the time those criteria were met.[2]

Work disability

We defined three self-reported outcome measures of work disability following the development of CTS reflecting different degrees of severity of disability rank ordered as follows: (1) a self-reported negative change in work pace or quality of work due to hand/wrist symptoms (level of agreement), (2) lost time due to hand/wrist symptoms (days unable to work) and/or (3) a job change due to hand/wrist symptoms within the same company (including light or restricted duty) or to a different one. Each measure of work disability was dichotomous (yes/no). Those reporting work disability at baseline were identified as prevalent disability cases (work pace/quality change, lost time or job change) and excluded from incident analyses. The outcome for these analyses was one of the measures of incident work disability which occurred at the onset or after the worker met the case definition for CTS.

Individual factors

Individual factors such as gender, age, measured body mass index (BMI), medical comorbidities and prior injuries were collected at baseline. Race, education and work history were also collected at baseline.

Work psychosocial factors

Elements from the Job Content Questionnaire (JCQ) were administered to collect information on work psychosocial factors at baseline. Four job strain 'quadrants' were created by using the median split of the JCQ subscales (psychological job demand and decision latitude) to form four groups of job strain including high strain (high demand, low control), passive strain (low demand, low control), active strain (high demand, high control) and low strain (low demand, high control).[12 13]

Biomechanical exposure

Baseline, task-level workplace exposure assessments were obtained for each worker. Exposure assessment typically included: worker interview, task observation by a trained ergonomist, workplace measurements of applied forces and tool and part weights, video recording, and video analyses[7] Estimates included the highest hand force requirements for a task using the Borg CR-10 rating scale, a 0–10 point scale ranging from 'nothing at all' to 'extremely strong' (Worker Rated Peak Hand Force; Analyst Rated Peak Hand Force). Estimates of the repetitiveness of a task used the Hand Activity Level (HAL) scale, a 0–10 point scale that has anchors describing the frequency of exertions and recovery. The 2018 American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for Hand Activity is a composite index that combines repetition (HAL scale) and peak hand force to calculate a Peak Force Index (PFI) score for the action limit and the TLV. Temporal exertion patterns for repetition (Total Hand Repetition Rate; Forceful Hand Repetition Rate), duty cycle (% time All Exertions; % time Forceful Exertions) and posture (% time ≥30°Wrist Extension; % time ≥30°Wrist Flexion) were determined by detailed time studies of task level.[10 14] Forceful exertions were those requiring ≥9N pinch force or ≥45N of power grip force or a Borg CR-10≥2. Exposure to hand vibration (yes/no) was recorded by the analyst for each. Exposures were measured at the individual task level at all study sites at the time of participant enrolment and measured again if the job changed.[8] An individual's job level exposure was calculated as a time-weighted average of task exposures based on self-reported weekly time spent performing each task.

Baseline covariates

Covariates known to be likely confounders such as age, gender and BMI, were included in every model. The other covariates considered for inclusion in the analyses were medical condition, ethnicity, highest education attained, prior distal UEMSD, time on the job at same company, smoking status, aerobic activity level and non-aerobic hand intensive activity level.

Statistical analysis

Cox proportional hazard models with robust CIs were used to estimate adjusted hazard ratios for personal, biomechanical and work psychosocial factors and CTS-related incident work disability. Person-time accrued from the time the worker met the case definition of CTS. Mean, median, IQR, IR, HRs and 95% CIs were calculated. Biomechanical exposures were categorised by tertiles. Models were adjusted for confounding by personal factors (age, gender, BMI), study site and non-overlapping biomechanical exposures.[8] Confounding by additional covariates that were not mediators on the pathway from exposure to outcome was assessed by successively including and removing each from the model and retaining it if the primary exposure coefficient changed more than 10%.

RESULTS

Among those included in this analysis (figure 1), compared with the incident CTS cases (N=140 (38%)) those with prevalent CTS (N=232 (62%)) had a slightly higher mean age(2.3 years), BMI (1.5 kg/m^2) and tenure (1.5 years); additionally, there were slightly more females(6%) and report of a comorbidity(7%). Overall, of the 372 workers included in the analysis, two-thirds were 40 years of age or older (50%=44.9 years; IQR 36.0–52.0) (table 1). The median year worked at enrolment was 6.5 years (IQR 3.2–12.0). Table 2 summarises exposures to biomechanical and psychosocial job factors. There were no significant differences between mean baseline exposure values between the prevalent and incident CTS cases, though the prevalent cases had slightly higher measures of repetition and duty cycle.

Disability prevalence, incidence and time to disability onset after CTS

Participants who met the criteria for a work disability at the time they met the CTS case definition were considered prevalent work disability cases (figure 1); incident rates by disability varied(table 3). The median time to onset of disability differed among those meeting the criteria for CTS at baseline (prevalent CTS cases) compared with those who developed incident CTS. Specifically, a change in work pace/quality was reported after a median interval of 521 days (IQR: 239–722) by prevalent CTS cases (n=114) compared with 155 days (IQR: 60–414) by incident CTS cases (n=43), lost work time was experienced after a median period of 459 days (IQR: 314–711) by prevalent CTS cases (n=72) compared with 227 days (IQR: 78–435) by incident CTS cases (n=25), and job change occurred after a median interval of 570 days (IQR: 244–729) among prevalent CTS cases (n=88) compared with 231 days (IQR: 116–535) among incident CTS cases (n=24).

Table 2 Summary of baseline biomechanical and work psychosocial exposures

	N	Mean (SD)
Force measures		
Peak Borg CR-10: Worker's rating (0–10 scale)	346	3.9 (2.2)
Peak Borg CR-10: Analyst's rating (0–10 scale)	365	3.0 (1.7)
Repetition measures		
Hand Activity Level Scale: Analyst's rating (0–10 scale)	367	4.9 (1.7)
Total repetition rate* (reps/min)	363	21.6 (15.7)
Forceful repetition rate* (reps/min)	363	7.7 (10.1)
Dty cycle		
% duration all exertions* (0%–100%)	363	67.1 (18.4)
% duration forceful exertions* (0%–100%)	363	22.4 (19.4)
Posture measures		
% time $\geq 30°$ wrist flexion* (0%–100%)	360	4.2 (9.1)
% time $\geq 30°$ wrist extension* (0%–100%)	360	13.8 (20.6)
Work psychosocial measures		
Psychological demand†	182	31.9 (4.9)
Decision latitude†	180	60.0 (8.5)
Other measures	N	%
Vibration		
None	190	54.6
Some	158	45.4
2018 ACGIH TLV for hand activity		
Lower tertile ($<PFI_{AL}$)	72	19.8
Middle tertile ($\geq PFI_{AL}$ and $< PFI_{TLV}$)	86	23.7
Upper tertile ($\geq PFI_{TLV}$)	205	56.5

*Direct measurements and/or from videotape analyses.
†Domain of the Karasek Job Strain Index.
ACGIH, American Conference of Governmental Industrial Hygienists; PFIAL, PFI action limit; PFITLV, Peak Force Index threshold limit value.

Sociodemographic factors, baseline health status and disability incidence

Regardless of outcome measure, females had non-significant, modestly higher rates of work disability than males (table 3), and older age was associated with lower rates of work disability. Hispanics experienced higher disability rates than other ethnic groups and having a high BMI more than tripled the rate of lost time following CTS.

Work history, biomechanical exposures, psychosocial job factors and disability incidence

Measures of hand repetition, such as a HAL of more than 4 or a total hand repetition rate of more than 13.6 reps/min or spending more than 76% of time in any hand exertion, or spending more than 29% of time in forceful hand exertion increased the rate of a job change (table 4).

Not all research sites in the consortium had compatible psychosocial data and thus the cohort having both biomechanical exposure and work psychosocial data was smaller than the main cohort. Nevertheless, among those with lost time or job change, 6 out of 12 (50%) and 7 out of 16 (44%) cases had high job strain, respectively, yet only 2 individuals in each model had low job strain (table 4).

A sensitivity analysis indicates that the incident CTS cases had consistently higher effect estimates than the prevalent CTS cases, despite wide confidence intervals due to a limited number of incident disability cases. For example, those with middle and high percent time in forceful exertion had a 2.37 (95% CI 0.62 to 9.05) and 3.04 (95% CI 0.94 to 9.84) increased in the rate of a job change compared with the prevalent CTS who had rates of 0.92 (95% CI 0.49 to 1.72) and 1.51 (95% CI 0.82 to 2.79).

DISCUSSION

This prospective cohort study of workers with CTS found that the incidence of those with CTS experiencing new changes in work pace/quality was much higher (33.2/100 pyrs) than the incidence of those who experienced lost time (16.3/100 pyrs) or job changes (20.0/100 pyrs) due to CTS. Changes in pace and quality of work are likely to precede lost time or job changes, and these self-reported difficulties in performing job tasks might continue for some time before a change in job duties or the inability to perform the job occurred. Another potential explanation for these findings is that the inconveniences and financial and other penalties associated with lost time resulted in that measure being lowest.

An important finding of this research was how non-occupational risk factors differed considerably for the three measures of disability. In contrast to prior studies,[15 16] being older was not associated with increased risk of CTS-related disability. In fact, workers older than 40 years reported a reduced rate of changes in work pace or quality or job changes. However, consistent with prior studies, women and workers with self-reported rheumatoid arthritis did have trends in increased rates of CTS-related disability.[7 17] Workers who reported their health as 'fair' or 'poor' had a 70%–80% increased rate in changes in work pace/quality or job change and obese workers had a higher rate of lost time due to CTS, but not pace/quality change or job change.

In a prior paper, we found that greater time in non-occupational hand intensive activity was associated with a lower risk of developing CTS.[7] In the current analyses, baseline hand intensive exposures outside of and during work were associated with a higher incidence of subsequent disability. There are various possible explanations for these seemingly disparate findings beyond a potentially spurious result. One explanation is that the risks for the development of CTS are not the same as those that produce disability. Another explanation is that, regardless of disease or symptoms, there is a minimal level of hand intensive activities that cannot be reduced, particularly among women caring for dependents in the home since activities of daily living were included as non-occupational hand intensive activity. Perhaps those caring for dependents may not have any alternatives to performing offhand intensive activities in the home, thus leading to lost time at work.

Workers with longer tenure at baseline tended to have reduced rates of CTS-related disability than those who worked for shorter durations. In fact, individuals who worked more than 12 years had a 58% reduction in the rate of lost time following CTS. Perhaps these workers had a greater ability to influence their work given their tenure. Alternatively, perhaps these workers represented a healthier population and were able to continue working despite their condition either due to greater ability to adapt to symptoms over time and/or potentially having milder symptoms.

Consistent with prior analyses on CTS incidence,[17] work psychosocial factors such as job dissatisfaction and job strain were independently associated with disability following CTS. However, associations with disability were much stronger; in fact, high job strain was the strongest predictor of severe disability outcomes, with a fourfold increased rate of lost time and a 6.5-fold increased rate of job change. High psychological job demands increased disability independent from biomechanical factors and high decision latitude on the job appeared to protect workers though confidence intervals

Table 3 Personal factors and risk of CTS-related work disability, HRs and 95% CIs adjusted for age, gender, BMI and consortium research site

	Pace/quality change (N=319; n=157; IR=33.2 per 100 PYs)				Lost time (N=362; n=97; IR=16.3 per 100 PYs)				Job change (N=360; n=112; IR=20.0 per 100 PYs;)			
	N	Cases (n)	HR	95% CI	N	Cases (n)	HR	95% CI	N	Cases (n)	HR	95% CI
Gender*	317	155			360	97			358	110		
Male		36	1.00			19	1.00			20	1.00	
Female		119	1.27	0.85 to 1.89		78	1.13	0.67 to 1.92		90	1.47	0.9 to 2.39
Age (years)†	317	155			360	97			358	110		
<30 years of age		18	1.00			8	1.00			12	1.00	
≥30 and <40 years of age		34	0.79	0.42 to 1.46		20	1.02	0.45 to 2.31		26	0.94	0.43 to 2.05
≥40 and <50 years of age		58	0.48	0.26 to 0.88		34	0.84	0.38 to 1.84		42	0.51	0.23 to 1.11
≥50 years of age		45	0.54	0.29 to 0.99		35	1.18	0.55 to 2.52		30	0.49	0.22 to 1.08
Ethnicity	274	130			314	82			312	94		
Caucasian		89	1.00			59	1.00			72	1.00	
Hispanic/Latino		37	1.92	1.24 to 2.97		15	1.64	0.85 to 3.17		15	1.54	0.84 to 2.83
Black/African American		30	0.86	0.38 to 1.94		--	0.00	0 to 0		--	0.00	0 to 0
Asian		13	0.99	0.29 to 3.39		--	0.00	0 to 0		--	0.00	0 to 0
Other		13	0.98	0.39 to 2.49		8	0.65	0.31 to 1.38		7	0.52	0.22 to 1.25
Education	312	150			355	96			353	109		
Some high school or less		17	1.00			13	1.00			8	1.00	
High school graduate or above		133	0.89	0.55 to 1.45		83	0.68	0.37 to 1.25		101	1.54	0.79 to 3.01
Handedness	317	155			360	97			358	110		
Left handed		13	1.00			10	1.00			8	1.00	
Right handed		142	1.78	1.06 to 2.99		87	1.17	0.66 to 2.06		110	2.11	1.12 to 3.98
Body mass index (kg/m²)	317	155			360	97			358	110		
<25		24	1.00			11	1.00			22	1.00	
≥25 and <30 (overweight)		54	1.30	0.83 to 2.03		29	1.88	0.88 to 4.0		33	0.80	0.46 to 1.39
≥30 (obese)		77	1.11	0.58 to 2.13		57	3.40	1.31 to 8.8		55	0.60	0.27 to 1.31
General health	305	145			346	93			343	106		
Very good or excellent		57	1.00			40	1.00			47	1.00	
Good		63	1.25	0.86 to 1.82		40	1.09	0.70 to 1.72		43	1.02	0.66 to 1.6
Fair or poor		25	1.80	1.12 to 2.88		13	1.37	0.64 to 2.91		16	1.69	1.00 to 2.86
Comorbidity	317	155			360	97			358	110		
No medical condition		124	1.00			74	1.00			85	1.00	
Current medical condition		31	0.91	0.61 to 1.36		23	1.01	0.62 to 1.64		25	1.01	0.65 to 1.58
Diabetes mellitus		9	0.70	0.31 to 1.58		8	1.12	0.55 to 2.29		7	0.71	0.31 to 1.63
Rheumatoid arthritis		12	1.50	0.79 to 2.85		9	1.40	0.71 to 2.74		7	0.92	0.41 to 2.05
Thyroid disease		14	0.70	0.43 to 1.14		12	1.01	0.54 to 1.9		15	1.13	0.7 to 1.83
Previous distal UEMSD	252	137			272	87			271	100		
No previous distal UEMSD		94	1.00			54	1.00			72	1.00	
Previous distal UEMSD		43	1.20	0.82 to 1.75		33	1.29	0.82 to 2.01		28	0.90	0.57 to 1.42

Table 3 continued

	Pace/quality change (N=319; n=157; IR=33.2 per 100 PYs)				Lost time (N=362; n=97; IR=16.3 per 100 PYs)				Job change (N=360; n=112; IR=20.0 per 100 PYs)			
	N	Cases (n)	HR	95% CI	N	Cases (n)	HR	95% CI	N	Cases (n)	HR	95% CI
Smoking status	**315**	**154**			**357**	**97**			**355**	**110**		
Never smoked		77	1.00			52	1.00			56	1.00	
Currently smokes		40	1.17	0.78 to 1.77		20	0.82	0.46 to 1.45		29	1.32	0.80 to 2.18
Previously smoked		37	1.10	0.74 to 1.66		25	0.97	0.60 to 1.56		25	1.01	0.62 to 1.64
Non-occupational weekly aerobic non-hand activity	**189**	**123**			**202**	**85**			**197**	**95**		
≤3 hours/week		56	1.00			25	1.00			43	1.00	
>3 hours/week		67	0.70	0.49 to 1.00		60	**1.88**	**1.18 to 3.00**		52	0.73	0.48 to 1.11
Non-occupational weekly hand intensive activity	**250**	**136**			**271**	**87**			**270**	**100**		
≤3 hours/week		28	1.00			10	1.00			14	1.00	
>3 hours/week		108	0.92	0.60 to 1.41		77	**2.09**	**1.06 to 4.13**		86	1.57	0.90 to 2.75
Summary of workplace factors												
Years worked at enrolment	**312**	**150**			**355**	**96**			**353**	**108**		
≤1 year		9	1.00			7	1.00			6	1.00	
>1 year and ≤3 years		13	1.73	0.65 to 4.60		7	0.63	0.23 to 1.73		12	**3.98**	**1.38 to 11.44**
>3 years and ≤7 years		56	**2.33**	**1.06 to 5.09**		38	1.20	0.53 to 2.71		34	2.26	0.83 to 6.18
>7 years and ≤12 years		40	2.00	0.88 to 4.53		28	0.74	0.31 to 1.76		31	**3.03**	**1.08 to 8.53**
>12 years		32	2.21	0.93 to 5.24		16	0.42	0.16 to 1.08		25	**3.17**	**1.05 to 9.56**
Job satisfaction	**308**	**147**			**350**	**95**			**347**	**108**		
Very satisfied		27	1.00			19	1.00			19	1.00	
Satisfied		82	**1.69**	**1.09 to 2.62**		50	0.89	0.50 to 1.58		61	1.57	0.94 to 2.63
Not satisfied		38	**2.02**	**1.21 to 3.37**		26	1.24	0.67 to 2.29		28	1.60	0.86 to 3.00

Bold text denotes statistical significance at p<0.05.
* Adjusted only for age, BMI and consortium research site.
† Adjusted only for gender, BMI and consortium research site.
BMI, body mass index; CTS, carpal tunnel syndrome; IR, incidence rate; UEMSDs, upper extremity musculoskeletal disorders.

Table 4 Biomechanical and psychosocial job factors and risk of CTS-related work disability, HR and 95% CIs adjusted for age, gender, BMI and Consortium research site

		Pace/quality change				Lost time				Job change			
	Cutoffs	Cohort (N)	Cases (n)	HR	95% CI	Cohort (N)	Cases (n)	HR	95% CI	Cohort (N)	Cases (n)	HR	95% CI
Force measures (adj; for total repetition rate, % duration all exertions, % time ≥30° Wrist Flexion)													
Peak Borg CR-10: Worker (0–10 scale)		276	142			309	89			305	105		
Lower tertile	≤3		48	1.00			31	1.00			35	1.00	
Middle tertile	>3 and ≤4.5		46	1.24	0.81 to 1.92		27	1.07	0.62 to 1.85		36	1.17	0.71 to 1.93
Upper tertile	>4.5		48	1.09	0.72 to 1.65		31	1.15	0.67 to 1.99		34	1.14	0.69 to 1.91
Peak Borg CR-10: Analyst (0–10 scale)		287	144			323	89			320	105		
Lower tertile	≤2.3		46	1.00			26	1.00			35	1.00	
Middle tertile	>2.3 and ≤3.8		58	1.17	0.74 to 1.84		36	1.14	0.66 to 1.97		39	0.91	0.54 to 1.56
Upper tertile	>3.8		40	0.99	0.62 to 1.59		27	1.43	0.81 to 2.56		31	1.25	0.70 to 2.25
Repetition measures (adj; for analyst rated peak CR-10, % time ≥30° Wrist Flexion)													
Hand activity level (HAL Scale: analyst (0–10 scale)		287	145			323	89			320	105		
Lower tertile	≤4		41	1.00			24	1.00			18	1.00	
Middle tertile	>4 and ≤6		71	1.45	1.00 to 2.13		37	0.84	0.48 to 1.48		56	2.37	1.34 to 4.21
Upper tertile	>6		33	1.09	0.68 to 1.77		28	1.17	0.67 to 2.06		31	2.17	1.18 to 4.02
Total repetition rate (reps/min)		287	144			323	89			320	105		
Lower tertile	≤13.6		40	1.00			20	1.00			21	1.00	
Middle tertile	>13.6 and ≤24.0		50	1.36	0.90 to 2.09		37	1.43	0.81 to 2.54		40	1.87	1.09 to 3.23
Upper tertile	>24.0		54	1.20	0.79 to 1.85		32	1.45	0.82 to 2.58		44	1.75	1.02 to 3.02
Forceful repetition rate* (reps/min)		293	145			329	89			326	105		
Lower tertile	≤2.3		41	1.00			25	1.00			26	1.00	
Middle Tertile	>2.3 and ≤8.1		49	1.09	0.70 to 1.72		30	1.44	0.82 to 2.55		33	1.14	0.66 to 2.00
Upper tertile	>8.1		55	1.28	0.79 to 2.09		34	1.36	0.81 to 2.30		46	1.62	0.94 to 2.80
Duty cycle (adj; for analyst rated CR-10, total repetition rate, % time ≥30°Wrist Flexion)													
% duration all exertions (0%–100%)		287	144			323	89			320	105		
Lower tertile	≤58.6		44	1.00			29	1.00			27	1.00	
Middle tertile	>58.6 and ≤75.8		46	0.90	0.61 to 1.36		30	0.96	0.56 to 1.65		43	1.82	1.09 to 3.06
Upper tertile	>75.8		54	1.62	1.03 to 2.56		30	1.15	0.69 to 1.93		35	2.20	1.22 to 4.01
% duration forceful exertions* (0%–100%)		293	145			329	89			326	105		
Lower tertile	≤11.0		39	1.00			27	1.00			28	1.00	
Middle tertile	>11.0 and ≤28.6		52	1.29	0.83 to 2.02		27	1.17	0.68 to 2.06		33	1.12	0.65 to 1.96
Upper tertile	>28.6		54	1.51	0.95 to 2.41		35	1.38	0.83 to 2.33		44	1.74	1.02 to 2.98
Posture measures (adj; for analyst rated CR-10, total repetition rate, % duration all exertions)													
% time ≥30° wrist extension (0%–100%)		287	144			323	89			320	105		
Lower half	≤3.3		66	1.00			45	1.00			45	1.00	
Upper half	>3.3		78	1.04	0.72 to 1.50		44	0.84	0.52 to 1.35		60	1.11	0.72 to 1.73

Table 4 continued

		Pace/quality change				Lost time				Job change			
	Cutoffs	Cohort (N)	Cases (n)	HR	95% CI	Cohort (N)	Cases (n)	HR	95% CI	Cohort (N)	Cases (n)	HR	95% CI
% time ≥30° wrist flexion (0%–100%)		287	144			323	89			320	105		
Lower half	≤0.8		76	1.00			42	1.00			48	1.00	
Upper half	>0.8		68	0.93	0.66 to 1.33		47	1.00	0.65 to 1.57		57	1.26	0.83 to 1.91
Other (adj; for analyst rated peak CR-10, total repetition rate, % duration all exertions, % time ≥30° Wrist Flexion)													
Vibration		276	139			306	88			303	104		
None	≤0		61	1.00			32	1.00			43	1.00	
Some	>0		78	0.84	0.57 to 1.24		56	1.05	0.67 to 1.66		61	0.88	0.57 to 1.38
2018 ACGIH TLV for hand activity		287	145			323	89			320	105		
Lower tertile	$<PFI_{AL}$		20	1.00			14	1.00			13	1.00	
Middle tertile	$\geq PFI_{AL}$ and $<PFI_{TLV}$		43	1.24	0.70 to 2.22		20	0.79	0.40 to 1.56		28	1.02	0.50 to 2.07
Upper tertile	$\geq PFI_{TLV}$		82	1.37	0.79 to 2.39		55	1.27	0.72 to 2.25		64	1.56	0.80 to 3.04
Work psychosocial exposures													
Psychological job demands*		142	38			175	12			176	16		
Low demands	<32		15	1.00			4	1.00			4	1.00	
High demands	≥32		23	1.53	0.82 to 2.89		8	2.15	0.60 to 7.73		12	**3.39**	**1.04 to 11.08**
Decision latitude		141	38			173	12			174	16		
Low latitude	<60		20	1.00			8	1.00			9	1.00	
High latitude	≥60		18	0.64	0.33 to 1.28		4	0.32	0.11 to 1.01		7	0.45	0.16 to 1.28
Job strain		141	38			173	12			174	16		
Low strain			9	1.00			2	1.00			2	1.00	
Passive strain			9	1.12	0.45 to 2.81		2	1.75	0.27 to 11.39		5	3.18	0.64 to 15.98
Active strain			6	1.09	0.41 to 2.95		2	2.83	0.45 to 18.2		2	2.09	0.33 to 13.29
High strain			14	2.15	0.95 to 4.91		6	**4.82**	**1.04 to 22.54**		7	**6.58**	**1.27 to 34.25**

Bold text denotes statistical significance at p<0.05.
*Only adjusted for posture (% time ≥30°Wrist Flexion).
BMI, body mass index; HAL, hand activity level; PFIAL, Peak Force Index action limit; TLV, threshold limit value.

were wide. Similar to studies of low back pain,[6] increased job strain may increase the rate of disability following CTS, suggesting that reducing job strain may be an early intervention strategy to prevent costly work disability.

In stark contrast to prior analyses on CTS incidence, peak force estimates showed weak positive associations with disability.[8] This suggests that while peak force contributes to the development of CTS, once a person has CTS, other factors become relatively more important contributors to disability. This is in line with the phase model of disability[18 19] and previous research demonstrating that risk factors for MSD incidence may differ from those for work disability and specific durations or phases of work disability.[6] It is also consistent with a substantial body of research suggesting disability is strongly related to psychosocial issues, although that literature is mostly related to spine pain,[20–22] and with the pyramid model of disability where different risk factors influence the transition between different states of injury and disability.[23]

In this regard, perhaps a more important finding from this study was the association between measures of total repetition rate, the % time spent in any hand exertion and some of the measures of disability. These measures were not strongly associated with incident CTS in our prior analyses,[8] yet they were associated with disability following CTS. This suggests that once a person meets a CTS case definition, stay-at-work and return-to-work strategies that reduce total repetition and the % time spent in any hand exertion (light or heavy) may reduce some of the measures of future disability. Regardless, it should be noted that these findings suggest that force is still an important predictor of CTS disability when it also includes a measure of duration. The TLV for Hand Activity has performed well as a predictor of incident CTS and may be useful as a surveillance tool.[3 9] These findings suggest that separately tracking HAL as a part of surveillance efforts may be useful in building proactive strategies for preventing disability following CTS among workers in high-risk groups.

Study results regarding disability from CTS are similar to what is seen in clinical practice. Our study used a clinically relevant case definition for CTS that requires both symptoms of median neuropathy and electrodiagnostic studies showing slowing of conduction in the median nerve at the wrist.[11] Our study found a greater chance of disability among workers with CTS who had more hand intensive activities at work. This finding has been seen in other studies,[24] is commonly seen in clinical practice and is reflected in clinical guidelines that recommend modifying work to decrease hand intensive activities among patients with CTS. Our study found that workers with CTS reported decreased pace or quality of work, a finding seen in other studies, where CTS patient reported decreased functional abilities[25] including symptoms that interfered with production rates and/or quality of work.[26] Clinically, loss of work capacity is commonly seen before the outcomes of lost work or change in jobs.

Strengths and limitations

The pooling of data from four cohort studies that included workers from different industries provides one of the largest and most diverse prospective cohort studies ever assembled for examining risk factors for work disability due to CTS and allows for greater generalisability than any single study sample. The large cohort increases precision of point estimates and allows for exploration of exposure–outcome relationships and thresholds of risk while adjusting for important covariates.

Despite the large size of the pooled cohort, there were not enough incident CTS cases to restrict these analyses to only those workers with incident CTS. Thus, individuals who had CTS at the inception of the cohort(and who subsequently developed CTS-related work disability) were also included. These prevalent CTS workers were likely to be either: (1) at a later stage of disease progression, (2) be chronic cases and/or (3) survivors somehow able to maintain work ability despite having CTS. However, a sensitivity analysis that included only the incident CTS cases showed the same patterns of association and with larger effect estimates indicating attenuation of the rates reported in this analysis of combined CTS incident and prevalent cases. Psychosocial job factors were not assessed at all workplaces and this reduced the number of individuals who had information on both biomechanical and psychosocial measures. Additionally, some studies only assessed psychosocial stress at baseline; thus, only baseline measurements are included in this analysis. Despite this limitation, strong independent effects of low job satisfaction on changes in work pace or quality and of job strain on lost time and job change were found. A much larger sample size would have been needed to determine interaction effects between biomechanical and work psychosocial exposures.

Reliance on self-reported measures of disability and varying intervals of assessment across study sites may have introduced varying amounts of recall or reporting bias; however, this limitation probably applies only to changes in work quality or pace and less to lost work time or job change. Further, the inclusion of prevalent CTS cases at baseline may have led to increased recall bias for those individuals and/or may have contributed to bias from the healthy worker survivor effect. In essence, those with CTS at baseline may have been a healthier cohort that could sustain work despite progressing disease than those who may have already left the workplace thereby leading to an underestimation of effect estimates. Additionally, we did not collect information related to workers compensation claim status or treatment. Therefore, we cannot make any inferences about how CTS management influences CTS-related work disability. Finally, while all three outcomes are plausible, if not likely consequences of CTS, they were not necessarily collected for studying CTS-related disability per se. Thus, the non-specific nature of the work disability questionnaire items which related the incidence of disability to any hand/wrist discomfort and not CTS specifically may have led to inclusion of disability related to concurrent hand/wrist tendinitis with CTS alone.

Future research

Our results indicate that effective strategies to prevent CTS-related disability need to include both ergonomic and organisational job redesign. Development of rapid and low-cost alternative technology that reliably and accurately measures biomechanical exposures may improve feasibility and expand the impact of such interventions.

CONCLUSION

To our knowledge, this is the first large prospective cohort study to estimate associations between biomechanical, work psychosocial and personal factors and subsequent CTS-related work disability based on rigorous case criteria and individualised exposure assessment. Understanding the risk factors associated with work disability among those with CTS is necessary to design comprehensive intervention strategies for those most likely to develop subsequent work disability.

The results of the current study show that reducing total repetition rate and the % time spent in any (light and heavy) hand exertion may reduce the risk of some measures of subsequent disability among those with CTS. The inclusion of prevalent CTS cases in this analysis attenuated the effect estimates reported. The results also suggest that increasing job satisfaction as well as lowering job strain by increasing decision latitude at work and reducing psychological job demands may be important organisational strategies to reduce risk of subsequent work disability.

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