

Association of Occupational and Non-Occupational Risk Factors With the Prevalence of Self-Reported Carpal Tunnel Syndrome in a National Survey of the Working Population

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To compare the association of occupational versus personal, nonoccupational risk factors with the prevalence of carpal tunnel syndrome (CTS), data from the 1988 National Health Interview Survey, Occupational Health Supplement, were analyzed. When both occupational factors (bending/twisting of the hands/wrists [B/T] and use of hand-held vibrating tools) and personal nonoccupational factors (gender, race, age, body mass index [BMI], smoking, education, and family income) were included in a multivariate logistic regression model, adjusted odds ratios (AORs) of these factors for reporting medically called CTS (MC-CTS) were: exposure to B/T, 5.5; exposure to vibration, 1.9; white race, 16.7; female gender, 2.3; BMI ≥ 25 , 2.0; history of cigarette smoking, 1.6; age ≥ 40 , 1.2; education >12 years, 1.2; and annual family income $\geq \$20,000$, 1.5. Although both occupational and nonoccupational factors are associated with reporting of CTS, repetitive bending/twisting of the hands/wrists and use of vibrating tools remain important risk factors for work-related carpal tunnel syndrome. Am. J. Ind. Med. 32:550-556, 1997. © 1997 Wiley-Liss, Inc.

KEY WORDS: *carpal tunnel syndrome; repetitive manual work; body mass index; health interview survey*

INTRODUCTION

Carpal tunnel syndrome (CTS) is a manifestation of median nerve compression within the carpal tunnel of the wrist due to increased intra-tunnel pressure from a variety of reasons [Gelberman et al., 1981; Spinner et al., 1989]. It has

been reported that CTS is associated with certain personal diseases and conditions such as diabetes, hypothyroidism, pregnancy, and rheumatoid arthritis [Spinner et al., 1989] or work-related factors such as repetitive manual work [Silverstein et al., 1987; Chiang et al., 1990] or exposure to hand-arm vibration [Bovenzi and Zadini, 1991]. In some cases, two or more of these risk factors may coexist, placing the individual at a higher risk of developing CTS. Previously, we reported that repetitive bending/twisting of the hand/wrist on the job was by far the most important risk factor for self-reporting CTS compared to other factors such as gender and age, based on the analysis of the 1988 National Health Interview Survey (NHIS), Occupational Health Supplement (OHS) data [Tanaka et al., 1995]. However, in view of recent reports indicating other personal risk factors such as obesity or increased body mass index [de Krom et al., 1990; Nathan et al., 1992; Letz and Gerr, 1994; Werner et al., 1994a], smoking habit [Vessey et al., 1990;

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Letz and Gerr, 1994; Nathan et al., 1996a], and income [Letz and Gerr, 1994], we conducted analyses on additional personal factors that were available in the 1988 NHIS/OHS.

MATERIALS AND METHODS

National Health Interview Survey (NHIS) is the annual health interview survey conducted by the National Center for Health Statistics (NCHS) on a multistage probability sample of noninstitutionalized civilian population residing in households in the United States [Massey et al., 1989]. In 1988 an occupational health supplement (OHS) sponsored by both the National Institute for Occupational Safety and Health (NIOSH) and the Bureau of Labor Statistics (BLS) was added to the core questions. It was designed to provide U.S. national prevalence estimates for selected occupational conditions and their risk factors. Detailed description of the data sets and the methods of statistical analyses were previously published [Massey et al., 1989; Park et al., 1993; Tanaka et al., 1995].

Briefly, out of the 50,061 initially sampled households, the 1988 NHIS/OHS was completed by 44,233 adults (response rate: 88%). Of these 44,233 individuals, there were 30,074 "recent workers." A "recent worker" was defined as an adult (age 18 or older) who worked at any time at a job or business, not counting work around the house, during the 12-month period prior to the interview. However, 389 "recent workers" with missing values for weight or height were excluded from the calculation of body mass index (BMI), which resulted in a reduction of 1.3% in the number of respondents. (In our previous report [Tanaka et al., 1995], we used 30,090 "recent workers" which inadvertently included 16 noncivilians. However, our recalculation showed that none of these 16 reported CTS, and this reduction of 0.05% in the denominator had no material effects on our previous results or conclusions.)

One-year period prevalence of carpal tunnel syndrome (CTS) was elicited in two ways. First, self-reported carpal tunnel syndrome (SR-CTS) was positive, if the interviewee responded "yes" to the question, "During the past 12 months, have you had a condition affecting the wrist and hand called carpal tunnel syndrome?" No additional probing inquiry or validation was conducted on the positive response. Second, recent workers who saw a medical person (medical doctor, chiropractor, physical therapist, or other medical person) for "prolonged hand discomfort" were asked, "What did the medical person call your hand discomfort?" (Prolonged hand discomfort was defined as "pain, burning, stiffness, numbness, or tingling in the hand, wrist, or fingers, that was felt 20 or more total days, or 7 or more consecutive days, in the past 12 months.) If the response was "carpal tunnel syndrome," it was counted as medically called carpal tunnel syndrome (MC-CTS). Although no medical records were reviewed for validation, this

response was elicited without a leading question. However, we avoided using the term "medically diagnosed," since the term "diagnosis" was not used in the questionnaire and no diagnostic criteria were specified. Neither did the questionnaire collect information on the practice specialties of "the medical person."

Two questions were included that elicited information on the occupational exposure factors that have been found in other studies to be related to the occurrence of carpal tunnel syndrome: "Did the (most recent) job require you to bend or twist your hands and wrists many times an hour?" (bend/twist or B/T) and "Did you work with hand-held or hand-operated vibrating tools or machinery?" (vibration). The effects of occupational exposures to bend/twist of the hands/wrists and to vibration, as well as personal factors such as age, gender, and race, on the prevalence of SR-CTS and MC-CTS were previously reported [Tanaka et al., 1995]. In this paper, the following additional personal factors available from the NHIS/OHS data were included in the analysis: BMI (derived by dividing the weight in kilograms by the height in meters squared), history of cigarette smoking, years of education, and annual household income. However, the data set did not include information on pregnancy or comorbidities such as diabetes, rheumatoid arthritis, and hypothyroidism.

Statistical analyses were performed on the weighted data using the Survey Data Analysis (sudaan) software [RTI, 1990]. For calculation of prevalence and 95% confidence interval (95%CI) for SR-CTS and MC-CTS, all "recent" workers were included. Multiple logistic regression analyses were performed to examine the contributions of the following independent variables: age, gender, race, BMI, smoking, education, and annual family income (as non work-related variables); and bend/twist and vibration (as work-related variables). In this analysis, age was dichotomized arbitrarily as 40 and older versus below 40. BMI was also divided into two categories as 25 and above versus below 25, since a BMI above this value is considered overweight or obese [Bray, 1985]. The current and past smokers were grouped together as "ever smoked" for comparison to the "never smoked" (a past smoker is defined as a person who is not a current smoker but had smoked at least 100 cigarettes in the past). Years of education were categorized as more than 12 years versus 12 years and less, and annual family income was categorized as \$20,000 and up versus less than \$20,000. Finally, we also conducted another series of multiple logistic regression analyses, in which the age and BMI factors were treated as continuous variables.

RESULTS

Among the 30,074 recent workers, 441 met the definition of SR-CTS to yield a prevalence of 1.5%. There were

TABLE I. Frequency of “Self-Reported” Carpal Tunnel Syndrome (SR-CTS) and “Medically Called” Carpal Tunnel Syndrome (MC-CTS) by Various Risk Factors Among “Recent Workers”

Variable	SR-CTS frequency (%)	MC-CTS frequency (%)	Recent workers frequency (%)
Bend/twist			
Yes	327 (74.1)	121 (83.4)	14,616 (48.6)
No	114 (25.9)	24 (16.6)	15,458 (51.4)
Vibration			
Yes	105 (23.8)	40 (27.6)	5,072 (16.9)
No	336 (76.2)	105 (72.4)	25,002 (83.1)
Gender			
Female	280 (63.5)	96 (66.2)	15,427 (51.3)
Male	161 (36.5)	49 (33.8)	14,647 (48.7)
Race			
White	404 (91.6)	140 (96.6)	25,262 (84.0)
Nonwhite	37 (8.4)	5 (3.4)	4,812 (16.0)
Age			
18–24 yr	30 (6.8)	8 (5.5)	4,598 (15.3)
25–34 yr	112 (25.4)	36 (24.8)	8,997 (29.9)
35–44 yr	149 (33.8)	50 (34.5)	7,545 (25.1)
45–54 yr	85 (19.3)	29 (20.0)	4,434 (14.7)
55–64 yr	47 (10.7)	16 (11.0)	3,195 (10.6)
≥65 yr	18 (4.1)	6 (4.1)	1,305 (4.3)
BMI			
≥25	231 (52.4)	81 (55.9)	12,537 (41.7)
<25	201 (45.6)	59 (40.7)	17,148 (57.0)
Unknown	9 (2.0)	5 (3.4)	389 (1.3)
Smoking			
Past	109 (24.7)	43 (29.7)	6,505 (21.6)
Current	151 (34.2)	50 (34.5)	9,109 (30.3)
Never	181 (41.0)	52 (35.9)	14,395 (47.9)
Unknown	0 (0.0)	0 (0.0)	65 (0.2)
Education			
<12 yr	51 (11.6)	17 (11.7)	4,362 (14.5)
12 yr	181 (41.0)	70 (48.3)	11,580 (38.5)
>12 yr	209 (47.4)	58 (40.0)	14,059 (46.8)
Unknown	0 (0.0)	0 (0.0)	73 (0.2)
Income			
<\$20,000	112 (25.4)	33 (22.8)	9,024 (30.0)
\$20,000–\$39,999	168 (38.1)	56 (38.6)	10,240 (34.1)
≥\$40,000	117 (26.5)	44 (30.3)	7,470 (24.8)
Unknown	44 (10.0)	12 (8.3)	3,340 (11.1)
Total:	441	145	30,074

145 (0.5%) who met the definitions of both SR-CTS and MC-CTS. Table I presents the frequency counts and percentages of the two categories of CTS by various occupational and nonoccupational risk factors that were examined in this analysis. Likewise, Table II lists their prevalence (in percent) and 95% confidence intervals.

TABLE II. Prevalence (%) and 95% Confidence Intervals of “Self-Reported” Carpal Tunnel Syndrome (SR-CTS) and “Medically Called” Carpal Tunnel Syndrome (MC-CTS) by Various Risk Factors Among “Recent Workers”

Variable	SR-CTS prevalence (95% CI)	MC-CTS prevalence (95% CI)
Bend/twist		
Yes	2.23 (1.94; 2.52)	0.92 (0.70; 1.14)
No	0.73 (0.57; 0.89)	0.15 (0.09; 0.21)
Vibration		
Yes	2.28 (1.73; 2.83)	0.94 (0.59; 1.29)
No	1.30 (1.12; 1.48)	0.44 (0.32; 0.56)
Gender		
Female	1.83 (1.59; 2.07)	0.67 (0.51; 0.83)
Male	1.17 (0.95; 1.39)	0.42 (0.26; 0.58)
Race		
White	1.60 (1.40; 1.80)	0.60 (0.46; 0.74)
Nonwhite	0.69 (0.44; 0.94)	0.10 (0.00; 0.20)
Age		
18–24 yr	0.52 (0.28; 0.76)	0.16 (0.00; 0.32)
25–34 yr	1.22 (0.98; 1.46)	0.44 (0.28; 0.60)
35–44 yr	2.10 (1.71; 2.49)	0.79 (0.50; 1.08)
45–54 yr	2.01 (1.56; 2.46)	0.73 (0.44; 1.02)
55–64 yr	1.54 (1.07; 2.01)	0.55 (0.28; 0.82)
≥65 yr	1.51 (0.73; 2.29)	0.46 (0.05; 0.87)
BMI		
≥25	1.90 (1.63; 2.17)	0.72 (0.54; 0.90)
<25	1.14 (0.94; 1.34)	0.37 (0.23; 0.51)
Smoking		
Past	1.82 (1.41; 2.23)	0.80 (0.51; 1.09)
Current	1.61 (1.30; 1.92)	0.60 (0.40; 0.80)
Never	1.24 (1.00; 1.48)	0.37 (0.23; 0.51)
Education		
<12 yr	1.24 (0.91; 1.57)	0.37 (0.19; 0.55)
12 yr	1.54 (1.27; 1.81)	0.69 (0.47; 0.91)
>12 yr	1.51 (1.26; 1.76)	0.45 (0.31; 0.59)
Income		
<\$20,000	1.28 (0.99; 1.57)	0.42 (0.24; 0.60)
\$20,000–\$39,999	1.62 (1.35; 1.89)	0.56 (0.40; 0.72)
≥\$40,000	1.55 (1.24; 1.86)	0.65 (0.41; 0.89)
Overall	1.47	0.53

As reported previously, those exposed to bending/twisting of the hands/wrists or use of vibrating hand tools had significantly higher prevalence of both SR-CTS and MC-CTS than those who were not exposed. Likewise, being female was a risk factor compared to being male, and being of white race was a risk factor compared to being of nonwhite race. By age category, those in the age brackets of 35–44 years and 45–54 years had the highest prevalence, as

TABLE III. Adjusted Odds Ratios (AORs) Based on the Multiple Logistic Regression Analysis of "Self-Reported" Carpal Tunnel Syndrome (SR-CTS) and "Medically Called" Carpal Tunnel Syndrome (MC-CTS) Among "Recent Workers"

Variable	SR-CTS adjusted odds ratio (95%CI)	MC-CTS adjusted odds ratio (95%CI)
Bend/twist (yes vs no)	3.18 (2.44; 4.14)	5.50 (3.21; 9.42)
Vibration (yes vs no)	1.68 (1.26; 2.24)	1.86 (1.23; 2.80)
Race (white vs nonwhite)	2.24 (1.44; 3.50)	16.69 (5.22; 53.32) ^a
Gender (female vs male)	2.09 (1.64; 2.68)	2.31 (1.48; 3.60)
BMI (≥ 25 vs < 25)	1.76 (1.37; 2.27)	2.00 (1.33; 3.02)
Smoking (ever vs never)	1.28 (0.97; 1.69)	1.64 (1.03; 2.62)
Age (≥ 40 vs < 40 yr)	1.35 (1.06; 1.72)	1.20 (0.81; 1.77)
Education (> 12 vs ≤ 12 yr)	1.43 (1.11; 1.83)	1.17 (0.77; 1.78)
Annual family/income ($\geq \$20,000$ vs $< \$20,000$)	1.26 (0.95; 1.67)	1.51 (0.95; 2.41)

^aThe markedly elevated odds ratio and large CI are likely due to a very small number of nonwhites with MC-CTS.

compared to the other age groups. These findings were common to both SR- and MC-CTS.

Prevalence of both SR-CTS and MC-CTS was significantly higher for people with BMI greater than or equal to 25 than for people with BMI less than 25. With regard to the effects of smoking, whether for SR-CTS or MC-CTS, the past smokers showed the highest prevalence, followed by the current smokers, and those who never smoked had the lowest prevalence. The difference between the prevalences of past smokers and never-smoked was of borderline significance. People with less than 12 years of education had a lower prevalence of both SR-CTS and MC-CTS than people with higher levels of education. However, differences among these three groups were not significant. Also, among the three family income levels used in this analysis, the lowest income group had a lower prevalence of SR-CTS and MC-CTS than the two higher income groups, although there were no significant differences in the prevalence among the three income groups.

Table III presents adjusted odds ratios (AORs) and their 95% confidence intervals (95%CI) of both the occupational and nonoccupational factors that were included in the two multiple logistic regression models. The bend/twist variable had the highest AOR in the SR-CTS model, followed by white race; in the MC-CTS model, however, this order was reversed. For both models, these two variables were followed by the other significant variables in descending order of AOR: gender (being female), BMI (≥ 25), and exposure to vibration. Smoking (present or past), age (above 40 years old), and education (more than 12 years) variables were all slightly elevated. However, the 95% confidence intervals of their AORs included unity in either the SR- or MC-CTS

model. No significant interactions were detected among any of the independent variables.

We also conducted additional logistic regression analyses by treating the age and BMI factors as continuous variables (not shown in Table III). In this case, the AOR for each year of age increase was 1.02 (95%CI: 1.01, 1.03) for either SR-CTS or MC-CTS, while the AOR for each unit increment of BMI was 1.02 (1.01, 1.03) for SR-CTS and 1.03 (1.02, 1.04) for MC-CTS. AORs for all other independent variables remained unchanged from the dichotomized model.

DISCUSSION

The incidence of "disorders associated with repetitive trauma" has increased dramatically during the past decade [Bureau of Labor Statistics, 1993]. Since the major portion of these disorders is CTS, there has been much debate as to whether or not repetitive manual work is a risk factor for CTS and, if so, to what extent. Since CTS is the manifestation of entrapment of the median nerve within the carpal tunnel, any processes that lead to sustained elevation of the carpal tunnel pressure could cause this syndrome [Gelberman et al., 1981]. It has been well known that underlying conditions or disorders such as pregnancy, use of oral contraceptives, rheumatoid arthritis, hypothyroidism, and diabetes mellitus are associated with CTS [Spinner et al., 1989]. It has also been reported that occupational factors such as repetitive bending/twisting of the hands during manual labor would lead to CTS [Stock, 1991; Hagberg et al., 1992], presumably through the stage of tenosynovial inflammation leading to local edema and ischemia within the carpal tunnel [Szabo and Chidgey, 1989]. The degree of work-relatedness of CTS reported in the literature ranged from very high [Masear et al., 1986; Silverstein et al., 1987; Chiang et al., 1990] to very low [Nathan et al., 1988].

Our previous analysis of the 1988 NHIS/OHS data [Tanaka et al., 1995] provided additional support to the work-relatedness of this disorder, in that the factor of bending/twisting the hand/wrist showed the highest AOR of 5.2 among the factors examined, while it also confirmed the previously known effects of female gender and aging as risk factors. In our new analysis of the same data including additional personal factors, our results are in agreement with previous reports that individuals with a high BMI were at a greater risk of developing CTS [de Krom et al., 1990] or showed prolongation of median sensory latency [Nathan et al., 1992; Letz and Gerr, 1994; Werner et al., 1994a]. Also, our results do not refute the previous reports that cigarette or tobacco smoking is a risk factor for reporting CTS [Vessey et al., 1990], that smoking decreases median nerve conduction velocity (NCV) [Letz and Gerr, 1994; Nathan et al., 1996a], or that smoking was associated with reporting musculoskeletal pain [Brage and Bjerkedal, 1996]. Our data, however,

indicate that the degree of association is not very strong. Therefore, despite the inclusion of various additional personal factors, some of which turned out to be significant, the new AOR of 5.5 for bending/twisting among those reporting MC-CTS remained virtually unchanged from our previous model. This is still the highest among the examined variables, with the exception of race. Our result that being white is a very high risk for reporting MC-CTS compared to being nonwhite is likely a result of a very small number of cases of nonwhites in this category.

The associations between SR-CTS or MC-CTS with the factors of years of education and annual family income were of marginal significance. Letz and Gerr [1994] reported that individuals in the lower income bracket tended to have slower median sensory latency. Our results (which were based on the entirely different methodology) went to the opposite direction in that the people with higher education or higher family income tended to report CTS more. We consider that this was possibly due to the increased awareness of CTS and to easier access to health care and/or health insurance among those with higher level of education or family income.

A major strength of analyzing the 1988 NHIS/OHS data is that they are based on a large multistage national sample of working population with a high participation rate and a minimum of selection bias [Massey et al., 1989]. A limitation of the NHIS data which are based on a household interview survey is that CTS cases were not medically validated, particularly for SR-CTS. However, compared to SR-CTS, which may result in an overestimation, the data on MC-CTS are considered more reliable and, by definition, are very close to "medically diagnosed" CTS, because the MC-CTS response was elicited without any leading questions from individuals who had reported a history of "prolonged hand discomfort," for which the respondent saw a medical person. Another limitation of the 1988 NHIS/OHS data is that not all suspected work-related factors of CTS were asked about, including forceful exertions or cold temperatures.

This study also has a weakness in that we could not control for information bias, which could result from reporting (recall) bias on the part of participants and from observer bias on the part of the health care provider who made the "call" of CTS. Since the study was conducted during the time when the awareness of CTS was increasing in the society in general, these biases could inflate the odds ratio of association between CTS and bending/twisting of the hands/wrists in employment. While it is extremely difficult to assess the magnitude of these biases, we believe that such inflation of the AOR is probably small for the following reasons. First, the size of the AORs in this study is comparable to those reported in other localized studies [Silverstein et al., 1987; Chiang et al., 1990]. Second,

although higher education and annual income were associated with increased CTS prevalence possibly reflecting information bias, these variables had little contribution toward reporting of CTS in the multivariate model. Third and most important, the 1988 NHIS/OHS survey questions were designed to minimize the extent of information bias in several ways, including (1) the respondents were not asked to attribute the CTS to any causal exposure; and (2) the questions about exposure to bend/twist and vibration were asked (along with other questions such as chemicals exposures) in the work history section administered early in the interview, and placed far apart from the questions pertaining to CTS which were asked towards the end.

When the BMI is treated as a continuous variable (not shown in Table III), our analysis indicates that for each unit increment of BMI, the AOR of reporting MC-CTS is 1.03. For example, the BMI of an individual with the height of 1.8 m and the weight of 70 kg (154 lb) is 21.6. If his weight doubled to 140 kg with no change in the height (a very obese person), his new BMI would be 43.2, and his new AOR of reporting MC-CTS will therefore be $(1.03)^{21.6} = 1.89$. This is still about one-third of the AOR of 5.5 for the bending/twisting factor. Increase in age has a similar but weaker effect in that the AOR of reporting MC-CTS is 1.02 for each year of increase. Therefore, with the BMI or age factor alone, even an extremely obese or old person would hardly reach the level of AOR for bending/twisting. In the reports by Vessey et al. [1990] or Werner et al. [1994a], no aspects of occupational exposure to repetitive manual work were examined. Werner et al. further stated that only 8% of CTS risk was accounted for by BMI, age and sex factors combined. Nathan et al. [1994] also estimated that only 8.6% of the total risk could be explained by BMI alone. Such findings are not incompatible with ours in that the biomechanical stress of repetitive manual work is still a very significant risk factor for work-related CTS, the strongest among the factors examined in our analysis. Had Vessey et al. and Werner et al. included the exposure factor in their studies, they would have likely found it to be significantly associated with CTS, as it was so reported by de Krom et al. [1990].

Some investigators have been arguing that the slowing of median NCV was overwhelmingly associated with personal factors but only weakly with occupational factors [Nathan et al., 1988, 1992]. However, serious flaws or limitations in their methodology have been identified [Gerr and Letz, 1992; Werner et al., 1994b], and reanalyses of the same data actually showed significant associations of the occupational factors with slowing of median NCV [Hales, 1991; Stock, 1991]. By looking at both work and non-work factors with similar amount of detail, the current study has determined that, compared to the occupational factor of bending/twisting the hands and wrists, the personal factors do not seem to play as big a role as claimed by Nathan et al.

[1994, 1996a, 1996b] toward contribution to work-related CTS.

Based on the currently available knowledge, it would be a mistake to attribute all CTS cases among employed individuals to their occupations. At the same time, it would also be inappropriate to attribute CTS of a worker simply to his/her excess weight, smoking, or some other personal factors without examining whether the person was actually performing repetitive and/or strenuous manual work. Further studies of the working populations performing repetitive manual tasks, including medical evaluations with electrodiagnostic testing and ergonomic risk assessment, will shed more light on this question.

Among significant chemical and physical occupational hazards potentially involving millions of workers today, repetitive manual work remains the one for which there is no quantitative standard or guideline for protection of workers. For prevention of low back pain, a quantitative guideline has been proposed for "safe" lifting in the form of an equation which incorporates various key ergonomic factors [Waters et al., 1993]. Therefore, there is a need to establish a population-based quantitative guideline for a "safe" limit of repetitive manual work, below which work-related CTS would not likely to occur. To be considered in such an equation for prevention of hand/wrist disorders are ergonomic factors of force, repetition, wrist angle, and time [Tanaka and McGlothlin, 1993]. It is encouraging to note that an increasing number of publications have been appearing recently, in which various physical factors of manual work were quantitatively studied [Moore et al., 1991; Moore and Garg, 1995; Malchaire et al., 1996].

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