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Risk factors for carpal tunnel syndrome in a general population

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Abstract

***Objective*—To determine the individual, physical, and psychosocial risk factors for carpal tunnel syndrome in a general population.**

***Methods*—Population based case-control study in Marshfield epidemiological study area in Wisconsin, USA. Cases were men and women aged 18–69 with newly diagnosed carpal tunnel syndrome (n=206 (83.1%) of 248 eligible). Controls were a random sample of residents of the study area who had no history of diagnosed carpal tunnel syndrome (n=211 (81.5%) of 259 eligible). Cases and controls were matched by age. Telephone interviews and reviews of medical records obtained height and weight, medical history, average daily hours of exposure to selected physical and organisational work factors, and self ratings on psychosocial work scales.**

***Results*—In the final logistic regression model, five work and three non-work variables were associated with risk of carpal tunnel syndrome, after adjusting for age. For each one unit of increase in body mass index (kg/m^2), risk increased 8% (odds ratio (OR) 1.08; 95% confidence interval (95% CI) 1.03 to 1.14). Having a previous musculoskeletal condition was positively associated with carpal tunnel syndrome (OR 2.54; 95% CI 1.03 to 6.23). People reporting the least influence at work had 2.86 times the risk (95% CI, 1.10 to 7.14) than those with the most influence at work.**

***Conclusions*—Carpal tunnel syndrome is a work related disease, although some important measures of occupational exposure, including keyboard use, were not risk factors in this general population study. The mechanism whereby a weight gain of about six pounds increases the risk of disease 8% requires explanation.**

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Keywords: carpal tunnel syndrome; case-control studies; risk factors

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There is dispute as to whether occupational factors increase the risk of occurrence of carpal tunnel syndrome (CTS), a disabling condition with a self reported prevalence of 1.55%[1] and direct medical costs of more than one billion dollars each year[2] in United States adults.[3 4] In the only report of the incidence of CTS in a general population,[5] cases were not interviewed, and job title was the main occupational item abstracted from the medical records.[6] An extensive search of published and unpublished work by investigators of work related physical factors and musculoskeletal disorders of the hands[7] found only three aetiological studies that met acceptable validity criteria. The possible individual, psychosocial, and physical risk factors for musculoskeletal disorders have not been studied simultaneously in any scientific investigation, so it is difficult to infer the true risk factors from an examination of the current evidence.[8–10] This paper reports a case-control study of CTS in a community population in which both work and non-work exposures were assessed.

Methods

The Marshfield Epidemiological Study Area is a catchment area with about 55 000 residents in 14 contiguous ZIP codes. All physicians in this area are staff at the Marshfield Clinic and the adjacent St Joseph's Hospital. The clinic and hospital share a joint record for each patient. It has been shown that clinic databases capture 94% of hospital discharges and 92% of outpatient visits of residents of the area.[11] The labour force in the area is 47% white collar, 30% blue collar, 13% service workers, and 10% farmers.

To determine incident events of CTS we used the Marshfield Clinic computerised diagnosis file, which is based on charge sheet information and contains diagnoses and procedures for Marshfield Clinic and St Joseph's Hospital back to 1960. Based on experience in a study of the incidence of CTS in 1991–3 in the Marshfield area any patient with initial diagnosis of international classification of diseases (ICD) code 354.0 (CTS), ICD 04.43 (carpal tunnel release surgery), current procedural terminology (CPT) 64721 (decompression of median nerve at carpal tunnel), CPT 29848 (arthroscopy, wrist, with release of carpal ligament), or the combination of ICD 356.9 (peripheral neuropathy) and any CPT code for splint or nerve conduction (appendix) between May 1994 and October 1995 while living in the Marshfield area was eligible as a potential case. Patients with an initial diagnosis between 1979 (the year the ICD ninth revision (ICD-9) was established) and April 1994 were considered prevalent cases and thus deemed ineligible for participation in the study.

Verification of case status required documentation in the medical record of: either (*a*) diagnosis of carpal tunnel syndrome by a phy-

Table 1 Non-work risk factors for carpal tunnel syndrome in working and non-working participants combined, from bivariate analysis

Risk factor	*Level*	*Cases (n=206) (%)*	*Controls (n=211) (%)*	*OR* (95% CI)*	*P value†*
		(missing=0)	(missing=0)		
Musculoskeletal condition	No	84.0	89.6	1.00 control	0.03
	Yes	16.0	10.4	1.92 (1.04 to 3.54)	
		(missing=0)	(missing=0)		
Play sports at least 3 months at least 3 hours a week	No	79.6	70.1	1.00 control	0.01
	Yes	20.4	29.9	0.55 (0.35 to 0.87)	
		(missing=0)	(missing=0)		
Have home typewriter	No	52.4	42.2	1.00 control	0.06
	Yes	47.6	57.8	0.69 (0.47 to 1.02)	
		(missing=9)	(missing=5)		
Body mass index (kg/m^2)	Slender	8.1	5.8	1.00 control	< 0.001
	Normal	43.1	61.7	0.63 (0.28 to 1.45)	
	Overweight	26.9	20.4	1.29 (0.53 to 3.14)	
	Obese	21.8	12.1	1.86 (0.72 to 4.80)	
		(missing=9)	(missing=9)		
Parent, child, or sibling had carpal tunnel syndrome	No	71.6	84.2	1.00 control	0.003
	Yes	28.4	15.8	2.09 (1.28 to 3.41)	
		(missing=23)	(missing=26)		
Income below poverty limit	No	88.0	93.0	1.00 control	0.14
	Yes	12.0	7.0	1.72 (0.82 to 3.59)	

* Adjusted for age.
† Determined by the likelihood ratio test.

sician; or (*b*) any explicit treatment for CTS; and (*c*) numbness, tingling, pain, or paraesthesia in the hand, wrist, arm, or forearm within one month of the date of diagnosis of CTS. Diagnoses by all specialties were eligible. Cases also had to be aged 18–69 at diagnosis. Electrophysical nerve conduction study, an invasive test performed in some patients diagnosed with CTS,[12] was not required as the history is usually pathognomonic[13 14] and such testing has not reached the stage of sensitivity or specificity required for aetiological research on CTS.[15] Control participants were people in the Marshfield area who had no history of diagnosed CTS in the medical record or in interviews conducted for this study. Controls had to be aged 18–69 at the time they were randomly sampled and were frequency matched to cases based on five age strata: 18–29, 30–39, 40–49, 50–59, and 60–69.

We examined a wide range of potential aetiological factors because no single behaviour or characteristic seemed to be a necessary and sufficient cause of CTS.[7 8] Information on risk factors for cases and controls was collected from two sources: the patient's medical record and a telephone interview of about 35 minutes. (Data collection forms are available from the authors.) We gave preference to medical records to define participants' history of chronic diseases. With approval of the Marshfield Clinic Institutional Review Board, we obtained informed consent by telephone. Cases were interviewed after verification of case status through review of medical records, whereas potential controls were interviewed before medical records were reviewed. About half of the questions in the interview came from previous occupational studies by the United States Centers for Disease Control and Prevention.[16-18] The job stress scales had acceptable reliability (Cronbach α) coefficients ranging from 0.65–0.90 (mean 0.81).[19] For many questions about exposure to risk factors, respondents answered for a 12 month period before a reference date. For cases, the reference date was the date of diagnosis of their CTS; for controls, it was the date of their interview. Methods to minimise information bias[20] included concealment of the study hypotheses from data collectors and study participants, careful interviewer training for even handed probing, asking the same structured questions for cases and controls, interviewing cases as soon as feasible after diagnosis, and asking cases and controls to recall information about times of similar duration before the interview. Cases had to report on a period about eight months further back than controls when providing information on exposure. Every 10th interview was tape recorded for review by the interviewers' supervisor, and a random sample of 10% of interviews and abstracts were independently re-entered by a statistical assistant to uncover data entry errors.

The main goal of this study was to find physical work factors associated with the risk of CTS. Based on clinical knowledge and suitable data quality, we chose a parsimonious list of variables for the risk factor analysis.[21] The hours of exposure were ascertained for physical factors at work. Of the 40 variables chosen, 23 were work factors and 17 were non-work factors. Some variables were multi-item scales—for example, job control was measured by a set of seven questions from the National Institute for Occupational Safety and Health, with answers ranging from 1 very little to 5 very much.[17] Visual aids—such as hand bending diagrams and some answer choices—were posted to potential study participants before the interview. Sex was not included as a potential risk factor because susceptibility to work related CTS among women does not seem to increase after controlling for exposure.[8] Sex was included instead in the final multivariable models to assess confounding and modification of effect.

We used unconditional logistic regression[22] for all analyses. All P values were calculated with the likelihood ratio test.[23] Variables were initially screened bivariately controlling only for age (the design variable). All such variables with a P value ≤0.10 were included in a multi-

Table 2 Work risk factors for carpal tunnel syndrome in working participants only, from bivariate analysis

Risk factor	*Level*	*Cases (n=182) (%)*	*Controls (n=188) (%)*	*OR* (95% CI)*	*P value†*
		(missing=3)	(missing=3)		
Mean workday use of power tools or machinery (h)	0	61.5	67.6	1.00 control	0.08
	0.08-0.75	5.6	10.8	0.60 (0.27 to 1.36)	
	1-2	8.9	7.0	1.43 (0.66 to 3.13)	
	2.5-5.5	10.1	9.2	1.20 (0.59 to 2.45)	
	6-11	14.0	5.4	2.52 (1.13 to 5.62)	
		(missing=7)	(missing=7)		
Mean workday bend or twist hands (h)	0	32.0	48.6	1.00 control	0.01
	0.25-1.75	9.7	11.0	1.34 (0.64 to 2.80)	
	2-3	10.3	11.6	1.23 (0.60 to 2.53)	
	3.5-6	20.6	12.7	2.33 (1.24 to 4.36)	
	7-16	27.4	16.0	2.47 (1.38 to 4.43)	
		(missing=7)	(missing=12)		
Mean workday work with solvents (h)	0	64.0	63.1	1.00 control	0.07
	0.08-0.75	16.0	23.9	0.63 (0.37 to 1.10)	
	1-11	20.0	13.1	1.43 (0.79 to 2.59)	
		(missing=1)	(missing=3)		
Employee health important to employer	Strongly agree	49.7	62.2	1.00 control	0.01
	Slightly agree	23.2	18.4	1.52 (0.89 to 2.60)	
	Slightly disagree	12.2	5.4	2.63 (1.18 to 5.88)	
	Strongly disagree	7.7	2.2	4.17 (1.31 to 13.29)	
	No such person	7.2	11.9	0.78 (0.37 to 1.67)	
		(missing=2)	(missing=1)		
Trade union member	No	81.1	87.2	1.00 control	0.10
	Yes	18.9	12.8	1.61 (0.91 to 2.87)	
		(missing=0)	(missing=0)		
Job control (low=little control)	1-2.7	31.3	19.7	1.00 control	0.01
	2.8-3.4	26.9	19.7	0.80 (0.44 to 1.47)	
	3.6-3.8	11.5	18.6	0.36 (0.18 to 0.71)	
	4-4.4	17.6	22.9	0.46 (0.24 to 0.86)	
	4.6-4.8	12.6	19.1	0.42 (0.21 to 0.83)	
		(missing=1)	(missing=1)		
Primary job cumulative hours since January 1993	0-2954	27.6	19.8	1.00 control	< 0.001
	3048-4857	42.5	21.9	1.51 (0.84 to 2.70)	
	4880-5383	11.6	19.3	0.46 (0.23 to 0.93)	
	5464-6507	9.9	19.3	0.41 (0.20 to 0.85)	
	6647-15510	8.3	19.8	0.34 (0.16 to 0.71)	

* Adjusted for age.
† Determined by the likelihood ratio test.

variable regression analysis. Variables with P values >0.10 required additional evidence of importance—for instance, significance or evidence of confounding in a previous study of CTS—before inclusion in the multivariable analysis. We constructed two multivariable models. Firstly, all bivariately significant non-work variables were placed in a model along with age to assess significance in the general population. A backward elimination technique was used to select this final non-work model. Secondly, all bivariately significant work variables and all variables in the final non-work multivariable model were placed in a model along with age to assess significance in participants working at a job or business, again with a backward elimination technique. As in the bivariate analysis, we set the cut-off point for significance in multivariable analysis at a P value ≤0.10. We first categorised each variable according to the cut-off points (tables 1 and 2). We categorised continuous exposure variables by examining their distribution among control subjects in our study. We chose cut-off points so that each level of exposure would contain reasonable numbers of cases and controls or because of initial considerations—such as recognising the discontinuity between 0 (no exposure) and 1 (some exposure). The only exception to this was body mass index (BMI), which we defined as weight (kg)/height squared (m^2) and categorised according to the criteria of the National Center for Health Statistics.[24] For slender men and women BMI is <20; for normal men 20–27.79 and for normal women 20–27.29; for overweight men 27.8–31.09 and for overweight women 27.3–32.29; and for obese men ≥31.1 and for obese women ≥32.3. Each k level variable was represented in the model as k-1 indicator variables. The P values in tables 1-4 correspond to a likelihood ratio test of whether these k-1 indicator variables simultaneously contribute significantly to the overall model. For each significant categorical variable, we also assessed the dose-response effects on risk of CTS by redefining the variable as continuous, replacing the indicator variables with the original data values, and testing for quadratic, and if not significant, linear effects. We assessed modification of effect for a few preselected variables. Three diagnostic statistics were measured,[23] and the Hosmer-Lemeshow test was applied[23] to assess overall model fit. All analyses were carried out with SAS, Version 6.11 (SAS Institute, Cary, NC).

We performed an informal sensitivity analysis with three alternative models. Two of these alternatives were (*a*) using only the subset of people who in our study reported their usual source of care is Marshfield Clinic (96% of cases and 89% of controls) and (*b*) using all people in the main model but replacing usual hours by peak hours per day for work with power tools, bending wrist, and solvents. Another alternative model was (*c*) using the subset of cases with positive median nerve conduction test (44.2% of cases) with all controls. For all three alternative models, results were similar to those in the main model.

Table 3 Final multivariable logistic regression model of non-working risk factors for carpal tunnel syndrome in working and non-working participants combined

Risk factor	*OR‡ (95% CI)*	*P value†*
Musculoskeletal condition	2.41 (1.24 to 4.67)	0.009
Play sport at least 3 months at least 3 hours a week	0.57 (0.35 to 0.95)	0.031
Have home typewriter	0.71 (0.46 to 1.09)	0.117
Body mass index (kg/m^2), per unit	1.06 (1.02 to 1.11)	0.002*
Parent, child, or sibling had CTS	2.00 (1.18 to 3.37)	0.009

* Significant linear dose-response effect (P < 0.05).
† Determined by the likelihood ratio test.
‡ Based on final model controlling for other factors listed and for the design variable, age.

Table 4 Final multivariable logistic regression model of work and non-work risk factors for carpal tunnel syndrome in working participants only

Risk factor	*OR§ (95% CI)*	*P value‡*
Musculoskeletal condition	2.54 (1.03 to 6.23)	0.04
Body mass index (kg/m^2), per unit	1.08 (1.03 to 1.14)	0.001*
Parent, child, or sibling had CTS	1.87 (0.97 to 3.60)	0.06
Power tools or machinery (mean h/day)		
0	1.00 control	0.11†
0.08-0.75	0.53 (0.17 to 1.64)	
1-2	1.43 (0.52 to 3.90)	
2.5-5.5	1.58 (0.63 to 4.00)	
6-11	3.30 (1.11 to 9.80)	
Bending or twisting hands or wrists (mean h/day)		
0	1.00 control	0.07†
0.25-1.75	2.42 (0.88 to 6.62)	
2-3	1.27 (0.50 to 3.26)	
3.5-6	2.65 (1.83 to 5.92)	
7-16	2.11 (0.98 to 4.52)	
Contact with solvents (mean h/day)		
0	1.00 control	0.08
0.08-0.75	0.44 (0.21 to 0.90)	
1-11	0.80 (0.36 to 1.79)	
Job control (low=little control)		
1-2.7	1.00 control	0.02*
2.8-3.4	1.05 (0.48 to 2.27)	
3.6-3.8	0.34 (0.14 to 0.82)	
4-4.4	0.64 (0.29 to 1.42)	
4.6-4.8	0.35 (0.14 to 0.91)	
Cumulative hours in primary job since January 1993		
0-2954	1.00 control	< 0.001*
3048-4857	1.54 (0.74 to 3.20)	
4880-5383	0.29 (0.12 to 0.72)	
5464-6507	0.43 (0.18 to 1.05)	
6647-15510	0.29 (0.10 to 0.78)	

* Significant linear dose-response effect (P < 0.05).
† Significant quadratic dose-response effect (P < 0.05).
‡ Determined by the likelihood ratio test.
§ Based on final model controlling for other factors listed and for the design variable, age.

Results

Overall, 378 potential cases and 325 potential controls were initially identified. Of the 248 verified eligible cases, 206 (83.1%) agreed to be interviewed. Also, 213 of 259 (82.2%) eligible controls agreed to be interviewed, and 211 of these were verified not to have CTS through review of records. All but one of the 206 cases was selected because of an ICD code of 354.0, the specific rubric for CTS. Cases had CTS diagnosed by one or more specialties. Most often cases were diagnosed by neurology (114, 57.6%), internal medicine (59, 29.8%), or family practice (44, 22.2%).

BIVARIATE ANALYSES

A previous diagnosis of a musculoskeletal condition (lupus, disk disease, osteoarthritis, rheumatoid arthritis, or other arthritis), non-participation in sports, obesity, and having a first degree relative with CTS each had about twice the relative risk as the control group (table 1). Among potential work risk factors, perception of employer's attention to occupational health and safety was strongly associated with CTS; cumulative hours in primary job, use of power tools or machinery, bending or twisting of the hand or wrist, and job control were moderately associated with CTS; and trade union membership, and contact with solvents were weakly associated with CTS (table 2). Forty seven subjects who were eligible for the overall analysis were not included in the work analysis because they had not worked at a job or business since 1993.

Of the 40 risk factors analysed, 27 were not significantly associated with the risk of CTS (data not shown). These included (*a*) the non-work exposures of metabolic conditions (including diabetes, hypothyroidism, Grave's disease, gout, or anaemia), stress perception, children under age 4 in household, share of housework, exercise at least 20 minutes, play musical instrument, make arts or crafts, home computer, home computer pointer device, smoke or chew tobacco, and number of cigarettes per day; and (*b*) the work exposures of work for wages versus commissions, lift objects >2 pounds, use electronic scanner, use computer keyboard, use computer pointer device, use typewriter, work on assembly line, twist forearm, pinch grip, wear gloves or mittens, work in cold temperatures, labour management safety committee, workers' compensation coverage, job satisfaction, quantitative workload, and mental demands.

MULTIVARIABLE ANALYSIS

Six risk factor variables (musculoskeletal conditions, sports participation, possession of a home typewriter, body mass index (BMI), family history of CTS, and poverty income) were entered into the initial non-work regression model along with age. Table 3 shows the results of the final non-work model. Having another musculoskeletal condition increased the risk of CTS 2.4 times (95% confidence interval (95% CI) 1.24 to 4.67). There was evidence of a linear dose-response relation between BMI and risk of CTS. Each unit increase in BMI (weight (kg)/height squared (m^2)) increased the risk of CTS by 6% (OR 1.06; 95% CI 1.02 to 1.11). Tests for interactions between sex and musculoskeletal conditions (P=0.35) and between sex and BMI (P=0.17) showed no modified effect. Also, when sex was included as a possible confounder, it did not alter any of the other odds ratios (ORs) by more than 10%. Regression diagnostic statistics and the Hosmer-Lemeshow test (P=0.89) provided no evidence of lack of fit.

Seven risk factor variables (perception of employer's attention to occupational health and safety, cumulative hours in primary job, use of power tools or machinery, bending or twisting the hand or wrist, job control, trade union membership, and use of solvents) were entered into the initial work regression model along with age and the variables from the final non-work model. Table 4 shows the results of the final work model. For each unit increase in BMI, risk of CTS increased 8% (OR 1.08, 95% CI 1.03 to 1.14). Having a previous musculoskeletal condition was again positively associated with CTS (OR 2.54; 95% CI 1.03 to 6.23). People reporting the least influence over

their work had 2.86 times the risk (95% CI 1.10 to 7.14) of those with the most influence at work. Power tools and bending of the hands each had evidence of a quadratic (upside down J) dose-response relation (P=0.01 and 0.03, respectively), and job control and cumulative hours in the primary job had linear dose-response relations (P=0.02 and 0.03) with risk of CTS, but these variables remained in the model as categorical for reasons of interpretation. Tests for interactions between job control and bending hands (P=0.26) and between sex and bending of hands (P=0.46) showed no modified effect. Sex was again included as a possible confounder and did not alter any of the other ORs by more than 10%. Regression diagnostic statistics and the Hosmer-Lemeshow test (P=0.97) provided no evidence of lack of fit.

Discussion

In a study that simultaneously assessed the role of a broad range of putative CTS risk factors for the first time in a general population, we found associations between CTS and eight personal, medical, and occupational factors. In particular, a weight gain of about six pounds was found to increase the risk of disease by 8%, and keyboard use was not found to be associated with CTS.

STRENGTHS AND LIMITATIONS

In comparison with earlier work on CTS, this study has major strengths. Study cases and controls may be considered as a representative sample of all residents of the area. The high and nearly equal response rates among cases and controls reduce the likelihood of bias in responses. The full scope of potential work and non-work risk factors for CTS was included in exposure assessment. Restriction of cases to newly diagnosed CTS and interview usually within a few months of diagnosis helped to insure that recorded exposure occurred before diagnosis of disease.

Perhaps the main limitation in this study is that most exposures were measured only as an average during one year. The typical occupational exposure situation is that of variation in intensity over time.[25] The maximum mean daily exposure in the current study exceeded the typical mean daily exposure by 44 minutes for hand bending, 33 minutes for use of power tools or machinery, and 15 minutes for contact with solvents. Few studies have been done that assess the validity of quantitative self reported data on work postures and manual handling of materials, and the findings are inconsistent.[26]

STUDY FINDINGS

The relation between BMI and CTS is very strong. For each increase of one unit of BMI, which for an average sized adult is about six pounds, risk of CTS increases by 8%. The finding of a positive association between BMI and CTS is consistent with other case-control studies[27-29] as well as evidence from cross sectional[30 31] and cohort[32] studies. Possible explanations for this relation include (*a*) design of workstations and tools for the build of average sized people; (*b*) a separate association between BMI and arthritis; (*c*) the relation between measures of height and weight and measures of strength and endurance;[8] or (*d*) a direct effect of adiposity on CTS, perhaps due to reduction in volume in the carpal tunnel or increased pressure on nerves within the carpal tunnel.[31]

Vibrating hand tools have been found to be associated with CTS in three previous case control studies.[33-35] Vibration may cause direct injury to peripheral nerves, resulting in the numbness of fingers, or decreased sensation of the hand may be secondary to constriction of the blood vessels, causing loss of blood supply to the peripheral nerves.[8 36] In the current study, 40% of those using power tools or machinery at work reported the tool to be a drill or saw, but many different tools and machines were reported, and they did not show clear differences between cases and controls. Perhaps exposure to vibration needs to exceed a daily threshold before it is hazardous. The few study participants reporting use of lasers or other electronic scanners may have prevented the finding of an association with the risk of CTS.

Previous case-control studies that found an association between repetitive hand motion and CTS[29 33-35 37 38] measured hand bending as a dichotomous variable. The opportunity to find a dose-response effect of self reported hours of hand bending in this study occurred because the hours were collected as continuous data. This study's results indicate that either hand motion alone is not a sufficient cause of CTS or the induction period of the disease exceeds 12 months. In agreement with findings of a cross sectional study of industrial workers,[39] we found high repetition to be a greater risk factor for CTS than high force. The association between keyboard use and musculoskeletal disorders that has been reported in cross sectional studies[40] was not confirmed in this study.

Although there are almost no studies of the relation between genetically determined tissue type and work related musculoskeletal disorders,[8] family history has been reported in two previous case-control studies to be a risk factor for CTS.[34 41] Delgrosso and Boillat ascertained antitrypsin phenotypes from blood samples, but their study was too small to enable any conclusion on the association of phenotype with CTS. Anecdotal evidence suggests a possible role for inheritance in the manifestation of CTS, but only in terms of very rare underlying conditions.[14] The association found in our study could have occurred if CTS cases were more likely to be aware of the syndrome in family members or were from larger families than controls or if people who were aware of CTS because of a family history were likely to seek medical care for their symptoms. An alternative explanation is that jobs run in families, thus work hazards for CTS affect families through work exposures.

This is the first reported finding of an association between job control and CTS. A cross sectional study among telecommunica-

tions workers found seven psychosocial variables, including routine work lacking decision making opportunities, associated with musculoskeletal disorders of various body regions.[42] In an experiment, a low self reported level of decision latitude at work and a high degree of sleep disturbance were associated with a low pain threshold.[43] Conversely, several other potential factors related to job stress, including perceived stress, job satisfaction, quantitative workload, time on an assembly line, union membership, type of earnings (wages *v* commissions), workers' compensation insurance coverage, labour management safety and health committee, employee perception of importance of occupational safety and health to employer, and mental demands, were not related to CTS in our study. Although some of these factors showed little variability in the study population—for example, assembly line work and workers' compensation coverage—it is surprising that neither quantitative workload nor employee perception of importance of occupational safety and health to employer were risk factors in the final model.

Conclusions

In conclusion, this study presents unconfounded estimates of relative risk of CTS in a general population. Of the eight risk factors identified in this study, the factors which seem to have a causal relation to CTS, based on the statistical and biological evidence from this study and others, are BMI, use of power tools or machinery, and repetitive hand bending.

Appendix: List of other codes searched for cases of CTS

ICD-9	*CPT*	*Description*
Diagnosis:		
	356.9	Peripheral neuropathy, unspecified
Procedures:		
	95900	Nerve conduction - motor
	95904	Nerve conduction - sensory
	95869	Needle electromyography
	69965	Cock-up wrist splint
	97157	Flexor tendon repair splint
	43766	Galveston splint
	68022	Safety pin splint
	76057	Wrist and forearm splint (Richards)
	68049	Wire foam safety splint
	69965	Zimmer elastic wrist brace
04.43		Carpal tunnel release
	64721	Carpal tunnel release
	29848	Arthroscopy with release of carpal ligament

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1 Tanaka S, Wild DK, Seligman PJ, Behrens V, Cameron L, Putz-Anderson V. The US prevalence of self-reported carpal tunnel syndrome: 1988 national health interview survey data. *Am J Public Health* 1994;**84**:1846–8.
2 Levine DW, Simmons BP, Koris MJ, Daltroy LH, Hohl GG, Fossel AH, Katz JN. A self-administered questionnaire for the assessment of severity of symptoms and functional status in carpal tunnel syndrome. *J Bone Joint Surg Am* 1993; 75:1585–92.
3 Hagberg M, Morgenstern H, Kelsh M. Impact of occupations and job tasks on the prevalence of carpal tunnel syndrome. *Scand J Work Environ Health* 1992;**18**:337–45.
4 Nathan PA, Keniston RC, Myers LD, Meadows KD. Longitudinal study of median nerve sensory conduction in industry: relationship to age, gender, hand dominance, occupational hand use, and clinical diagnosis. *J Hand Surg* 1992;**17**:850–7.
5 Stevens JC, Sun S, Beard CM, O'Fallon WM, Kurland LT. Carpal tunnel syndrome in Rochester, Minnesota, 1961 to 1980. *Neurology* 1988;**38**:134–8.
6 Stevens JC, Beard CM, O'Fallon WM, Kurland LT. Conditions associated with carpal tunnel syndrome. *Mayo Clin Proc* 1992;**67**:541–8.
7 Stock SR. Workplace ergonomic factors and the development of musculoskeletal disorders of the neck and upper limbs: a meta-analysis. *Am J Ind Med* 1991;**19**:87-107.
8 Kuorinka I, Forcier L, Hagberg M, Silverstein B, Wells R, Smith MJ, *et al. Work-related musculoskeletal disorders (WMSDs): a reference book for prevention.* Bristol, PA: Taylor and Francis, 1995.
9 Bongers PM, de Winter CR. *Psychosocial factors and musculoskeletal disease; a review of the literature.* Leiden: Nederlands Instituut voor Praeventieve Gezondheidszorg TNO, 1992.
10 Bongers PM, de Winter CR, Kompier MAJ, Hildebrandt VH. Psychosocial factors at work and musculoskeletal disease. *Scand J Work Environ Health* 1993;**19**:297–312.
11 DeStefano F, Eaker ED, Broste SK, Nordstrom DL, Peissig PL, Vierkant RA, *et al.* Epidemiologic research in an integrated regional medical care system: the Marshfield epidemiologic study area. *J Clin Epidemiol* 1996;**49**:643–52.
12 Katz JN, Stirrat CR, Larson MG, Fossel AH, Eaton HM, Liang MH. A self-administered hand symptom diagram for the diagnosis and epidemiologic study of carpal tunnel syndrome. *J Rheumatol* 1990;**17**:1495–8.
13 Brown PW. Peripheral nerve lesions. In: RD D'Ambrosia, ed. *Musculoskeletal disorders.* Philadelphia: Lippincott, 1986:153–187.
14 Rosenbaum RB, Ochoa JL. Carpal tunnel syndrome and other disorders of the median nerve. Boston: Butterworth-Heinemann, 1993.
15 Stetson DS, Albers JW, Silverstein BA, Wolfe RA. Effects of age, sex, and anthropometric factors on nerve conduction measures. *Muscle Nerve* 1992;**15**:1095–104.
16 Park CH, Wagener DK, Winn DM, Pierce JP. Health conditions among the currently employed: United States, 1988. *Vital Health Stat* 1993;**10**:186.
17 National Institute for Occupational Safety and Health. *Generic job stress; questionnaire.* Cincinnati, OH: NIOSH, (nd).
18 National Center for Health Statistics. Questionnaires from the national health interview survey, 1985–89. *Vital Health Stat* 1993;**31**:1–412.
19 Hurrell JJ Jr, McLaney MA. Exposure to job stress — a new psychometric instument. *Scand J Work Environ Health* 1988;**14**(suppl 1):27–8.
20 Armstrong BK, White E, Saracci R. *Principles of exposure measurement in epidemiology.* Vol 21. Oxford: Oxford University Press, 1994.
21 Concato J, Feinstein AR, Holford TR. The risk of determining risk with multivariable models. *Ann Intern Med* 1993;**118**:201–10.
22 Breslow NE, Day NE. *Statistical methods in cancer research: volume 1- the analysis of case-control studies.* Lyon: International Agency for Research on Cancer, 1980.
23 Hosmer DW Jr, Lemeshow S. *Applied logistic regression.* New York: John Wiley, 1989.
24 Najjar MF, Rowland M. Anthropometric reference data and prevalence of overweight. *Vital Health Stat* 1987;**238**:1–73.
25 Axelson O. Dealing with the exposure variable in occupational and environmental epidemiology. *Scand J Soc Med* 1985;**13**:147–52.
26 Wiktorin C, Karlqvist L, Winkel J, Stockholm MUSIC I Study Group. Validity of self-reported exposures to work postures and manual materials handling. *Scand J Work Environ Health* 1993;**19**:208–14.
27 De Krom MCTFM, Kester ADM, Knipschild PG, Spaans F. Risk factors for carpal tunnel syndrome. *Am J Epidemiol* 1990;**132**:1102–10.
28 Dieck GS, Kelsey JL. An epidemiologic study of the carpal tunnel syndrome in an adult female population. *Prev Med* 1985;**14**:63–9.
29 English CJ, Maclaren WM, Court-Brown C, Hughes SPF, Porter RW, Wallace WA, *et al.* Relations between upper limb soft tissue disorders and repetitive movements at work. *Am J Ind Med* 1995;**27**:75–90.
30 Nathan PA, Keniston RC, Myers LD, Meadows KD. Obesity as a risk factor for slowing of sensory conduction of the median nerve in industry: a cross-sectional and longitudinal study involving 429 workers. *J Occup Med* 1992;**34**: 379–83.
31 Werner RA, Albers JW, Franzblau A, Armstrong TJ. The relationship between body mass index and the diagnosis of carpal tunnel syndrome. *Muscle Nerve* 1994;**17**:632–6.
32 Vessey MP, Villard-MacKintosh L, Yeates D. Epidemiology of carpal tunnel syndrome in women of childbearing age. Findings in a large cohort study. *Int J Epidemiol* 1990;**19**:655–9.
33 Cannon LJ, Bernacki EJ, Walter SD. Personal and occupational factors associated with carpal tunnel syndrome. *J Occup Med* 1981;**23**:255–8.

34 Delgrosso I, Boillat MA. Carpal tunnel syndrome: role of occupation. *Int Arch Occup Environ Health* 1991;**63**:267–70.
35 Wieslander G, Norbäck D, Göthe C-J, Juhlin L. Carpal tunnel syndrome (CTS) and exposure to vibration, repetitive wrist movements, and heavy manual work: a case-referent study. *Br J Ind Med* 1989;**46**:43–7.
36 Weeks JL, Levy BS, Wagner GR, eds. *Preventing occupational disease and injury*. Washington, DC: American Public Health Association, 1991.
37 Franklin G, Boteler D, Nelson L. Occupational carpal tunnel syndrome in an Oregon neurology practice [abstract]. *Am J Epidemiol* 1984;**120**:493.
38 Turner JP, Buckle PW, Stubbs DA. *A case-control study of the carpal tunnel syndrome. Paper presented at the meeting on Occupational Disorders of the Upper Extremities, March 29–30.* Ann Arbor, MI: The University of Michigan, 1990.
39 Silverstein BA, Fine LJ, Armstrong TJ. Occupational factors and carpal tunnel syndrome. *Am J Ind Med* 1987;**11**:343–58.
40 Punnett L. *A review of the evidence of work-relatedness of musculoskeletal disorders in keyboard operation and data entry tasks. Paper presented at the International Conference on Occupational Disorders of the Upper Extremities, Dec 1–2.* San Francisco, CA: University of California, 1994.
41 Radecki P. The familial occurrence of carpal tunnel syndrome. *Muscle Nerve* 1994;**17**:325–30.
42 Hales TR, Sauter SL, Peterson MR, Fine LJ, Putz-Anderson V, Schleifer LR, *et al.* Musculoskeletal disorders among visual display terminal users in a telecommunications company. *Ergonomics* 1994;**37**:1603–21.
43 Theorell T, Nordemar R, Michélsen H, Stockhom Music I Study Group. Pain thresholds during standardized psychological stress in relation to perceived psychosocial work situation. *J Psychosom Res* 1993;**37**:299–305.

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