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Original Contribution

General Population Job Exposure Matrix Applied to a Pooled Study of Prevalent Carpal Tunnel Syndrome

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A job exposure matrix may be useful for the study of biomechanical workplace risk factors when individual-level exposure data are unavailable. We used job title–based exposure data from a public data source to construct a job exposure matrix and test exposure-response relationships with prevalent carpal tunnel syndrome (CTS). Exposures of repetitive motion and force from the Occupational Information Network were assigned to 3,452 active workers from several industries, enrolled between 2001 and 2008 from 6 studies. Repetitive motion and force exposures were combined into high/high, high/low, and low/low exposure groupings in each of 4 multivariable logistic regression models, adjusted for personal factors. Although force measures alone were not independent predictors of CTS in these data, strong associations between combined physical exposures of force and repetition and CTS were observed in all models. Consistent with previous literature, this report shows that workers with high force/high repetition jobs had the highest prevalence of CTS (odds ratio = 2.14–2.95) followed by intermediate values (odds ratio = 1.09–2.27) in mixed exposed jobs relative to the lowest exposed workers. This study supports the use of a general population job exposure matrix to estimate workplace physical exposures in epidemiologic studies of musculoskeletal disorders when measures of individual exposures are unavailable.

cross-sectional study; ergonomics; general worker population; job exposure matrix; musculoskeletal disorders; O*NET; pooled study; upper extremity

Abbreviations: CTS, carpal tunnel syndrome; O*NET, Occupational Information Network; OR, odds ratio; SOC, Standard Occupational Classification.

Workplace physical exposures have been associated with musculoskeletal disorders in many industries (1). Exposure measurements pose a particular challenge in this research because of the difficulty in collecting past exposure data and the resources required to collect precise physical exposure measures for current jobs (2–4). Job exposure matrices provide a way to more efficiently estimate exposure levels than individually measured exposures (5), making them potentially useful in large-scale epidemiologic studies. Job exposure matrices have been used for several decades to study chronic health conditions related to occupational exposures including chemicals, particulates, electromagnetic radiation, silica, and asbestos (5–9). Recent studies have used job exposure matrices to examine exposure-response relationships between current or cumulative physical exposures and musculoskeletal disorders including low back pain (10), ulnar neuropathy (11), subacromial impingment (12), and osteoarthritis (13–15). Although exposure estimates provided by job exposure matrices have less precision than individual exposure measurements and lead to exposure misclassification by assigning the same exposure level to all workers within a job group, they provide a useful method for assigning exposures to workers when measured individual-level data are not available or are logistically infeasible to collect (16).

Job exposure matrices have several potential advantages as a source of exposure estimates. They are particularly useful when prior exposures are not otherwise quantified; with addition of job exposure data, the job exposure matrix can expand the populations available for study (17). Job exposure matrices reduce exposure misclassification related to some information biases (16), because exposure reporting is completely independent of the health outcome. In case-control and retrospective study designs when the outcome is already known, job exposure matrices have the advantage of offering an unbiased retrospective exposure assignment (6). Assigned exposures from a job exposure matrix may also be used as substitutes for missing data to examine selection and survivor biases in subjects lost to follow-up (18).

Construction of a job exposure matrix for physical exposures may require use of information from industry-specific sources, databases applicable to a general working population, prior studies, and/or expert opinion. In the United States, national data on the physical demands of jobs are publicly available through the Occupational Information Network (O*NET; https://onet.rti.org/), which contains multiple data sets describing the physical and mental requirements of more than 800 jobs. These data are linked to job titles based on the 2010 Standard Occupational Classification (SOC) codes. O*NET has demonstrated value as a data source in exposure estimation, but it has been used in relatively few epidemiologic studies demonstrating associations between work exposures and health conditions (19–25). The purpose of this study was to evaluate whether estimates of occupational force and repetition derived from a job exposure matrix based on O*NET would show exposure-response relationships with carpal tunnel syndrome (CTS) similar to those found in previous studies. Use of a job exposure matrix allowed occupational force and repetition exposures to be assigned retrospectively to subjects on the basis of their current or prior job titles at the time of examination. The study was performed in a large group of active workers from more than 50 workplaces across multiple industries.

METHODS

Data were pooled from 6 separate studies of workplace risk factors for upper extremity musculoskeletal disorders, conducted as part of the Upper Extremity Musculoskeletal Disorder Consortium sponsored by the National Institute for Occupational Safety and Health. Detailed descriptions of data sources and pooling procedures have been previously reported (2, 26). The respective institutional review boards provided the ethical approval of each study, and written informed consent was obtained from all subjects.

Subjects from all studies were adults, mainly employed in hand-intensive industries including manufacturing, production, service, construction, and health care. This study used baseline data collected at the time of subjects' entry into 1 of the 6 consortium studies between 2001 and 2008. Data came from questionnaires and physical examinations that included nerve conduction studies performed at the wrist. Questionnaires gathered information on demographics, medical history, work history, and musculoskeletal symptoms. For this study, we selected the personal variables of age, sex, and body mass index; reported past medical history of arthritis, diabetes, or thyroid disease; and reported hand symptoms (26, 27). Current and prior job titles, industry, dates of employment, and job task descriptions were available for each worker.

Health outcome

The primary outcome was an epidemiologic case definition of prevalent CTS that required both hand symptoms typical of CTS and median nerve conduction abnormality (28). Required symptoms were tingling, numbness, burning, or pain in at least 1 of 3 digits (thumb, index, or long finger) (29, 30). The electrodiagnostic sensory latencies were adjusted to a standard stimulus-response distance of 14 cm, and skin temperatures were adjusted to 32°C. Median nerve abnormality criteria included an absolute peak median sensory latency of >3.7 ms (onset, >3.2 ms), a median motor latency of >4.5 ms, or a transcarpal difference of the median and ulnar sensory latencies of >0.85 ms (31). Test latencies that were not obtainable because of extremely prolonged latencies were marked as abnormal median nerve results. Workers having hand symptoms and abnormal nerve study results in the dominant hand were considered cases of CTS.

Job title–based exposures

Using a worker's job title, primary work tasks, and employer information, we assigned an SOC code (version 16.0) to each subject. In most cases, subjects were assigned the SOC code for the job they currently held at the time of study entry. In cases where a worker had recently started a new job, we assigned exposures based on their prior job. SOC codes were assigned by using the job title selection feature provided by O*NET OnLine (http://www.onetonline.org/) and selecting the occupational code that best matched the primary tasks and employer information (20, 24). Assigned job codes were reviewed independently by 2 raters experienced in assigning SOC codes in prior work (24) and by 1 rater from each of the 6 study sites to ensure consistency of job assignments of similar jobs across studies.

We used the SOC code assignments for each subject to extract physical work exposure values from the O*NET database (version 16.0) (32). We selected 6 items that estimated physical exposures for hand force and repetitive movements of the upper extremity; these items came from 3 separate O*NET databases (work activities, work context, and work abilities). The questions and response scales may be found in the Web Appendix (available at http://aje.oxfordjournals.org/). The selected hand force items were dynamic strength and static strength requirements. The items for repetitive movements involving the hands were handling and moving objects, wrist/finger speed, time spent making repetitive motions, and time spent using hands to hold objects. The scores for the 2 strength items and for the handling and moving objects and wrist/finger speed items ranged from 0 to 7, with 0 indicating a level of exposure that had no importance to the job and 1–7 indicating a level of exposure (strength required, speed of movements, or ability to use hands) that had any importance to the job on the basis of a 2-part question (importance item and exposure level item). The values in the O*NET databases are the means of scores obtained from job incumbents or occupational analysts for each SOC code. Values for repetitive motion, using hands to hold objects, and handling and moving objects are based on a national sample of worker surveys; the sample size of workers surveyed varies by job code, ranging from 13 to 209 workers. Values for dynamic strength, static strength, and wrist/finger speed come from scores submitted by 8 expert occupational analysts.

Our study dichotomized these exposures at the median split, with the higher category indicating a modest level of static strength (>2.5 on a 0–7 point scale) and a modest force level of dynamic strength (>2.12 on a 0–7 point scale). The median split for wrist/finger speed was similar to "typing a document at 90 words per minute" (median, >5.44 on a 0–7 point scale) and for handling and moving objects it was similar to "changing settings on a copy machine" (median, >1.88 on a 0–7 point scale). The 2 time-based exposures, making repetitive motions and using hands to hold objects, were scored on a 5-point scale based on the average proportion of daily time spent performing the activity, with response options ranging between no daily time to continuous. The median split value for making repetitive motions was >4.04, or more than half of the time, and for using hands to hold objects was >4.58, between more than half and continually.

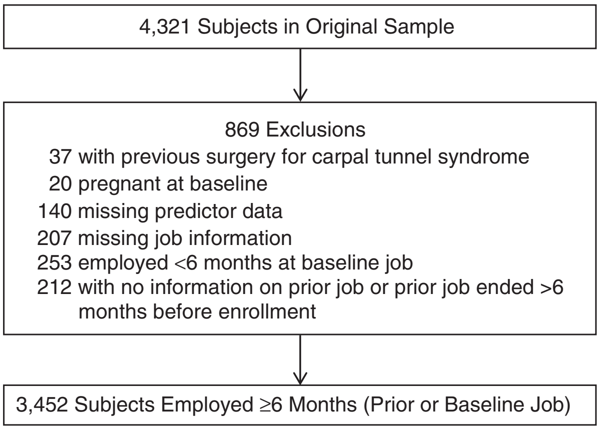

Figure 1. Flow diagram of subjects from 6 consortium studies included in the analyses, 2001–2008.

Data analysis

The distributions and colinearity of exposures to hand force and repetitive hand movements were examined by using Spearman's nonparametric correlations. The exposure variables from each category that showed the strongest association with the outcome from univariate logistic regression models were selected for final models. Each exposure variable was dichotomized at the median and split into high and low exposure levels. Dichotomized hand force and repetitive movement exposures were used to create categories of combined exposure variables that included 1 exposure from hand force and 1 from repetitive hand movements: high force/high repetition, high force/low repetition, low force/high repetition, and low force/low repetition. In separate random effects logistic regression models for prevalent CTS, a different hand force/repetitive movement exposure combination was tested, controlling for personal factors (age, sex, and body mass index), past medical history, and study site. Although the study variables were standardized across sites, the study sites had different populations and study protocols. To account for site differences, random intercepts for each site were estimated in all models (33). Because O*NET exposures are averages by job title, we used an empirical error estimator derived by Morel et al. (34) to correct bias in the variance estimates. Several sensitivity analyses were run to evaluate the robustness of the main analysis and to account for potential differences in job factors. First, the random effects of the study site were eliminated from the model; second, we added the length of time employed in the baseline job to the full model; third, we eliminated prior jobs and restricted the sample to workers who had been employed for at least 6 months in their job at the time of study entry. All analyses were conducted by using SAS, version 9.3, software (SAS Institute, Inc., Cary, North Carolina).

RESULTS

Of the 4,321 subjects in the original pooled sample, 869 subjects were excluded because of missing outcome or job information, pregnancy, or prior surgery for CTS or for not meeting the inclusion criteria of duration of time employed (Figure 1). The final sample of 3,452 subjects had been employed for at least 6 months in their baseline job or employed for at least 6 months in a prior job that had ended no more than 6 months before study enrollment. On average, the final sample of 3,452 workers were middle aged (mean = 39.1 years), overweight (body mass index, 28.6), and employed for a mean of 8 years in the baseline job. There were 269 subjects (7.8%) who met the case definition for prevalent CTS (Table 1). Those excluded from the final sample shown in Figure 1 were younger (36.2 years vs. 39.1 years; $P < 0.0001$) with a shorter mean time employed (mean = 2.4 years vs. 8.0 years; $P < 0.0001$), but there were no differences in sex, body mass index, or prevalence of diabetes mellitus or thyroid diseases.

The 3,452 workers in the final sample were employed in 54 different companies across the United States and classified into 264 separate SOC job codes. Summary distributions of the O*NET-derived exposure values for the 6 different measures of force and repetition are presented in Table 1. For purposes of analysis, exposure values from O*NET for the SOC groups were classified as high force/high repetition, low force/low repetition, or in the mixed exposure groups of high force/low repetition or low force/high repetition. Table 2 shows a sample of job titles or job categories by these exposure combinations. Construction work, upholstering, and some manufacturing jobs had high physical exposures for both hand force and repetition. The lowest exposure groups had predominantly professional or office jobs. Workers with mixed exposures were common in manual work across a broad range of job titles; the largest single group of workers, team assemblers ($n = 850$), was found in the mixed exposure group.

There were strong correlations in the ordinal scales between static and dynamic strength ($r = 0.8$), time spent in repetitive motion and time spent using hands to hold objects ($r = 0.7$), and handling and moving objects and time spent using hands to hold objects ($r = 0.7$), supporting the decision to include only 1 force and 1 repetition exposure in each of the final models. There were low correlations between the force

Table 1. Demographic Characteristics and Physical Exposures of Subjects From 6 Consortium Studies for the Prevalent CTS and No CTS Groups and Univariate Relationship With Prevalent CTS, 2001–2008

	All ($n = 3,452$)			CTS ($n = 269$)			No CTS ($n = 3,183$)			POR[a]	95% CI
	No.	%	Mean (SD)	No.	%	Mean (SD)	No.	%	Mean (SD)		
Demographic and clinical variables											
Age, years			39.1 (11.6)			43.3 (0.5)			38.7 (11.6)	1.03	1.01, 1.04
Body mass index[b]			28.6 (6.2)			31.5 (6.9)			28.3 (6.1)	1.07	1.05, 1.09
Employed time, months			8.0 (8.3)			9.2 (8.7)			7.9 (8.2)	1.01	0.99, 1.03
Sex											
Female	1,673	49		164	61		1,509	47		1.48	0.84, 2.62
Male	1,779	52		105	39		1,674	53		1.00	
Diabetes	137	4		20	7		117	4		1.97	1.31, 2.95
Rheumatoid arthritis	76	2		12	5		64	2		1.86	1.01, 3.43
Thyroid disease	168	5		23	9		145	5		1.66	0.84, 3.28
Work-related physical exposures											
High dynamic strength (>2.12)[c,d]				68	25		855	27		1.35	0.79, 2.30
High static strength (>2.5)[c,d]				121	45		1,456	46		1.15	0.83, 1.59
High handling and moving objects (>1.88)[c,e]				177	66		1,567	49		1.52	0.71, 3.28
High wrist/finger speed (>5.44)[c,e]				81	30		1,155	36		0.81	0.49, 1.36
High time in repetitive motion (>4.04)[e,f]				169	63		1,515	48		1.51	1.17, 1.95
High time in using hand to hold objects (>4.58)[e,f]				172	64		1,505	47		1.66	1.14, 2.42

Abbreviations: CI, confidence interval; CTS, carpal tunnel syndrome; POR, prevalence odds ratio; SD, standard deviation.

[a] Adjusted for random site intercepts.

[b] Weight (kg)/height (m)^2.

[c] Median split values for scale range 0–7.

[d] Category: hand force.

[e] Category: hand repetition.

[f] Median split values for scale range 1–5.

and repetition variables ($r < 0.4$). Univariate logistic regression models for the repetition exposures showed that time spent making repetitive motions and time spent using hands to hold objects had the strongest associations with prevalent CTS; these 2 variables were retained as repetition measures for use in the combined exposures for the multivariable models. Two force exposures and 2 repetition exposures were used to create 4 groups of combined exposures (Table 3).

In the 4 multivariable regression models shown in Table 4, personal factors of age and body mass index were associated with CTS, with similar effect sizes and confidence intervals across models containing different combinations of job physical exposures. The random intercepts by study site showed differences across sites, indicating that adjustment was appropriate to capture unmeasured differences and differences in exposure distribution of job types between studies. Sensitivity analyses that excluded the random intercept for study site showed little change in odds ratios for exposures, but there was notable narrowing of the confidence intervals. Models without the site random intercept showed a statistically significant association between sex and CTS, illustrating differences in sex distribution across study sites as previously reported in data from this pooled sample (26).

We performed a sensitivity analysis adding duration of employment to our regression models. There was no significant association between CTS and the time employed prior to case ascertainment, and there was no meaningful change in any of the other estimates compared with the original models (data not shown). In another analysis, we reduced the worker sample to those employed in their baseline job for at least 6 months ($n = 2,923$) prior to baseline; findings retained the same exposure-response pattern seen in Table 4.

DISCUSSION

This study found a strong association between prevalent CTS and physical exposures assigned by job titles among a heterogeneous group of workers employed in a variety of industries across the United States. Consistent exposure-response relationships with CTS were seen across 4 different combined force/repetition exposure combinations in separate models. Age and body mass index were significant predictors of CTS across all exposure models, but they did not show meaningful association with the risk of CTS related to work exposures. The number of years employed in a job was not related to CTS in this cross-sectional study.

Limitations

There are several potential limitations to this study. Pooling data from 6 studies allowed us to study a large sample with a

Table 2. Representative Job Titles or Job Groupings of Subjects From 6 Consortium Studies, by Exposure Level, 2001–2008

Exposure Combinations	No. of Workers	Standard Occupational Classification	Job Titles and Job Groupings
Low repetition/low force	25	11-XXXX	Management
	23	13-XXXX	Business/finance operations
	20	15-XXXX	Computer
	28	19-XXXX	Life and physical scientists
	2	23-XXXX	Legal
	17	25-XXXX	Education
	24	29-1XXX	Health-care practitioners (pharmacists, therapists)
Mix of high/low repetition and force	103	29-2XXX	Health technologists (sonographers, home health aides, surgical technologists)
	12	31-1015	Orderlies
	2	33-9032	Security guards
	4	35-1011	Chefs and head cooks
	61	37-20XX	Janitors, maids, and housekeeping cleaners
	24	43-4051	Customer service representatives
	96	45-2092	Nursery workers
	23	47-2211	Sheet metal workers
	850	51-2092	Team assemblers
	184	51-40XX	Machine operators (electronic, lathe, milling, welding, printing, textile)
	83	53-7064	Packers and packagers, hand
High repetition/high force	6	35-9021	Dishwashers
	1	47-2021	Brick masons
	5	47-2041	Carpet installers
	15	47-2081	Drywall installers
	3	49-3023	Automotive technicians
	94	51-2031	Engine and other machine assemblers
	1	51-2091	Fiberglass laminators and fabricators
	27	51-6093	Upholsterers

large number of cases of CTS across a wide range of occupations. However, pooling also raised potential issues related to differences in disease prevalence, demographics, work demands, and outcome assessment procedures used by different study groups. We used a random intercepts model to account for correlated observations within site. As long as there is substantial overlap in levels of exposure between the sites, random effects (multilevel) models provide reasonable parameter estimates, even in the presence of confounding with site (33). Although the sample represented many different industries, it was predominantly drawn from hand-intensive industries, and results may not be generalizable to workers with less hand-intensive jobs. We restricted our analyses of CTS to the dominant hand, a common practice in CTS epidemiology research but one that likely underestimates the true prevalence of disease. Use of O*NET limited our analyses to exposures contained in this national database. In particular, the O*NET data did not allow us to estimate exposures to hand vibration and to prolonged awkward postures, factors associated with CTS in some literature (35). For simplicity, we dichotomized exposure values; more precise estimates should be explored in future studies. Finally, use of exposures assigned at the level of job title does not capture individual differences in exposure among workers performing the same job. This likely leads to significant nondifferential exposure misclassification, which must be balanced against the advantages of using a common exposure estimator that is unbiased by subject recall or systematic measurement error.

Implications

In this study of prevalent CTS, workers' past exposures were of most relevance to the outcome. To estimate past work exposures across this large, multicenter study, we used job titles and industry to extract estimates of job physical demands from O*NET, a large national database. Use of O*NET to

Table 3. Distribution of Prevalent CTS Among Subjects From 6 Consortium Studies, by Exposure Level, 2001–2008

Combination Exposure Categories	All ($n = 3{,}452$)	CTS ($n = 269$) No.	CTS ($n = 269$) %	No CTS ($n = 3{,}183$) No.	No CTS ($n = 3{,}183$) %
Repetitive motion-dynamic strength[a]					
Low repetition/low force	1,196	72	26.8	1,124	35.3
Low repetition/high force	572	28	10.4	544	17.1
High repetition/low force	1,333	129	48.0	1,204	37.8
High repetition/high force	351	40	14.9	311	9.8
Repetitive motion-static strength[a]					
Low repetition/low force	689	28	10.4	661	20.8
Low repetition/high force	1,079	72	26.8	1,007	31.6
High repetition/low force	1,186	120	44.6	1,066	33.5
High repetition/high force	498	49	18.2	449	14.1
Hand use-dynamic strength[a]					
Low repetition/low force	1,217	68	25.3	1,149	36.1
Low repetition/high force	558	29	10.8	529	16.6
High repetition/low force	1,312	133	49.4	1,179	37.0
High repetition/high force	365	39	14.5	326	10.2
Hand use-static strength[a]					
Low repetition/low force	958	56	20.8	902	28.3
Low repetition/high force	817	41	15.2	776	24.4
High repetition/low force	917	92	34.2	825	25.9
High repetition/high force	760	80	29.8	680	21.4

Abbreviation: CTS, carpal tunnel syndrome.

[a] Categories for dynamic strength: high (>2.12), low (≤2.12); static strength: high (>2.50), low (≤2.50); time in repetitive motion: high (>4.04), low (≤4.04); time using hands to hold objects: high (>4.58), low (≤4.58).

estimate work exposures eliminated the potential for symptomatic conditions to bias workers' self-report of work exposures and allowed assignment of exposures for the most recent job held, even when that job could not be directly observed. Although future analysis of incident CTS cases in this sample will proceed by using observations of individual workplace exposures (2), use of a job exposure matrix allowed estimation of the past exposures relevant to prevalent cases. This paper used a job exposure matrix similar to those previously applied to 2 single-site studies of prevalent and incident CTS (23, 24) but extended this exposure estimation method to a large heterogeneous multicenter data set. Concordance with results from other studies suggests that use of a general population job exposure matrix is a feasible method to obtain valid estimates of workplace physical exposures for epidemiologic studies.

In this study, use of retrospective exposure estimates derived from a job exposure matrix found exposure-response relationships with prevalent CTS consistent with associations between CTS and forceful repetitive work seen in other studies (36–45) and consistent with prior results from a subset of this worker sample using different exposure methods. Another study examined the association of detailed biomechanical exposures derived from observations of the current job in a subset of this population ($n = 2{,}981$) and found that prevalent CTS was associated in an exposure-dependent fashion with hand force, the duration of time spent in forceful work, and a composite variable (hand activity level–threshold limit values) that combined force and repetition (46). These findings are similar to those found in OCTOPUS, a large Italian cohort study on CTS (47), that also found increasing risk of CTS for an intermediate level of exposure using the composite hand activity level–threshold limit values (odds ratio (OR) = 1.95) and a higher risk for a higher composite exposure (OR = 2.7). The classic study by Silverstein et al. (41) used directly measured and observed exposures to create exposures categorized by combined force and repetition similar to those of the current study and examined associations with CTS in a group of 652 manufacturing workers. When compared with workers with low force and low repetition exposures, workers in the study by Silverstein et al. exposed to both high force and high repetition (OR = 15.5) showed the highest risk for CTS, with lower risk among those with low force/high repetition (OR = 2.7) and high force/low repetition (OR = 1.8) exposures. This same pattern was seen in the current study using a job exposure matrix to estimate past exposures.

Generalizability

As noted in a recent editorial and prior publication on CTS (24, 48), job exposure matrices have been underutilized in musculoskeletal disease epidemiology. Use of a job exposure matrix to estimate physical exposures is a promising approach

Table 4. Univariate and Multivariable Regression Models for Full ($n = 3{,}452$) and Reduced ($n = 2{,}923$) Samples From 6 Consortium Studies, 2001–2008

Combination Exposure Categories	Univariate POR	95% CI	Full Sample ($n = 3{,}452$)		Reduced Sample ($n = 2{,}923$)	
			Adjusted POR[a]	95% CI	Adjusted POR[a]	95% CI
Repetitive motion-dynamic strength[b]						
Low repetition/low force	1.00		1.00		1.00	
Low repetition/high force	1.19	0.66, 2.13	1.41	0.68, 2.92	1.03	0.54, 1.97
High repetition/low force	1.43	1.12, 1.83	1.48	1.02, 2.15	1.44	0.99, 2.10
High repetition/high force	2.05	1.10, 3.83	2.33	1.12, 4.85	2.21	1.03, 4.74
Repetitive motion-static strength[b]						
Low repetition/low force	1.00		1.00		1.00	
Low repetition/high force	1.67	0.93, 3.02	2.03	1.02, 4.06	2.03	0.94, 4.39
High repetition/low force	2.05	1.24, 3.41	2.27	1.23, 4.19	2.39	1.25, 4.56
High repetition/high force	2.31	1.35, 3.95	2.95	1.50, 5.80	3.10	1.48, 6.47
Hand use-dynamic strength[b]						
Low repetition/low force	1.00		1.00		1.00	
Low repetition/high force	1.12	0.56, 2.21	1.35	0.62, 2.94	1.12	0.52, 2.39
High repetition/low force	1.54	1.08, 2.20	1.88	1.19, 2.98	1.81	1.13, 2.89
High repetition/high force	2.20	1.27, 3.82	2.90	1.47, 5.72	2.70	1.29, 5.68
Hand use-static strength[b]						
Low repetition/low force	1.00		1.00		1.00	
Low repetition/high force	0.89	0.46, 1.74	1.09	0.57, 2.09	1.01	0.50, 2.06
High repetition/low force	1.43	0.97, 2.13	1.76	1.07, 2.90	1.69	1.00, 2.87
High repetition/high force	1.74	1.12, 2.71	2.14	1.26, 3.63	2.07	1.19, 3.59

Abbreviations: CI, confidence interval; POR, prevalence odds ratio.

[a] Adjusted for age, body mass index, sex, diabetes, rheumatoid arthritis, and study site.

[b] Categories for dynamic strength: high (>2.12), low (≤2.12); static strength: high (>2.50), low (≤2.50); time in repetitive motion: high (>4.04), low (≤4.04); time using hands to hold objects: high (>4.58), low (≤4.58).

that can expand the data available for the study of work-related musculoskeletal disorders in the general population (48) and in studies that include a broad range of industries. This study also adds to the small but growing number of studies that have used O*NET as a source of job exposure data for constructing a job exposure matrix that can be linked to outcome data (19, 25).

Strengths

Strengths of this study included a large and diverse sample of workers with a large number of cases of CTS, defined by using an epidemiologic case definition requiring both symptoms and nerve conduction abnormalities (28). Work exposures were evaluated in models that adjusted for multiple other potential risk factors for CTS, including age, sex, body mass index, and comorbid medical conditions. Even with the limitations in exposure estimates discussed above, this study showed that work exposures to force and repetition were associated with strong and consistent increases in prevalent CTS. Study data also showed consistent exposure-response associations across 4 different exposure combinations, with workers in high force/high repetition jobs having the highest prevalence of CTS and those in mixed exposure jobs (high force/low repetition or low force/high repetition) having intermediate values compared with the lowest risk group of low force/low repetition. The presence of clear independent risk factors for CTS related to both work factors and to personal risk factors has implications for prevention, treatment, and medical-legal issues.

This study's demonstration of the usefulness of the job title–based job exposure matrix for work-related musculoskeletal disorders using publicly available data may enable other researchers to incorporate more detailed occupational exposure data into existing data sets containing job titles and health outcome information. In addition, prospective studies that use directly measured exposures may use a job exposure matrix to account for exposures on past jobs that could not otherwise be measured.

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