Upper Extremity Mononeuropathy Among Engineers

Craig F. Conlon, MD
David M. Rempel, MD, MPH

Objectives: *The objectives of this study were to estimate the prevalence of mononeuropathy at the wrist among engineers who use computers and to identify associated risk factors.* ***Methods:*** *This is a cross-sectional study of 202 engineers using questionnaires and electrophysiological nerve testing. The definition for median or ulnar mononeuropathy required the combination of distal upper extremity discomfort and abnormal distal motor latency.* ***Results:*** *The prevalence of neuropathy at the wrist among engineers was 10.3% (right median), 3.4% (left median), 1.8% (right ulnar), and 2.9% (left ulnar). Logistic regression analysis identified three variables with positive associations (body mass index, hours of computer use, and antihypertensive medication) and three variables with negative associations (typing speed, driving hours, total break time).* ***Conclusions:*** *Mononeuropathies at the wrist occur among computer-using engineers and are related to a number of factors, including hours of computer use.* (J Occup Environ Med. *2005;47:1276–1284*)

From the School of Public Health, University of California, Los Angeles (Dr Conlon) and the Division of Occupational and Environmental Medicine, Department of Medicine (Dr Rempel), University of California, San Francisco, San Francisco, California.

Address correspondence to: David Rempel, MD, MPH, Division of Occupational and Environmental Medicine, University of California, San Francisco, 1301 South 46th Street, Building 163, Richmond, CA 94804; E-mail: drempel@itsa.ucsf.edu.

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Despite much speculation regarding a link between computer use and entrapment neuropathy at the wrist such as carpal tunnel syndrome (CTS), the evidence for this association is mixed. There is a robust literature linking forceful and repetitive hand intensive tasks to CTS.[1–5] There is some evidence that repetitive tasks without high force may be a risk factor for CTS. Thomsen et al reported an association between CTS and highly repetitive work among Danish postal or bank employees who performed mail sorting, enveloping, and data entry.[6] Although computer work is repetitive, computer work does not usually involve high forces. Most studies of entrapment neuropathies among computer users are cross-sectional in design and suffer from a lack of variability of exposure or no measure of nerve conduction latency.[7–9]

There are two prospective studies of computer users that include CTS as an end point. Gerr et al conducted a 3-year study of 632 computer users and performed nerve conduction studies when participants experienced moderately severe hand symptoms (symptoms greater than 5 on a 10-point scale).[10] The authors reported an annual incidence of 0.9 cases of CTS per 100 person-years. However, they concluded that their study did not have an adequate sample size to examine the relationship between hours of computer use and risk of developing carpal tunnel syndrome. In the second prospective study, a 1-year study by Andersen et al of 5658 Danish professional technicians, the authors reported no rela-

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tionship between hours of keyboard use and incidence of CTS.[11] For computer use, participants were grouped by hours of keyboard use (mean, 8–9 hours per week) and hours of mouse use. However, despite the large size of this study, the authors reported the need to collapse the higher keyboard use categories as a result of small numbers of cases. They used a single category of greater than 20 hours of keyboard use per week, which had an elevated, but not significant, odds ratio of 1.4 and 1.6 for CTS prevalence and incidence, respectively. The Andersen study average computer use is less than that reported for customer service operators[7] and newspaper employees.[12] The Andersen study did report a significantly increased risk of CTS (odds ratio, 2.6–3.2) in subjects who reported use of a mouse for more than 20 hours per week.

The exploration of the relationship between computer use and CTS is complicated by an apparent relationship between this condition and other medical conditions such as diabetes, inflammatory arthritis, pregnancy, hypothyroidism, and renal failure.[13–17] Several studies also report a relationship between prolonged latency and body mass index or weight.[18–20] Therefore, studies exploring the relationship between computer use and entrapment neuropathy should account for these potential confounders.

Determining whether there is a link between entrapment neuropathy and computer use is important as a result of the morbidity associated with entrapment neuropathies and the ever increasing use of computers in the workplace and at home. Carpal tunnel syndrome is associated with greater lost work time than other common work-related musculoskeletal disorders.[21,22] These studies do not report what proportion of the CTS cases were associated with computer use; however, an evaluation of the data from the Massachusetts Sentinel Event Notification System for Occupational Risks (SENSOR) reported a high state burden of work-related CTS among office workers.[23] U.S. national statistics show a rising secular trend of upper extremity musculoskeletal injuries.[24] These statistics reveal that although upper extremity musculoskeletal disorders made up only 18% of all work-related illness in 1982, by 2001, these disorders made up 65% of the total. U.S. Bureau of Census numbers demonstrate a corresponding temporal rise in home computer use.[25] In 1984, the first year this census question was asked, 8.2% of households had computers. By 1998, this number had risen to 42% of households, and by 2000, computers were present in 51% of households.

Studies of computer users have examined nonprofessional populations such as transcriptionists,[9] clerical workers,[9,10] or customer service operators[7,26] and professional populations such as reporters[12,27] and technical workers.[11,28] Engineers are a professional population with extensive exposure to computers but who are thought to have greater decision latitude and control at the workplace than nonprofessionals. Therefore, they may experience a different risk pattern for upper extremity disorders in comparison to other computer users. This is a cross-sectional study of engineering professionals to investigate the risk factors associated with entrapment neuropathies at the wrist. The study used a new, portable nerve conduction system to measure motor latency of the median and ulnar nerve at the wrist. The primary null hypothesis was that increasing hours of computer use was not related to increased risk of entrapment neuropathy at the wrist.

Materials and Methods

Design and Study Population

This is a cross-sectional epidemiologic study of engineers employed at a large engineering firm in Southern California. Participants completed a health questionnaire, and nerve conduction studies were conducted of their median and ulnar nerves at both wrists. The study was carried out in 2002 and 2003.

Eligibility criteria included employment as a member of the engineering staff or related professional field and use of a computer for at least 15 hours per week. Although the majority of participants worked in traditional engineering fields such as electrical, mechanical, design, industrial hygiene, and quality engineering (Table 1), the study also included professional categories that support the engineering projects such as computer programming, graphic design, financial planning, and project developers. Nonprofessional occupations were excluded; these included administrative assistants (secretaries) and production technicians (ie, welders, machinists, test mechanics, plumbers, inspectors, carpenters, and facilities personnel).

Potential participants were recruited at small departmental meetings where the study and eligibility criteria were described. All eligible employees were asked to complete a brief anonymous survey to assess current symptoms to compare participants with nonparticipants. Those who were eligible and agreed to participate completed the health questionnaire and a nerve conduction test at a later time. The University of California at San Francisco Committee on Human Research approved the study design.

Anonymous Survey

The anonymous survey included demographic questions (eg, age, gender, job title), questions about hours

TABLE 1
Subject Occupations (n = 202)

Job Titles	N	(%)
Engineers–staff	164	(81.2)
Engineering managers	9	(4.4)
Engineering team leaders	7	(3.5)
Engineering–industrial hygiene	8	(4.0)
Engineering support staff	14	(6.9)

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of computer use both at work and outside of work, and years of computer use above 20 hours per week. The survey also collected the "worst discomfort level experienced during the prior week" in the right and left elbow, forearm, wrist or hand, hereafter referred to as the distal upper extremity. For each region, discomfort was rated on a visual analog scale with numeric anchors from 0 to 10 and verbal anchors at either end of the scale of "no discomfort" to "unbearable discomfort." Subjects also reported how many days during the prior week they had difficulty working as a result of musculoskeletal discomfort and how many days they took medications as a result of discomfort.

Health Questionnaire

Each participant completed an online health questionnaire that was prepared in five parts in hypertext markup language and placed on a company server. The link to the questionnaire was provided to participants through an e-mail message so that the subject could simply click on a hyperlink to open up and fill out the questionnaire. As the participants completed each part of the five-part questionnaire, they electronically submitted their answers directly into a Microsoft Access database.

The health questionnaire collected demographic information such as age, marital status, gender, ethnicity, and highest level of schooling. The questionnaire also assessed information on known or suspected risk factors for CTS such as pregnancy, menopause, hysterectomy, oophorectomy, diabetes, renal failure, arthritis, medication use, prior trauma, and prior upper extremity surgeries. The participants were also surveyed for other potential risk factors or confounders for entrapment neuropathies such as height, weight, number of small children or disabled individuals in the home, smoking history, exercise habits, and hobbies.

Nerve Testing

Upper extremity peripheral nerve function at the wrist was tested in each participant using an automated electrophysiological neurodiagnostic device (NC-Stat; NeuroMetrix, Inc.). The device measures distal motor latency (DML) and has been found to have good accuracy when compared with conventional methods.[29] Four tests were performed using a different biosensor for the ulnar nerve and the median nerve in both extremities. The biosensor consists of two stimulation electrodes, two detection electrodes, a temperature electrode, and one reference electrode. Biosensors for the median nerve come in small, medium, and large and are selected based on the participant's weight. Motor latency is measured by stimulating the nerve proximal to the wrist. The electrical stimuli evoke myoelectric responses in the innervated muscles. The biosensor detects these myoelectric responses, which are compound muscle action potentials, as electrical potentials on the skin. For example, with the median nerve test, the stimulus cathode is located 3 cm proximal to the distal wrist crease. The compound muscle action potential of the abductor pollicis brevis (APB) is detected through volume conduction by electrodes located proximal to the wrist crease. The measurements used in this study included the DML for the ulnar and median nerves at the wrist. The device calculates the median or ulnar distal motor latency (calculated DMLs) and adjusts for skin temperature. The collected responses to stimuli are downloaded to the NeuroMetrix server and normative values, adjusted for age, gender, and height, are returned as temperature-corrected DML values and as percentiles. In the logistic analyses, an abnormal DML was defined as a value at or below the population fifth percentile. Our case definition of ulnar or median entrapment neuropathy required the presence of an abnormal DML and the participant's rating of ipsilateral distal upper extremity discomfort greater than 1 on the scale of 0 to 10.[30] Because of technical difficulties or subject compliance, complete studies were not available for all subjects (Table 2).

TABLE 2
Total Nerves Tested by Site (n = 202)

Nerve	N (%)
Right median DMLs	196 (97.0)
Left median DMLs	197 (97.5)
Right ulnar DMLs	191 (94.6)
Left ulnar DMLs	192 (95.0)

DMLs indicates distal motor latencies.

Data Analysis

The anonymous survey was used to compare participants with nonparticipants using the *t* test or χ^2 analysis. Participants with medical conditions associated with peripheral neuropathies (eg, pregnancy, diabetes, rheumatoid arthritis or lupus erythematosus, renal failure, or thyroid disorders) were excluded from the subsequent data analysis.[8,15,17,31–33] The relationship between independent variables, as derived from the health questionnaire, to entrapment neuropathy was initially investigated using univariate logistic regression analysis. Variables with a P value of less than 0.50 in the univariate analysis were then tested in a combined model. Those variables with the highest P value were sequentially eliminated from this combined model. The final model included only those variables with a P value less than 0.10.

The relationship between independent variables and DML was similarly investigated by univariate linear regression. Again, a multivariate linear regression model was developed by stepwise elimination of variables. Estimates of computer use at work ranged from 15 hours to 50 hours per week. Four levels of computer use exposure were developed as exposure quartiles. Because subject estimates of hours of computer use at work tended to cluster, the number of subjects per quartile is not the same.

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Results

Participants

Based on meetings with department supervisors and employees at department meetings, 441 eligible employees were identified and all completed the anonymous survey. Of these, 206 (47%) consented to participate in the study. Of these 206 volunteers, 202 (98%) complied with all aspects of the study. The study participants differed from the nonparticipants in several characteristics (Table 3). Participants reported higher levels of discomfort in the right and left distal upper extremities. Participants were also more likely to take medications for discomfort related to work. Although females represented 22% of the eligible employees, they were more likely to volunteer for the study than males. Study participants' ages were only slightly lower on average than nonparticipants (42.5 vs 44.2), and this difference did not reach statistical significance. Study participants did not differ from nonparticipants on hours worked per week, hours per week on a computer at work, total hours per week on a computer, or the number of years before their current position that they worked on computers at greater than 20 hours per week.

The presence of medical conditions associated with peripheral neuropathies was an a priori exclusion criterion for data analysis and resulted in the elimination of 22 subjects (12 subjects with diabetes, 3 subjects with rheumatoid arthritis or systemic lupus, 3 subjects with renal failure, 7 subjects with thyroid disorders, and one pregnancy), leaving 180 subjects in the final analysis.

Prevalence of Entrapment Neuropathy

The prevalence of distal upper extremity discomfort and prolonged distal motor latency are presented in Table 4. Of the 180 subjects, 57.2% reported right distal upper extremity discomfort in the past week of greater than 1 on a scale of 0 to 10 and 46.2% reported left distal upper extremity discomfort. Subjects received a diagnosis of an entrapment neuropathy if they reported regional discomfort in the distal upper extremity and the distal motor latency was abnormal (Table 4). The most common entrapment neuropathy involved the right median nerve with a prevalence of 10.3%. Of the 25 neuropathy cases, 18 (72%) were identified with right median neuropathy. The prevalence of left median, right ulnar, and left ulnar neuropathy was less common. Of the eight cases with ulnar neuropathy, two were also diagnosed with median neuropathy. Five of the 19 cases identified with median neuropathy were bilateral (26%).

The relationship between the independent variables and entrapment neuropathy ($N = 25$) was initially evaluated using univariate logistic regression (Table 5). Independent variables with a P value of less than 0.50 in this univariate analysis were tested in a combined model. Variables with the highest P value were sequentially eliminated from this combined model and the final model included only those variables with a P value less than 0.10.

In the final logistic regression model (Table 6), body mass index, number of hours per day on a computer at work, and taking blood pressure medications were associated with an increased risk of entrapment neuropathy (odds ratio greater than 1.0), whereas typing speed, total driving hours per week, and total

TABLE 3
Comparison of Participants With Nonparticipants

Characteristic	Participants ($n = 202$) No. (SD)	Nonparticipants ($n = 239$) No. (SD)	P Value*
Mean age (yr)	42.5 (9.7)	44.2 (10.3)	0.07
Gender (% female)	27.5%	16.9%	0.007
Right distal upper extremity discomfort†	3.1 (2.9)	2.0 (2.3)	<0.001
Left distal upper extremity discomfort†	1.5 (2.2)	0.93 (1.7)	0.003
Right distal upper extremity discomfort >1 (%)	60.2%	47.2%	0.006
Left distal upper extremity discomfort >1 (%)	31.6%	19.2%	0.003
Medications taken for discomfort‡	0.77 (1.6)	0.26 (1.0)	0.0001
Days affected by discomfort§	0.23 (0.86)	0.12 (0.67)	0.15
Work hours (hr/wk)	41.4 (4.5)	41.5 (3.6)	0.78
Computer use at work (hr/wk)	29.2 (7.5)	29.6 (7.9)	0.51
Other computer use (hr per wk)	7.0 (5.8)	6.8 (6.5)	0.73
Total computer use (hr per wk)	36.2 (9.5)	36.3 (11.0)	0.91
Computer use before current employment (yr)	5.5 (6.1)	5.3 (6.2)	0.79

*Student t test for comparison of means. χ^2 statistic for testing of frequencies.
†Mean rating; discomfort range 0–10.
‡"How many days during the past week, if any, did you take medications for the discomfort?"
§"Please indicate how many days in the past week, if any, you were unable to keep up with your usual work duties due to discomfort."
SD indicates standard deviation.

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TABLE 4
Prevalence of Symptoms, Prolonged Motor Latency, and Entrapment Neuropathy (N = 180)

Nerve	N	Total Subjects	Prevalence
Right distal upper extremity discomfort*	103	180	57.2%
Left distal upper extremity discomfort*	55	180	30.6%
Right median prolonged DML	33	180	18.3%
Left median prolonged DML	19	180	10.1%
Right ulnar prolonged DML	9	180	5.0%
Left ulnar prolonged DML	21	180	11.7%
Right median neuropathy†	18	175	10.3%
Left median neuropathy	6	177	3.4%
Right ulnar neuropathy	3	170	1.8%
Left ulnar neuropathy	5	172	2.9%
Total cases of neuropathy:	25	180	13.9%
Bilateral median	5	180	2.8%
Bilateral ulnar	0	180	0%
Isolated median	14	180	7.8%
Isolated ulnar	6	180	3.3%

*Discomfort is defined as discomfort greater than 1 out of 10 on a scale from 0 to 10.
†A neuropathy case requires both abnormal symptoms and prolonged motor latency.
DML indicates distal motor latency.

TABLE 5
Univariate Logistic Regression for Independent Variables and Cases of Entrapment Neuropathy

Variable	OR (95% CI)	$P > z$*
Age	1.07 (1.02–1.13)	**0.004**
Gender (female)	1.30 (0.46–3.70)	0.624
Computer use at work (units in 10 hrs/wk)	1.73 (0.94–3.18)	**0.076**
Additional hr on a computer per week	1.01 (0.95–1.08)	0.739
Hours of computer use per week		
15–21 hr/wk	1.0	—
22–28 hr/wk	0.92 (0.14–5.86)	0.929
29–35 hr/wk	2.67 (0.68–10.5)	**0.162**
Over 35 hr/wk	3.58 (0.93–13.8)	**0.064**
Hours per week at work	1.03 (0.92–1.15)	0.621
Previous yr at >20 hrs/wk on computer†	0.95 (0.87–1.04)	**0.266**
Total yr at >20 hrs/wk on computer‡	1.00 (0.99–1.00)	0.789
Typing speed (words/min)	0.98 (0.95–1.00)	**0.104**
Break time per day (units in 20 min/d)	0.84 (0.54–1.31)	**0.454**
Total number of breaks per day	1.19 (0.74–1.91)	**0.472**
Blood pressure medication use	4.08 (1.24–13.4)	**0.020**
Cholesterol medication use	0.68 (0.08–5.58)	0.716
Current smoker	1.25 (0.14–11.2)	0.842
Pack-yr (current smokers)	1.00 (0.89–1.12)	0.971
Exercise frequency§	1.23 (0.74–2.05)	**0.424**
Aerobic activity (hr/wk)‖	1.09 (0.93–1.27)	**0.298**
Upper extremity activity (hr/wk)¶	1.01 (0.98–1.05)	0.567
Driving a car (hr per week)	0.91 (0.81–1.02)	**0.091**
Weight (kg)	1.03 (1.00–1.05)	**0.027**
Body mass index (kg/m^2)	1.11 (1.01–1.21)	**0.023**

*Variables with P value < 0.5 are identified in bold and were tested in the combined model.
†Number of yr at prior jobs with at least 20 hr/wk spent at a computer.
‡Total number of yr at any job with at least 20 hr/wk at a computer.
§Number of times per week individual exercises or plays sports.
‖Hours per week performing aerobic exercises.
¶Hours per week performing hand intensive hobbies or exercises.
OR indicates odds ratio; CI, confidence interval.

minutes of break time per day were associated with a lower risk of entrapment neuropathy (odds ratio less than 1.0).

Distal Motor Latency Analysis

The association between potential covariates and the subjects' right median nerve DML results was explored with linear regression. In the final linear regression model (Table 7), body mass index, height, and taking blood pressure medications were associated with an increased right median nerve DML (coefficient greater than zero), whereas typing speed was associated with a decreased right median nerve DML (coefficient less than zero).

Discussion

This is the first study of peripheral neuropathies at the wrist among engineers and associated professionals who use a computer for more than 15 hours per week. The most common neuropathy was median entrapment neuropathy at the wrist (eg, CTS) with a prevalence of 10.3%. In the final entrapment neuropathy model, number of hours of computer use per week, using antihypertensive medications, and body mass index were associated with an increased risk of neuropathy, whereas increasing typing speed and hours of driving per week were protective. Other variables related to computer use such as hours of computer use outside of work, years of heavy (>20 hours per week) computer use, number of breaks per day, or break time per day were not significantly related to risk of peripheral neuropathy, although in the final model, total number of minutes break time per day was of borderline significance (P = 0.06). The linear regression analysis of the effect of the same independent variables on the right median nerve DML also showed an adverse effect with increasing body mass index and using antihypertensive medications and a protective effect of typing speed. However, total minutes of break time and hours of com-

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TABLE 6
Final Logistic Model for Entrapment Neuropathy ($n = 180$)*

Variable	OR	*P* Value	95% CI	Delta R^2	Mean
Hours of computer use at work				0.072	29
15–21 hr per week ($n = 43$)	1.00				
22–28 hr per week ($n = 31$)	1.28	0.80	0.18–9.23		
29–35 hr per week ($n = 54$)	5.78	0.025	1.24–26.9		
Over 35 hr per week ($n = 52$)	6.53	0.015	1.44–29.7		
Typing speed (words/min)	0.96	0.004	0.93–0.98	0.069	39
Driving (hr/wk)	0.84	0.014	0.73–0.96	0.056	8.8
Taking blood pressure medications	5.26	0.022	1.28–21.8	0.034	
Body mass index (kg/m^2)	1.11	0.044	1.00–1.23	0.027	27
Total break time (20 min/d)	0.57	0.062	0.32–1.02	0.025	2.0

*Model's pseudo $R^2 = 0.20$ ($P < 0.001$).
OR indicates odds ratio; CI, confidence interval.

puter use did not reach statistical significance.

This study also evaluated ulnar neuropathy at the wrist, which is less common than CTS.[34] Given the similar anatomic position of the ulnar nerve and the median nerve at the wrist, the risk factors involved in computer use may be similar.[35,36] Werner and Franzblau evaluated median and ulnar nerve testing based on hand dominance.[37] They found no significant difference between the right and left hand for both ulnar and median nerve amplitudes for lefthanders, but significantly worse amplitude in the dominant hand for righthanders. Although they could not duplicate this finding with nerve latency testing, they concluded that right hand-dominant workers tend not to use their nondominant hand in comparison to left hand-dominant workers.

Participants in this study reported a mean exposure to computer use at work of 29 hours per week (interquartile range of 25 to 35). Among newspaper employees, self-reported assessments of computer use duration are double actual exposure when compared with independent exposure monitoring.[38] However, the correlation between self-reported exposure and more objective measures is high. It is not known how accurately engineers self-report exposure.

Few studies have investigated the association between computer use and upper extremity neuropathy. As a result of differences in study methods, a comparison of our study with the Gerr et al[10] and Andersen et al[11] studies is problematic but provides some insight about relationships between CTS and keyboard or mouse use. As noted in the introduction, the sample size of the prospective study by Gerr et al was too small to examine the relationship between hours of computer use and increased risk of CTS. The study by Andersen et al found a statistically significant increased risk of CTS symptoms with more than 20 hours of mouse use per week and a not significant increased risk of CTS symptoms with more than 20 hours of keyboard use per week (odds ratio of 1.6 for CTS prevalence, 1.4 for CTS incidence). In considering the lack of association in their study between keyboard use and CTS, it is important to note that in their analyses of keyboard use, the highest categorical levels of use were collapsed to ">20 hours per week." In our study, subjects with low hours of computer use (<15 hours per week) were excluded and the median hours of computer use for participants was 29 hours per week. Therefore, our analysis compared moderate computer use with high levels of computer use, whereas the Andersen study looked at a broader range. Our findings are suggestive of a threshold effect occurring above 28 hours per week of computer use. Our study collected data on hours of "computer use" and did not differentiate between hours of mouse and keyboard use. Based on pilot data collected from this same population of engineers, we estimate that hours of device exposure during computer use are evenly split between keyboard and mouse. If so, the mean exposure to keyboards is higher in our study than that reported in the Andersen et al study, whereas mouse use is lower.

Stevens et al conducted a cross-sectional study of 257 medical secretaries, schedulers, and transcriptionists with a symptom survey and nerve conduction study.[9] They found no difference in weekly hours of keyboard use between subjects with CTS and those without CTS. The participants reported an average of 32 hours per week of keyboard use. However, there was a relationship between frequent mouse use and CTS that was not discussed by the authors. Of the clerical workers with CTS, 48.1% reported frequent mouse use, whereas among the non-CTS clerical workers, 27.9% reported frequent mouse use ($P = 0.03$, χ^2 test).

In our study, entrapment neuropathy was defined as the combination of a prolonged DML plus distal upper extremity discomfort. Based on this definition, we found a 13.9%

TABLE 7
Final Linear Regression Model for Distal Motor Latency ($n = 174$)*

Variable	β Coefficient	*P* Value	Delta R^2
Height (inches)	0.033	0.00	0.049
Typing speed (words/min)	−0.004	0.03	0.018
Taking blood pressure medications	0.253	0.04	0.017
Body mass index (kg/m^2)	0.017	0.02	0.010

*Model's adjusted $R^2 = 0.15$ ($P < 0.0001$).

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prevalence of upper extremity entrapment neuropathy at the wrist in a population of engineers. The prevalence of median nerve entrapment was just over 10%. Because no gold standard exists, CTS continues to remain a clinical diagnosis based on a combination of symptoms, physical examination findings, and electrophysiological findings.[39] Reported prevalences of CTS, when using the combination of symptom reporting and abnormal nerve conduction studies, vary between studies. Studies of the general population have reported a prevalence of CTS ranging from less than 1% to over 16%.[40–43] The annual incidence of CTS has been reported as 0.1% in a general population[44] and 0.9% in a population of computer users.[10] Among blue collar workers, the prevalence of CTS has varied between 0.6% and 61%.[1,45–49] Among computer users, the prevalence range is 0.5% to 18.5%.[9,10,28] The differences in prevalence appear to be a function of differing populations and differences in case definition. In the study of medical clerical workers, Stevens et al reported a CTS prevalence of 10.5% by clinical evaluation and 3.5% with clinical CTS plus nerve conduction study confirmation.[9] However, in comparison to our study, this study population was predominantly clerical and over 90% female. Gerr et al describes an initial prevalence of 0.5% among newly hired employees whose jobs required greater than 15 hours of computer use per week.[10] Because this was a study of new hires, this study population differed from ours by age (78% under 40 years old vs our mean of 42.5 years), obesity (60% less than 25 kg/m^2 vs our mean of 27 kg/m^2), and years exposure to high computer use (73% with less than 6 prior years of keying ≥20 hours per week vs our mean of 5.5 years). Our study excluded participants with medical risk factors for CTS, an exclusion that will lower our estimated prevalence of median neuropathy. The majority of our study population included engineers who often perform computer-aided design tasks. Our study would be expected to differ from computer use studies of data entry personnel because finger forces exerted when using a keyboard and mouse are higher in computer-aided design activities in comparison to data entry tasks.[50]

The association between CTS and obesity or body mass index has been observed in a number of studies.[18,19,20,51] In our study, the 25th, 50th, and 75th percentiles of body mass index quartiles are 23.1, 26.6, and 29.1 kg/m^2, respectively. With an odds ratio of 1.11, each increase in body mass index by 5.0 kg/m^2 doubles the odds of entrapment neuropathy. The association between CTS and blood pressure medications has not been previously studied. There are several anecdotal reports of patients with CTS on beta blockers whose symptoms resolved after discontinuation of the beta blockers.[52–54] Because extraneural pressure is elevated in patients with CTS, the reduction in mean arterial pressure with antihypertensive medications may compromise blood flow to the nerve and lead to hand symptoms.[55] Diuretic antihypertensives have been studied for the treatment of CTS, following the theory that edema may contribute to increased extraneural pressure, but were found to be ineffective.[56] Although taking blood pressure medications is associated with a large odds ratio, the relatively low delta R^2 (Table 6) indicates that the taking of blood pressure medications plays a minor role in predicting the prevalence of neuropathy in this study population (approximately 9% of the subjects were on blood pressure medications).

Increased automobile driving was protective in our study with an odds ratio of 0.84. Based on this odds ratio, every additional 1-hour increase in driving per week reduces the odds of developing entrapment neuropathy by 20%. No other studies have evaluated the relationship of commute driving and the risk of CTS. An explanation may be that those with hand symptoms elect to drive less or that driving may actually provide some protective value, although the mechanisms for protecting the nerve are not clear. Increased break time during the day was also protective with an odds ratio of 0.57. This odds ratio predicts a 50% decline in the odds of developing entrapment neuropathy with the addition of a 23-minute break each day. In a study of data entry clerks, Galinsky reported a significant reduction in right wrist, hand, and forearm discomfort with the addition of 20 extra minutes of break time per day.[57]

One of the limitations of this study is the cross-sectional design. An attempt was made to include predictor variables that are stable over time and less sensitive to the outcome, neuropathy. For variables that are relatively stable with time, eg, body mass index, use of blood pressure medications, and driving hours, there will be greater confidence in the findings in the final model. For those factors that may be influenced by a neuropathy, eg, use of pain medications, sleep pattern, typing speed, and hours of computer work, there will be less confidence in a causal relationship. It is possible that estimates of typing speed could decrease with symptoms of entrapment neuropathy and thereby produce an artificial appearance that typing speed is protective. However, it would be unlikely that entrapment neuropathy would lead to increasing hours of computer work.

Another limitation is the relatively low participation rate (47%) combined with the increased prevalence of upper extremity symptoms among the participants in comparison with the nonparticipants. This self-selection bias is likely to increase the estimated population prevalence of neuropathy but is unlikely to change the identified risk factors in the final model. If we assume that the prevalence of median neuropathy among the nonparticipants was related to

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their prevalence of distal upper extremity symptoms, then the prevalence estimation for right median neuropathy would decrease from 10.3% to approximately 9.2%.

Our case definition of entrapment neuropathy included nonspecific distal upper extremity symptoms that may have led to a higher estimation of prevalence of upper extremity neuropathy compared with the use of a more specific question on paresthesias in the median nerve distribution of the hand or the use of a hand diagram.[58] However, this is balanced against our requirement of an abnormal distal motor latency. An abnormal DML is highly specific for CTS but less sensitive than a conventional nerve conduction study that also includes sensory latency.[59] The high specificity of DML will improve the accuracy of the diagnosis of neuropathy, but the low sensitivity could lead to an underestimation of entrapment neuropathy prevalence. Therefore, we are uncertain whether the case definition that we adopted will increase or decrease the estimated prevalence of neuropathy in comparison to use of a hand diagram and a conventional nerve conduction study.

This study, with a unique population of engineers and related professionals, revealed a prevalence of neuropathy at the wrist of 13% and a prevalence of 10% for the most common neuropathy, right median neuropathy at the wrist. The actual prevalence of neuropathy in this population is likely to be somewhat less because nonparticipants were less symptomatic. The risk of entrapment neuropathy increased with increasing hours of computer use per week and increasing body mass index, whereas increasing typing speed, break time, and hours of driving per week were protective. The finding of an association between computer work and entrapment neuropathy at the wrist among engineers should be confirmed by other studies. However, these findings suggest the need to evaluate interventions to reduce these and other risk factors for entrapment neuropathy.

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References

1. Silverstein BA, Fine LJ, Armstrong TJ. Occupational factors and carpal tunnel syndrome. *Am J Ind Med*. 1987;11:343–358.
2. Werner RA, Franzblau A, Albers JW, Armstrong TJ. Median neuropathy among active workers: are there differences between symptomatic and asymptomatic workers? *Am J Ind Med*. 1998; 33:374–378.
3. Tanaka S, Petersen M, Cameron L. Prevalence and risk factors of tendinitis and related disorders of the distal upper extremity among US workers: comparison to carpal tunnel syndrome. *Am J Ind Med*. 2001;39:328–335.
4. Viikari-Juntura E, Silverstein B. Role of physical load factors in carpal tunnel syndrome. *Scand J Work Environ Health*. 1999;25:163–185.
5. Roquelaure Y, Mechali S, Dano C, et al. Occupational and personal risk factors for carpal tunnel syndrome in industrial workers. *Scand J Work Environ Health*. 1997;23:364–369.
6. Thomsen JF, Hansson G, Mikkelsen S, Lauritzen M. Carpal tunnel syndrome in repetitive work: a follow-up study. *Am J Ind Med*. 2002;42:344–353.
7. Hales TR, Sauter SL, Peterson MR, et al. Musculoskeletal disorders among visual display terminal users in a telecommunication company. *Ergonomics*. 1994;37: 1603–1621.
8. de Krom M, Kester A, Knipschild P, Spaans S. Risk factors for carpal tunnel syndrome. *Am J Epidemiol*. 1990;132: 1102–1110.
9. Stevens JC, Witt JC, Benn ES, Weaver AL. The frequency of carpal tunnel syndrome in computer users at a medical facility. *Neurology*. 2001;56:1568–1570.
10. Gerr F, Marcus M, Ensor C, et al. A prospective study of computer users: I. Study design and incidence of musculoskeletal symptoms and disorders. *Am J Ind Med*. 2002;41:221–235.
11. Andersen JH, Thomsen JF, Overgaard E, et al. Computer use and carpal tunnel syndrome: a 1-year follow-up study. *JAMA*. 2003;289:2963–2969.
12. Faucett J, Rempel D. VDT-related musculoskeletal symptoms: interactions between work posture and psychosocial work factors. *Am J Ind Med*. 1994;26: 597–612.
13. Solomon DH, Katz JN, Bohn R, Mogun H, Avorn J. Non-occupational risk factors for carpal tunnel syndrome. *J Gen Intern Med*. 1999;14:310–314.
14. Stevens JC, Beard CM, O'Fallon WM, Kurland LT. Conditions associated with carpal tunnel syndrome. *Mayo Clin Proc*. 1992;67:541–548.
15. Phalen GS. The carpal-tunnel syndrome. *Clin Orthop*. 1972;83:29–40.
16. Fraser CL, Arieff AI. Nervous system complications in uremia. *Ann Intern Med*. 1988;109:143–153.
17. Palumbo CF, Szabo RM, Olmsted SL. The effects of hypothyroidism and thyroid replacement on the development of carpal tunnel syndrome. *J Hand Surg*. 2000;25A:734–739.
18. Werner RA, Franzblau A, Albers JW, Armstrong TJ. Influence of body mass index and work activity on the prevalence of median mononeuropathy at the wrist. *Occup Environ Med*. 1997;54:268–271.
19. Nathan PA, Keniston RC, Myers LD, Meadows KD. Obesity as a risk factor for slowing of sensory conduction of the median nerve in industry. *J Occup Med*. 1992;34:379–383.
20. Kouyoumdjian JA, Morita M, Rocha PR, Miranda RC, Gouveia GM. Body mass index and carpal tunnel syndrome. *Ar Qneuropsiquiatr*. 2000;58:252–256.
21. Cheadle AF, Wolfhagen C, Savarino J, Liu PY, Salley C, Weaver M. Factors influencing the duration of work-related disability: a population-based study of Washington State workers' compensation. *Am J Public Health*. 1994;84:190–196.
22. US Department of Labor, Bureau of Labor Statistics. Lost-Worktime Injuries and Illnesses: Characteristics and Resulting Days Away From Work, 2002. 2004; USDL 04–460.
23. Wellman H, Davis L, Punnett L, Dewey R. Work-related carpal tunnel syndrome (WR-CTS) in Massachusetts, 1992–1997: source of WR-CTS, outcomes, and employer intervention practices. *Am J Ind Med*. 2004;45:139–152.
24. US Department of Labor, Bureau of Labor Statistics. Workplace Injuries and Illness in 2001. 2001; USDL 02–687.
25. US Census Bureau 2000. Home Comput-

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ers and Internet Use in the United States; August 2000.

26. Toomingas A, Nilsson T, Hagberg M, Hagman M, Tornqvist EW. Symptoms and clinical findings from the musculoskeletal system among operators at a call center in Sweden—a 10-month follow-up study. *Int J Occup Saf Ergon*. 2003;9:405–418.
27. Bernard B, Sauter S, Fine L, Peterson M, Hales T. Job task and psychosocial risk factors for work-related musculoskeletal disorders among newspaper employees. *Scand J Work Environ Health*. 1994;20:417–426.
28. Franzblau A, Flaschner D, Albers J, Blitz S, Werner R, Armstrong T. Medical screening of office workers for upper extremity cumulative trauma disorders. *Arch Environ Health*. 1993;48:164–170.
29. Leffler CT, Gozani SN, Cros D. Median neuropathy at the wrist: diagnostic utility of clinical findings and an automated electrodiagnostic device. *J Occup Environ Med*. 2000;42:398–409.
30. Hales T, Sauter S, Peterson M, et al. Health hazard evaluation report. US West Communications. 1992; HETA 89-299-2230.
31. Atcheson S, Ward J, Lowe W. Concurrent medical disease in work-related carpal tunnel syndrome. *Arch Intern Med*. 1998;158:1506–1512.
32. Phalen GS. The carpal-tunnel syndrome. *J Bone Joint Surg [Am]*. 1966;48:211–228.
33. Roquer J, Cano J. Carpal tunnel syndrome and hyperthyroidism: a prospective study. *Acta Neurol Scand*. 1993;88:149–152.
34. Kothari MJ. Ulnar neuropathy at the wrist. *Neurol Clin*. 1999;17:463–476.
35. Wright TW, Glowczewskie F, Cowin D, Wheeler DL. Ulnar nerve excursion and strain at the elbow and wrist associated with upper extremity motion. *Hand Surg*. 2001;26A:655–662.
36. Murata K, Shih JT, Tsai TM. Causes of ulnar tunnel syndrome: a retrospective study of 31 subjects. *J Hand Surg*. 2003;28:647–651.
37. Werner RA, Franzblau A. Hand dominance effect on median and ulnar sensory evoked amplitude and latency in asymptomatic workers. *Arch Phys Med Rehabil*. 1996;77:473–476.
38. Faucett J, Rempel D. Musculoskeletal symptoms related to video display terminal use: an analysis of objective and subjective exposure estimates. *AAOHN J*. 1996;44:33–39.
39. Rempel D, Evanoff B, Amadio P, et al. Consensus criteria for the classification of carpal tunnel syndrome in epidemiologic studies. *Am J Public Health*. 1998;88:1447–1451.
40. de Krom M, Knipschild P, Kester A, Thijs C, Boekkooi P, Spaans F. Carpal tunnel syndrome: prevalence in the general population. *J Clin Epidemiol*. 1992;45:373–376.
41. Ferry S, Pritchard T, Keenan J, Croft P, Silman AJ. Estimating the prevalence of delayed median nerve conduction in the general population. *Br J Rheumatol*. 1998;37:630–655.
42. Atroshi I, Gummesson C, Ragnar J, Ornstein E, Ranstam J, Rosen I. Prevalence of carpal tunnel syndrome in a general population. *JAMA*. 1999;282:153–158.
43. Papanicolaou GD, McCabe SJ, Firrell J. The prevalence and characteristics of nerve compression symptoms in the general population. *J Hand Surg*. 2001;26A:460–466.
44. Stevens JC, Sun S, Beard CM, O'Fallon WM, Kurland LT. Carpal tunnel syndrome in Rochester, Minnesota. *Neurology*. 1988;38:134–138.
45. Barnhart S, Demers PA, Miller M, Longstreth WT, Rosenstock L. Carpal tunnel syndrome among ski manufacturing workers. *Scand J Work Environ Health*. 1991;17:46–52.
46. Bingham RC, Rosecrance JC, Cook TM. Prevalence of abnormal median nerve conduction in applicants for industrial jobs. *Am J Ind Med*. 1996;30:355–361.
47. 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;18:337–345.
48. Osorio AM, Ames RG, Jones J, Castorina J, Rempel D, Estrin W, Thompson D. Carpal tunnel syndrome among grocery store workers. *Am J Ind Med*. 1994;25:229–245.
49. Rosecrance JC, Cook TM, Anton DC, Merline LA. Carpal tunnel syndrome among apprentice construction workers. *Am J Ind Med*. 2002;42:107–116.
50. Cail F, Aptel M. Biomechanical stresses in computer-aided design and in data entry. *Int J Occup Saf Ergon*. 2003;9:235–255.
51. Werner RA, Albers JW, Franzblau A, Armstrong TJ. The relationship between body mass index and the diagnosis of carpal tunnel syndrome. *Muscle Nerve*. 1994;17:1491–1493.
52. Anand KS, Mittal S, Singh NP. Carpal tunnel syndrome with propranolol. *J Assoc Physicians India*. 1993;41:313.
53. Emara MK, Saadah AM. The carpal tunnel syndrome in hypertensive patients treated with beta-blockers. *Postgrad Med J*. 1988;64:191–192.
54. Lipponi G, Lucantoni C, Antonicelli R, Gaetti R. Clinical and electromyographic evidence of carpal tunnel syndrome in a hypertensive patient with chronic beta-blocker treatment. *Ital J Neurol Sci*. 1992;13:157–159.
55. Rempel D, Dahlin L, Lundberg G. Pathophysiology of nerve compression syndromes: response of peripheral nerves to loading. *J Bone Joint Surg [Am]*. 1999;81:1600–1610.
56. Gerritsen AA, de Krom MC, Struijs MA, Scholten RJ, de Vet HC, Bouter LM. Conservative treatment options for carpal tunnel syndrome: a systematic review of randomized controlled trials. *J Neurol*. 2002;249:272–280.
57. Galinsky TL, Swanson NG, Sauter SL, Hurrell JJ, Schleifer LM. A field study of supplementary rest breaks for data-entry operators. *Ergonomics*. 2000;43:622–638.
58. Katz JN, Larson MG, Sabra A, et al. The carpal tunnel syndrome: diagnostic utility of the history and physical examination findings. *Ann Intern Med*. 1990;112:321–327.
59. Jablecki CK, Andary MT, So YT, Wilkins DE, Williams FH. Literature review of the usefulness of nerve conduction studies and the electromyography for the evaluation of patients with carpal tunnel syndrome. *Muscle Nerve*. 1993;16:1392–1414.

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