Personal and Workplace Factors and Median Nerve Function in a Pooled Study of 2396 US Workers

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Objective: Evaluate associations between personal and workplace factors and median nerve conduction latency at the wrist. **Methods:** Baseline data on workplace psychosocial and physical exposures were pooled from four prospective studies of production and service workers ($N = 2396$). During the follow-up period, electrophysiologic measures of median nerve function were collected at regular intervals. **Results:** Significant adjusted associations were observed between age, body mass index, sex, peak hand force, duration of forceful hand exertions, Threshold Limit Value for Hand Activity Limit, forceful repetition rate, wrist extension, and decision latitude on median nerve latencies. **Conclusions:** Occupational and nonoccupational factors have adverse effects on median nerve function. Measuring median nerve function eliminates possible reporting bias that may affect symptom-based carpal tunnel syndrome case definitions. These results suggest that previously observed associations between carpal tunnel syndrome and occupational factors are not the result of such reporting bias.

Carpal tunnel syndrome (CTS) is a common condition among workers with reported prevalence rates between 3% and 11% depending on the industry studied.[1–4] It is associated with considerable disability and risk of job loss.[5,6] There remains some controversy over specific workplace factors associated with CTS and their exposure–response associations because of imprecise exposure measures, differences in study outcomes, small sample sizes, and lack of longitudinal studies.[2]

The physiologic hallmark of CTS is median nerve mononeuropathy at the wrist. Electrophysiologic evidence of median mononeuropathy is ascertained by measurement of median nerve conduction parameters, most commonly conduction latency and conduction velocity. Although the classic clinical definition of CTS requires both characteristic symptoms and electrophysiologic abnormality,[7] the use of electrophysiologic measures alone has several advantages. First, unlike symptom reporting, electrophysiologic measures are free of any potential participant or investigator biases associated with knowledge of exposure circumstances. Second, although symptoms in the distribution of the median nerve may be due to a wide range of potential pathologies, isolated median mononeuropathy is highly specific for localized median nerve dysfunction consistent with CTS. Finally, unlike symptoms, electrophysiologic parameters can be analyzed as continuous variables, thereby improving statistical power.

In this study, electrophysiologic measures of median nerve function were available for a large number of participants who were included in four National Institute for Occupational Safety and Health funded studies, examining associations between occupational risk factors and a wide range of upper extremity conditions and disorders, including CTS. To examine the purely physiologic effects of occupational exposures on median nerve function, we explored associations between electrophysiologic measures of median nerve conduction latency across the wrist and individual-level exposures to occupational psychosocial and biomechanical risk factors while controlling for personal factors such as age, sex, and obesity. Associations of personal and occupational factors to the classic clinical case definition for CTS, for example, characteristic symptoms and electrophysiologic abnormality, using this data set, have been published elsewhere.[8,9]

METHODS

Participants

Six research groups conducted coordinated prospective studies of production and service workers at 54 companies in the United States to evaluate personal and work-related risk factors for upper extremity disorders. We have previously described the details of study designs, inclusion criteria, and the process of pooling health outcome and exposure data.[4,10] This analysis only includes data from the four research groups that (1) measured median and ulnar nerve latencies at the wrist at regular intervals and (2) measured job task–level biomechanical exposures of the hand among participating workers ($N = 2868$; sites A, B, C, and E[4]). Potential participants were ineligible if they had a prior carpal tunnel release surgery ($n = 36$), had baseline ($n = 55$) or incident ($n = 26$) polyneuropathy (defined below), or worked less than 1 year on the job ($N = 309$). There was varied representation of workers across standard industrial classification divisions, with nearly all coming from the agriculture (7%), manufacturing (81%), and service (12%) industries.

Data Collection

In all four studies, questionnaires were administered at enrollment (baseline) to collect information on work history, demographics, medical history, and musculoskeletal symptoms. All studies collected electrophysiologic measures across the wrist, including median nerve sensory latency, median nerve motor latency, and ulnar nerve sensory latency. The methods used by each site have been previously described.[4] Investigators responsible for collecting nerve

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latency measures were blinded to exposure status. Exposure was assessed on the individual level at baseline for all studies. For most subjects, symptom assessment, physical examinations, and electrodiagnostic studies were repeated at regular follow-up intervals.[4,10] If repeated electrophysiologic measures were performed during the follow-up period, then the last measurement was used for the current analyses.

Personal Factors

Age, sex, body mass index (BMI), race/ethnicity, education, smoking status, hand dominance, and comorbid medical conditions such as rheumatoid arthritis, diabetes mellitus, and thyroid disease status were collected from all participants. General health was assessed on a five-point scale from "poor" to "excellent."

Occupational Factors

Survey or interview questions regarding the psychosocial work environment were administered at study enrollment in three of the four studies. Items from the Job Content Questionnaire[11] were used to calculate psychological job demand and decision latitude scale scores. The psychological demand scale is based on five items (excessive work, conflicting demands, insufficient time to work, work fast, and work hard). The decision latitude scale is based on skill discretion (eg, learning new things and task variety) and decision authority (choice in how to perform work and making decision).

Biomechanical Workplace Exposures

All studies measured workplace exposures within the biomechanical domains of hand force, hand repetition, hand duty cycle, and wrist posture. Measurements were made at the level of the job task, using methods comparable with those used in previous studies.[12–17] For most exposure domains, multiple variables were calculated to quantify specific exposure metrics.[10] For three study sites, analysts recorded the presence or absence of hand vibration by task.

The pooled data set included estimates of peak force—the highest hand force requirements of a task—using the Borg CR-10 rating scale-estimated separately by workers and analysts. Temporal exertion patterns such as repetition and duty cycle were determined by detailed time studies of videotapes of subjects performing their tasks. The hand activities of the workers were analyzed on a frame-by-frame basis by trained analysts who were blinded to the health status of workers. Estimates of the repetitiveness of a task were quantified using the analyst HAL rating (verbal anchors), the total number of all exertions per minute based on video analysis, and the total number of forceful exertions per minute based on video analysis and task force data. Forceful exertions were those performed at greater than 45 N of power grip, greater than 9 N of pinch, or rated as 2 or more on the Borg CR-10 scale. Duty cycle was quantified from video analysis as percentage time for all hand exertions and also the percentage time for forceful hand exertions. Posture was quantified from video analysis as the percentage time spent in greater than 30° of wrist extension and the percentage time spent in greater than 30° of wrist flexion, as measured from a neutral (0°) wrist position. Finally, any (yes/no) exposure to hand/arm vibration through visible hand/arm vibration and/or the use of vibratory hand tools was recorded by task. A composite exposure score for each task was calculated using the combination of analyst HAL scale and analyst peak force according to the methods described for the ACGIH TLV for HAL.[18] Further details on exposure assessment methods are described in a prior publication.[10]

Job physical exposures were collected at baseline for each task (up to eight) that each worker performed. If workers performed multiple tasks for their job, then a job-level exposure was calculated using time weighted averaging, where each task-level exposure was weighted by the proportion of time the task was performed each week.

Outcomes

The primary outcome measures were the median peak sensory latency, median motor latency, and median–ulnar peak sensory latency difference (MUD) collected from the dominant hand of each participant. Subjects were excluded from the analysis if they had polyneuropathy defined as ulnar sensory peak latency of 3.68 ms or more (corresponds to a conduction velocity of 44 m/s).

Statistical Analysis

Regression coefficients were estimated using multiple linear regression with separate analyses conducted for each of the three outcome measures. Time weighted averaging exposures were included in the regression models as continuous independent variables. Potential confounding by personal factors was assessed using both empirical observation and directed acyclic graphs to posit structural relationships among the variables. Directed acyclic graphs are a method of modeling variables that considers the ordering of the variables in a potential causal pathway. Covariates not on the pathway from exposure to outcome and that were available for 90% or more of the participants were initially included in each model as potential confounders. Those covariates that changed the effect estimate of the primary exposure variable by more than 10% on removal from the model were subsequently included in the final models to adjust for confounding. Because of prior research demonstrating important associations between age, sex, and BMI and CTS, these factors were retained in every model regardless of strength of association in this sample.[8] Comorbid medical conditions were not included in any models because all prevalent and incident polyneuropathy cases were excluded from the analysis.

To provide the least biased estimates of associations between exposure and outcome, models examining associations between each biomechanical exposure metric and each outcome metric were adjusted by study site and by one variable from each of the other biomechanical exposure domains (force, repetition, duty cycle, and posture). Because each exposure domain had more than one candidate variable, the variable within each domain with the highest number of participants was selected to maximize statistical power. In addition to adjusted model R^2, a dimensionless metric of effect size analogous to the Cohen *d* was calculated for each exposure variable.[19] Specifically, the effect size metric was calculated as follows:

Effect size = (interquartile range of exposure variable*β exposure variable)/SD dependent variable

Essentially, the effect size metric is the magnitude of change in the dependent variable resulting from an interquartile range value of change in the exposure variable, reported in units of dependent variable standard deviation. The effect sizes for the Cohen *d* are the following: small effect = 0.2 or greater, medium effect = 0.5 or greater, and large effects = 0.8 or greater.[19] All analyses were implemented with the Stata statistical package (Stata, College Station, TX).

RESULTS

Of the 2442 potential participants, those with unobtainable nerve latency measures ($N = 23$) or no workplace exposure data ($N = 23$) were eliminated from the current analyses. Demographic and occupational characteristics of the 2396 participating workers are provided in Table 1; demographic characteristics are similar to US workplace data.[20] Approximately 11% of subjects reported a physician-diagnosed medical condition (eg, diabetes, rheumatoid arthritis, thyroid disorder, or pregnancy), and 10% reported a previously diagnosed distal upper extremity disorder. Most participants (72%) had worked for more than 3 years; the number of years worked was correlated with age ($R^2 = 0.46$, data not shown).

Summary measures of upper extremity biomechanical exposures, psychosocial measures, and nerve latency values are provided

TABLE 1. Demographic Characteristics of Study Population

	$N = 2,396$	%
Sex		
Male	1,122	47
Female	1,274	53
Age, yrs		
<30	469	20
≥30 and <40	603	25
≥40 and <50	766	32
≥50	558	23
Ethnicity		
White	1,133	47
Hispanic	548	23
African American	178	7
Asian	145	6
Other	75	3
Education		
Some high school or less	509	21
High school graduate or above	1,871	78
Handedness		
Left handed	187	8
Right handed	2,209	92
Body mass index		
Body mass index (<25)	734	31
Body mass index (≥25 and <30: overweight)	807	34
Body mass index (≥30: obese)	844	35
General health		
Very good or excellent	961	40
Good	969	40
Fair or poor	315	13
Medical condition		
No medical condition	2,102	88
Current medical condition	290	12
Diabetes	103	4
Rheumatoid arthritis	59	3
Thyroid disease (hyper/hypo)	133	6
Pregnancy	18	1
Previous distal upper extremity disorder		
No previous distal upper extremity	1,658	69
Previous distal upper extremity	286	12
Smoking status		
Never smoked	1,282	54
Currently smokes	588	25
Previously smoked	513	21
Years worked at enrollment		
>1 and ≤3	536	22
>3 and ≤7	631	26
>7 and ≤12	623	26
>12	426	18

in Table 2. Some of the measures were collected among a subset of subjects, for example, work psychosocial factors; therefore, some sample sizes in Table 2 are smaller than others. The three nerve latency variables were moderately to strongly correlated (median sensory latency to median motor latency, $R^2 = 0.68$; median sensory latency to MUD, $R^2 = 0.84$; and median motor latency to MUD, $R^2 = 0.63$).

TABLE 2. Summary of Job Exposure Values (TWA) and Median Nerve Latency Measures

Biomechanical Measures	*n*	Mean	SD	Median	IQR
Force measures					
Peak force: worker rated Borg CR10	2,119	3.5	2.2	3.3	2–5
Peak force: analyst rated Borg CR10	2,279	3.0	1.8	3.0	1.3–4
Repetition measures					
Analyst HAL rating	2,286	4.8	1.7	4.9	4–6
Total repetition rate	2,289	24.3	19.2	18.1	10.5–32
Forceful repetition rate	2,289	9.4	13.5	4.3	1.1–10.4
Duty cycle					
% duration all exertions	2,289	66.6	19.3	68.0	54.8–80.6
% duration forceful exertions	2,289	22.6	20.3	17.3	5.6–35.3
Posture measures					
% time ≥30° wrist extension	2,272	15.1	22.4	5.0	0–20
% time ≥30° wrist flexion	2,272	3.2	6.8	0.4	0–3.7
Other					
Vibration (N/Y)	1,972	0.34			0–1
Composite measures					
TLV for HAL (analyst peak force)	2,238	0.70	0.61	0.57	0.29–0.86
Work Psychosocial Measures					
Psychological demand scale	1,410	31.39	4.87	31.00	28–34
Decision latitude	1,403	61.04	9.10	62.00	56–66
Latency Measures					
Median sensory latency	2,326	3.578	0.625	3.448	3.15–3.85
Median motor latency	2,367	3.929	0.926	3.800	3.40–4.22
Sensory median–ulnar difference	2,257	0.467	0.532	0.288	0.12–0.60

IQR, interquartile range; SD, standard deviation; TWA, time weighted averaging.

Adjusted regression models for median sensory latency outcome measures are presented in Table 3. Among the demographic variables, statistically significant associations were observed between median sensory latency and age, sex, and BMI. The effect size of BMI was moderate (Cohen $d = 0.59$). There was no significant relationship between previous distal upper extremity disorder and latency. Among the psychosocial variables, decision latitude was significantly associated with *shorter* latency, indicating better nerve function with greater decision latitude, although the effect size was small (Cohen $d = 0.031$). Statistically significant adjusted associations were observed between both worker and analyst estimates of peak hand force and median sensory latency with greater forces associated with longer latency ($\text{coefficient}_{\text{worker rated force}} = 0.03$, $P < 0.001$; $\text{coefficient}_{\text{analyst rated force}} = 0.03$, $P < 0.001$). The effect sizes were small with a Cohen *d* for worker rated peak force of 0.15 and Cohen *d* for analyst rated peak force of 0.14. Of the three measures of repetition, only the forceful repetition rate obtained from video analysis was significantly positively associated with median sensory latency ($\text{coefficient}_{\text{forceful repetition rate}} = 0.003$; $P = 0.01$). Among duty cycle measures, only percentage duration forceful exertions were significantly associated with latency ($\text{coefficient}_{\text{percentage duration forceful exertions}} = 0.002$; $P = 0.007$). The effect size was small. No association between either posture measure or vibrating tool use and sensory latency was observed. Finally, a

TABLE 3. Linear Regression Models for Median Sensory Latency With Work Psychosocial or Biomechanical Exposures. Models Adjusted for Age, Sex, BMI, Study Site, and the Job Physical Exposures Identified in the Table

	n	Coefficient	*P*	Cohen *d*
Age, yrs	2,315	0.015	0.000	0.400
Sex (female)		0.049	0.043	
BMI		0.022	0.000	0.593
Work psychosocial variables (adjusted for peak force, total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Psychological demand	1,052	0.003	0.322	0.016
Decision latitude	1,050	− 0.005	0.010	− 0.031
Biomechanical exposures				
Force measures (adjusted for total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Peak force: worker rated	1,982	0.031	0.000	0.151
Peak force: analyst rated	2,139	0.033	0.000	0.141
Repetition measures (adjusted for peak force, % time ≥30° wrist flexion)				
Analyst HAL rating	2,121	0.013	0.111	0.041
Total repetition rate: video	2,139	0.002	0.130	0.055
Forceful repetition rate: video*	2,196	0.003	0.011	0.041
Duty cycle (adjusted for peak force, % time ≥30° wrist flexion)				
% duration all exertions	2,139	0.001	0.132	0.042
% duration forceful exertions*	2,196	0.002	0.007	0.079
Posture measures (adjusted peak force, total repetition rate, % duration all exertions)				
% time ≥30° wrist extension	2,139	0.000	0.647	0.009
% time ≥30° wrist flexion	2,139	− 0.002	0.253	− 0.012
Other measures (adjusted for peak force, total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Vibrating power tools used	1,874	0.012	0.698	0.019
Composite measures (adjusted for % time ≥30° wrist flexion)				
TLV for HAL (analyst peak force)	2,108	0.060	0.006	0.055

*Not adjusted for peak force.
BMI, body mass index; TWA, time weighted averaging; TLV for HAL, threshold limit value for hand activity level.

significant association was observed between the TLV for HAL (using the analyst peak force rating) and sensory latency. The adjusted R^2 for the models ranged from 0.20 to 0.23.

Adjusted regression models for median motor latency outcome measure are presented in Table 4. As was observed for median sensory latency, age, sex, and BMI were significantly associated with median motor latency. Contrary to the results of median sensory latency, neither of the work psychosocial variables was significantly associated with motor latency. Both metrics of peak hand force were associated with median motor latency with coefficients and effect sizes of similar magnitude to their associations with median sensory latency ($\text{coefficient}_{\text{worker rated force}} = 0.04$, $P < 0.001$; $\text{coefficient}_{\text{analyst rated force}} = 0.04$, $P < 0.001$). The effect sizes were small (Cohen $d_{\text{worker rated force}} = 0.13$; Cohen $d_{\text{analyst rated force}} = 0.11$). Significant but small associations were also observed for the repetition measures of analyst HAL and forceful repetition rate from video analysis, the posture measure of percentage time 30° or greater of wrist extension, and the composite TLV for HAL. No Cohen *d* value exceeded 0.05 for any of these associations. No significant associations were observed for percentage duration of forceful exertions, percentage duration of all exertions, or percentage time 30° or greater of wrist flexion. The adjusted R^2 for the models ranged from 0.18 to 0.20.

Adjusted regression models for median–ulnar latency difference measures are presented in Table 5. As was observed for median sensory latency and median motor latency, age, sex, and BMI were each significantly associated with median–ulnar latency difference. Among the psychosocial variables, decision latitude was significantly *negatively* associated with median–ulnar latency difference, although the effect size was small ($\text{coefficient}_{\text{decision latitude}} = -0.004$, $P = 0.02$; Cohen $d = 0.03$). As was observed for the other two outcomes, forceful repetition rate obtained from video analyses was significantly associated with median–ulnar latency difference ($\text{coefficient}_{\text{forceful repetition rate}} = 0.003$; $P = 0.01$). Among duty cycle measures, only percentage duration forceful exertions was significantly associated with latency ($\text{coefficient}_{\text{percentage duration forceful exertions}} = 0.002$; $P < 0.001$); the effect size was small. Among the posture measures, percentage time 30° or greater of wrist extension was significantly associated with median–ulnar latency difference. The TLV for HAL was also significantly associated with the median–ulnar latency difference. The adjusted R^2 for the models ranged from 0.11 to 0.13.

DISCUSSION

This study presents a unique analysis of associations between personal and work-related factors and an objective, quantitative metric of nerve physiology, median nerve conduction across the wrist. Most recent studies of risk factors for CTS among working populations have used a case definition requiring both a prolonged median nerve latency across the wrist and the reporting of symptoms in the distribution of the median nerve as the outcome measure.[3,8,17,21,22] Although methodologically orthodox,[7] this approach may result in differential error because of reporting bias, with highly exposed participants possibly overreporting hand symptoms in comparison with less highly exposed participants. Should such bias occur, it would result in observed associations that are stronger than true associations. For example, if workers who perform very repetitive hand activities report hand symptoms related to arthritis or cuts more frequently

TABLE 4. Linear Regression Models for Median Motor Latency and Work Psychosocial Exposure or TWA Biomechanical Exposures. Adjusted Models Include Age, Sex, BMI, Study Site, and Selected Job Physical Exposures

	n	Coefficient	*P*	Cohen *d*
Age, yrs	2,356	0.017	0.000	0.308
Sex (female)		0.136	0.000	
BMI		0.032	0.000	0.594
Work psychosocial variables (adjusted for peak force, total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Psychological demand	1,059	− 0.002	0.755	− 0.005
Decision latitude	1,057	− 0.003	0.253	− 0.014
Biomechanical exposures				
Force measures (adjusted for total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Peak force: worker rated	2,019	0.041	0.000	0.133
Peak force: analyst rated	2,175	0.037	0.000	0.109
Repetition measures (adjusted for peak force, % time ≥30° wrist flexion)				
Analyst HAL rating	2,157	0.025	0.041	0.054
Total repetition rate: video	2,175	0.002	0.185	0.049
Forceful repetition rate: video*	2,233	0.004	0.019	0.039
Duty cycle (adjusted for peak force, % time ≥30° wrist flexion)				
% duration all exertions	2,175	0.001	0.174	0.039
% duration forceful exertions*	2,233	0.001	0.137	0.045
Posture measures (adjusted peak force, total repetition rate, % duration all exertions)				
% time ≥30° wrist extension	2,175	0.002	0.020	0.045
% time ≥30° wrist flexion	2,175	0.001	0.595	0.006
Other measures (adjusted for peak force, total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Vibrating power tools used	1,909	− 0.060	0.224	− 0.065
Composite measures (adjusted for % time ≥30° wrist flexion)				
TLV for HAL (analyst peak force)	2,144	0.082	0.016	0.050

*Not adjusted for peak force.
BMI, body mass index; TWA, time weighted averaging; TLV for HAL, threshold limit value for hand activity level.

than others they might be misdiagnosed as having CTS, in which case, the resultant risk estimate for repetition and CTS would be higher than the true estimate.

The use of a physiological measure of median nerve function (a measure that requires no subjective response by the study participant), collected by technicians unaware of participant exposure, is unlikely to be characterized by differential error of the kind that may occur with symptom surveys. Nevertheless, relatively few studies have analyzed median nerve function this way,[23–27] in part because in many studies median nerve function is only measured among the subset of workers with hand symptoms.[28–30]

In addition to the use of a quantitative, objective physiological measure of median nerve function, this study also involved a large population of workers from various industries across the United States, and participants were substantially representative of the age, sex, race, and ethnicity of US workers. Therefore, the findings are more generalizable to the US workforce than studies of just one industry.[23,29]

Personal factors had varied effects on sensory latency, motor latency, and MUD. Medium to large positive effects were observed for age, BMI, and female sex (ie, greater age and BMI and female sex were all associated with longer median nerve conduction latency). Personal factors not significantly related to latency were previous distal upper extremity disorders, education level, and aerobic or hand-intensive activity outside of work. Mostly consistent with this study, prior population and workplace studies have reported positive associations between height, BMI (or weight), age, sex, poverty, and smoking with median motor or sensory conduction measures.[23–27] The linear parameter estimates for age and estimated latency from the all-male study of Letz and Gerr[24] (0.011 to 0.013 ms/year) were similar to this study (0.007 to 0.017 ms/year). Nevertheless, their parameter estimates for BMI (kg/m^2) were wider (0.0007 to 0.0065 ms/[kg/m^2]) than those observed in this study (0.002 to 0.003 ms/[kg/m^2]).

Several occupational factors were significantly associated with prolongation of median nerve latency measures. Significant associations, in decreasing order of effect size, were analyst and worker estimated peak hand force, video-quantified percentage duration of forceful hand exertions, TLV for HAL, video-quantified forceful repetition rate, video-quantified wrist extension, and low decision latitude. Work-related factors that were not significantly associated with latency were psychological demand, total repetition rate, wrist flexion, duty cycle for all hand exertions, and vibration. Few studies have evaluated the associations of workplace factors and latency.[23] The study by Nathan et al[23] found no associations with latency, but the precision of workplace exposure estimates was poor[31] and the sample size was much smaller ($N = 316$). Although the effect sizes were not large, this study shows associations between occupational exposures and nerve physiology. These results clearly demonstrate that workplace physical exposures are associated nerve conduction abnormalities characteristic of CTS.

In general, associations observed in this study using median nerve latency measures as the health outcome are similar to recent high-quality workplace studies that used a more clinical case definition of CTS that includes both symptoms and prolonged median nerve latency. For example, a recent prospective study of 3860 workers found that age, sex, BMI, comorbid medical conditions, and TLV for HAL were independent predictors of CTS.[17]

TABLE 5. Linear Regression Models for Median–Ulnar Sensory Latency Difference and Work Psychosocial Exposure or TWA Biomechanical Exposures. Adjusted Models Include Age, Sex, BMI, Study Site, and Selected Job Physical Exposures

	n	Coefficient	*P*	Cohen *d*
Age, yrs	2,246	0.007	0.000	0.228
Sex (female)		− 0.030	0.171	
BMI		0.025	0.000	0.806
Work psychosocial variables (adjusted for peak force, total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Psychological demand	1,029	0.003	0.301	0.018
Decision latitude	1,027	− 0.004	0.015	− 0.031
Biomechanical exposures				
Force measures (adjusted for total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Peak force: worker rated	1,922	0.026	0.000	0.147
Peak force: analyst rated	2,078	0.030	0.000	0.150
Repetition measures (adjusted for peak force, % time ≥30° wrist flexion)				
Analyst HAL rating	2,061	0.010	0.189	0.036
Total repetition rate: video	2,078	0.001	0.278	0.042
Forceful repetition rate: video*	2,129	0.003	0.009	0.045
Duty cycle (adjusted for peak force, % time ≥30° wrist flexion)				
% duration all exertions	2,078	0.001	0.218	0.036
% duration forceful exertions*	2,129	0.002	0.000	0.120
Posture measures (adjusted peak force, total repetition rate, % duration all exertions)				
% time ≥30° wrist extension	2,078	0.000	0.417	− 0.016
% time ≥30° wrist flexion	2,078	− 0.001	0.510	− 0.008
Other measures (adjusted for peak force, total repetition rate, % duration all exertions, % time ≥30° wrist flexion)				
Vibrating power tools used	1,831	− 0.013	0.652	− 0.024
Composite measures (adjusted for % time ≥30° wrist flexion)				
TLV for HAL (analyst peak force)	2,048	0.054	0.007	0.057

*Not adjusted for peak force.
BMI, body mass index; TWA, time weighted averaging; TLV for HAL, threshold limit value for hand activity level.

This study found relatively little difference in the strength of association across the three median nerve latency measures for age, sex, BMI, and occupational biomechanical factors. An exception was that MUD was more sensitive to changes in BMI and less sensitive to sex compared with the other latency measures. Overall, the association coefficients and effect sizes (the Cohen *d*) were similar in direction and magnitude across the three metrics of median nerve function. This might be expected, given the strong correlations between the three latency measures as noted above. Interestingly, inspection of the adjusted R^2 values for the models suggests that the proportion of variance of the outcomes attributable to the independent variables is greatest for sensory latency, slightly smaller for motor latency, and smallest for MUD.

Several limitations of the study should be noted. Although the data were collected during prospective studies of workers, the duration of follow-up for the prospective component was too brief to observe important changes in median nerve latency measures. Therefore, the analysis used each subjects' final median nerve latency measures as the outcome of interest. A longer duration of follow-up might have allowed for a study of change in latency measures over time. The use of nerve conduction latency alone may be questioned. Nevertheless, this study sought to specifically exclude subjective symptom reporting from the disease outcome. A second limitation was that the workplace exposure assessment relied on both analyst observations and video analysis from recordings of 1 day of work. To the extent that the day observed was not representative of usual work, there may be nondifferential exposure misclassification. This would bias the findings toward the null, and therefore the actual associations with workplace physical factors may be greater than those reported. Finally, the lack of an association for vibration should be interpreted with caution because the assessment was crude (eg, yes/no). Studies with more precise measures of vibration have found associations between vibration and risk of CTS.[32]

Because of their large effect sizes, some readers may conclude that personal factors are more important than occupational factors in the etiology of CTS. We believe that such inferences should be made with caution. Age, BMI, and sex were all measured with extraordinarily high precision and accuracy. Error in these metrics is very low. On the other hand, measures of forceful exertions, repetitive exertions, and postural deviations are not easily measured and are never measured continuously over long time periods (ie, durations similar to the time necessary for physiological changes in nerve physiology to occur). Hence, substantial nondifferential error in estimation of these occupational risk factors was likely. Despite this bias toward the null, statistically significant associations between measures of exposure to occupational factors and median nerve physiology were still observed.

CONCLUSIONS

This analysis evaluated associations between personal and workplace factors and a physiologic outcome related to CTS instead of the more commonly used subjective clinical case definition. In a large and diverse working population, decrements in the three measures of median nerve latency were associated with age, BMI, and sex, as well as the workplace factors of peak hand force and percentage duration of forceful hand exertions. The effect of workplace exposures to the upper quartile of hand force (Borg CR-10 of greater than 4), compared with the lower quartile, were similar to the effect of 6 to 11 years of aging (calculated from the parameter estimates of each exposure variable and each latency outcome). This means that workers who regularly perform hand activities with a Borg exertion rating of greater than 4 will, over time, experience a decline in their nerve function that is equivalent to the decline associated with 6 to 11 years of aging. Overall, the findings of this study are similar to those of other epidemiologic studies that used a clinical case definition CTS as the outcome. We believe that when taken in the context of a largely positive literature, evidence shows that CTS (whether measured as a clinical entity or with pure neurophysiological methods) is associated with both occupational and nonoccupational factors. Resources should be directed toward intervention efforts designed to mitigate the known occupational risk factors for this condition.

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