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Prevalence and Work-Relatedness of Self-Reported Carpal Tunnel Syndrome Among U.S. Workers: Analysis of the Occupational Health Supplement Data of 1988 National Health Interview Survey

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To estimate the prevalence and work-relatedness of self-reported carpal tunnel syndrome (CTS) among U.S. workers, data from the Occupational Health Supplement of 1988 National Health Interview Survey (NHIS) were analyzed. Among 127 million "recent workers" who worked during the 12 months prior to the survey, 1.47% (95% CI: 1.30; 1.65), or 1.87 million self-reported CTS, and 0.53% (95% CI: 0.42; 0.65), or 675,000, stated that their prolonged hand discomfort was called CTS by a medical person. Occupations with the highest prevalence of self-reported CTS were mail service, health care, construction, and assembly and fabrication. Industries with the highest prevalence were food products, repair services, transportation, and construction. The risk factor most strongly associated with medically called CTS was exposure to repetitive bending/twisting of the hands/wrists at work (OR = 5.2), followed by race (OR = 4.2; whites higher than nonwhites), gender (OR = 2.2; females higher than males), use of vibrating hand tools (OR = 1.8), and age (OR = 1.03; risk increasing per year). This result is consistent with previous reports in that repeated bending/twisting of the hands and wrists during manual work is etiologically related to occupational carpal tunnel syndrome.

Key words: carpal tunnel syndrome, cumulative trauma disorders, ergonomics, repetitive manual work

INTRODUCTION

The number of cumulative trauma disorders (CTDs) or disorders associated with repeated trauma (DART) reported to the Bureau of Labor Statistics increased dramatically during the 1980s, and this trend appears to continue well into the 1990s

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[BLS, 1992]. Carpal tunnel syndrome (CTS), one of various CTDs, is caused by entrapment of the median nerve within the carpal tunnel of the wrist [Phalen et al., 1950; Gelberman et al., 1981; Eversmann, 1988; Pfeffer et al., 1988; Spinner et al., 1989]. CTS has received much attention by the news media due to its disabling effects as well as clusters of cases in certain industries such as meat packing [Applebome, 1989; Stix, 1991; Gorner, 1992]. However, no national data on the prevalence and work-relatedness of this condition have been available.

A questionnaire pertaining to hand discomfort and CTS was administered as part of the Occupational Health Supplement (OHS) in the 1988 National Health Interview Survey (NHIS) [Adams and Hardy, 1988; Massey et al., 1989; Park et al., 1993] for the purpose of estimating the number of CTS cases among U.S. workers, identifying industries and occupations with high prevalence of CTS, and examining the effects of exposure to repetitive manual work on the prevalence of CTS. Initial analyses of the NHIS data estimated that the overall prevalence of self-reported CTS among the U.S. adult population (both working and not working) was 1.55% (~ 2.6 million) [Tanaka et al., 1994].

MATERIALS AND METHODS

Sample and Survey

The National Health Interview Survey (NHIS), conducted by the National Center for Health Statistics (NCHS), is a continuous survey designed to make national estimates of health characteristics for the civilian, noninstitutionalized population of the United States. Households, which are the sampling unit of the survey design, are selected by a multistage probability sampling strategy [Massey et al., 1989]. Each year supplemental health surveys are added to the core survey. In 1988, the National Institute for Occupational Safety and Health (NIOSH) and Bureau of Labor Statistics (BLS) sponsored a supplement on occupational health. Questions related to hand discomfort and carpal tunnel syndrome were included in this Occupational Health Supplement (OHS) [Park et al., 1993].

At each sampled household, one adult (18 years old or older) was randomly selected for the OHS interview without allowing a proxy. Altogether, 44,233 interviews were completed with an overall response rate of 91.5%. Nonresponses (8.5%), which were due to refusal or failure to obtain an interview within the time allotted, were adjusted for by the statistical weighting [Adams and Hardy, 1988; Massey et al., 1989; Park et al., 1993].

Measures and Definitions

In accordance with the questionnaire design, the U.S. adult population was first categorized by their recent work history, and presence or absence of hand discomfort, self-reported CTS (SR-CTS) and medically called CTS (MC-CTS). Definitions of these terms and the flow of the questions are presented in Table I.

The "ever-worked" individuals were asked: "During the past 12 months, have you had a condition affecting the wrist and hand called carpal tunnel syndrome?" A positive response was counted as an SR-CTS case without further probe or validation. Thus the results are presented as *period* frequency and *period* prevalence for the 12-month period (see definitions in Table I).

Questions related to occupation/industry, hand discomfort, exposure to repetitive manual work, and medical evaluation of CTS were asked only of "recent work-

TABLE I. Terms and Dichotomous Flow of Questionnaire on Work History, Hand Discomfort, and CTS*

<table>
<tr><td colspan="6">U.S. adults (age ≥18) [177,300] [numbers in thousands]</td><td>Level</td></tr>
<tr><td rowspan="2">[7,100]
(4%)
"Never worked" or did only work around the house; no question on CTS[c] asked</td><td colspan="5">[170,200] (96%) "Ever-worked"
Reported "a kind of work he/she has done the longest, including work done in the armed forces, self-employment, or family business/farm without pay"
SR-CTS[a] 1.55% {=2,650/170,200}
"Had condition called carpal tunnel syndrome in past 12 months"</td><td>A</td></tr>
<tr><td rowspan="5">[43,200]
(25%)
"Nonrecent workers" who did not work any time during past 12 months
SR-CTS[a] 1.78% {=771/43,200}</td><td colspan="4">[127,000=[b]] (75%) "Recent workers"
Worked anytime during past 12 months (excluding armed forces)
SR-CTS[a] 1.47% {=1,874/[b]}</td><td>B</td></tr>
<tr><td rowspan="4">[99,560]
(78%)
No hand discomfort in past 12 months
SR-CTS[a] 0.20% {=254/99,560}</td><td colspan="3">[27,440] (22%) Hand discomfort (for 1 or more days): "Pain, burning, stiffness, numbness, or tingling in the hands, wrists, or fingers"
SR-CTS[a] = 5.90% {1,620/27,440}</td><td>C</td></tr>
<tr><td rowspan="3">[6,730]
(25%)
Due entirely to injury
SR-CTS[a] 0.86% {=236/27,440}</td><td colspan="2">[20,710] (75%)
Not due entirely to an injury such as cut, sprain, or broken bone</td><td>D1</td></tr>
<tr><td rowspan="2">[9,070]
(44%)
Fewer days of hand discomfort
SR-CTS[a] 3.02% {=274/9,070}</td><td colspan="2">[11,640] (56%)
Prolonged hand discomfort (20 days or more altogether, or 7 or more consecutive days)
SR-CTS[c] 9.54% {=1,110/11,640}</td><td>D2</td></tr>
<tr><td>[1,110] (10%)
SR-CTS[a] 0.87% {=1,110/*}
[675] (6%)
SR-CTS[a] and MC-CTS[c] 0.53% {=675/[b]}</td><td>[435] (4%)
SR-CTS[a] but not MC-CTS[c]</td><td>[10,530]
(90%)
No CTS*
(but may have other condition)</td><td>E</td></tr>
</table>

*CTS = carpal tunnel syndrome. Questionnaire used in 1988 National Health Interview Survey (NHIS), Occupational Health Supplement (OHS).
Legend: [ ] = population estimates in thousands; ( ) = percentage to the denominator above; { } = explains reason for percentage. Percentages rounded up or down.

[a]Self-reported carpal tunnel syndrome = yes to question: "During the past 12 months, have you had a condition affecting the wrist and hand called carpal tunnel syndrome?"

[b]Number of "recent workers" (127 million).

[c]Medically called carpal tunnel syndrome = a response of "carpal tunnel syndrome" to question: "What did the medical person call your hand discomfort?"

ers'' who worked anytime during the 12 months prior to the survey. ''Nonrecent workers''—those who did not work in that time period—were not asked any of these questions, except for the experience of SR-CTS.

The ''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 hand discomfort that was felt 20 total days or more, or 7 or more consecutive days during the past 12 months.) If the response was ''carpal tunnel syndrome,'' it was counted as an MC-CTS case without validation of the medical record. SR-CTS among people who had a hand injury was not included in this analysis, because CTS caused by an injury did not meet the definition of cumulative trauma disorder, and there was no assurance that the CTS actually resulted from the injury.

Exposure to manual work was assessed by asking questions: Did the (most recent) job require you to bend or twist your hands or wrists many times an hour? Did you work with hand-held or hand-operated vibrating tools or machinery? For classifying the occupations and industries of respondents, their current or most recent job in the past 12 months prior to the interview was used. Categories of occupations and industries similar to those used in the 1980 Census were adopted [BC, 1981], but related categories were regrouped into 42 occupational and 42 industrial subgroups [Collins, 1989].

Analysis

The data tape provided by NCHS contained both the raw (unweighted) counts and the weights necessary to convert the raw counts to populationwide estimates. Each respondent was given a weight of anywhere from 3,000 to 10,000 people in his/her demographic category, depending on such factors as the inverse of the probability of selection and household nonresponse adjustment [Massey et al., 1989]. Following the practice of the NCHS, this report presents only the weighted data. The prevalences of SR-CTS and MC-CTS were calculated with their 95% confidence intervals (95% CIs) using Survey Data Analysis (SUDAAN) software [RTI, 1990]. When two prevalences derived from the same single sample were being compared, we first used SUDAAN to calculate the standard error (SE) of the difference of the two estimates: $SE(P_1 - P_2) = [SE(P_1)^2 + SE(P_2)^2 - 2rSE(P_1)SE(P_2)]^{1/2}$, where $SE(P_1)$ and $SE(P_2)$ are the standard errors of the two prevalence estimates and r is the correlation coefficient between P_1 and P_2 [Schoenborn, 1988]. Then we computed $(P_1 - P_2) \pm 1.96SE(P_1 - P_2)$. If this resulting 95% CI included zero, we concluded that there was no significant difference between the two prevalences. Multiple logistic regression analyses, also using SUDAAN, were performed to examine the contributions of five independent variables (age, gender, race, and exposures to vibration, and to bending/twisting of the hands/wrists) to the odds of reporting CTS.

RESULTS

Self-Reported Carpal Tunnel Syndrome (SR-CTS)

As shown in Table I (levels A and B), 170.2 million U.S. adults who ''ever worked'' were subdivided into 127 million ''recent workers'' and 43.2 million ''nonrecent workers.'' The prevalence of SR-CTS was 1.47% (95% CI: 1.30; 1.65) among

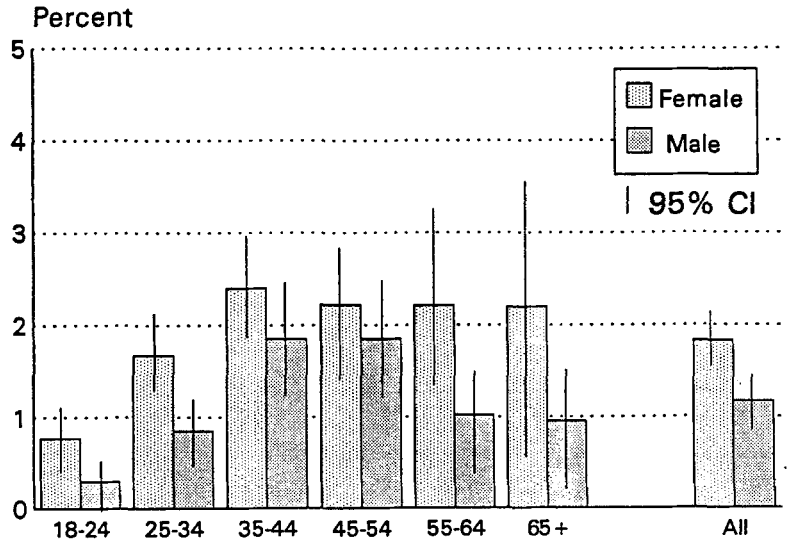

Fig. 1. Age-gender specific prevalence of self-reported carpal tunnel syndrome (SR-CTS) among "recent workers."

"recent workers" (CTS frequency = 1.87 million), whereas the prevalence among "nonrecent workers" was 1.78% (95% CI: 1.48; 2.07; frequency = 0.77 million). The difference between these prevalences was not statistically significant. The age-gender specific prevalences of SR-CTS for these populations are shown in Figure 1 ("recent" workers) and Figure 2 ("nonrecent" workers).

Among "recent workers," the overall prevalence for females (1.83%; 95% CI: 1.59; 2.08) was significantly higher than that for males (1.17%; 95% CI: 0.95; 1.40) as shown by the nonoverlapping 95% CIs (Fig. 1; Table II). For each age group, the female prevalence was higher than the male prevalence, but the difference was significant only for age groups 18–24, 25–34, and 55–64, although some of these prevalences had slightly overlapping 95% CIs between females and males. Among females, the highest prevalence was observed in the 35–44 age group, but the prevalence remained almost constant from the 35–44 age group through the 65+ age group. In contrast, the prevalence for males peaked in the 35–44 and 45–54 age groups, but declined in both the younger and older age groups.

Prevalence of SR-CTS among "nonrecent workers" showed a different pattern from that of "recent workers" (Fig. 2). Overall, females (1.97%; 95% CI = 1.62; 2.32) had a significantly higher prevalence than males (1.39%; 95% CI = 0.99; 1.79), although the 95% CIs overlapped slightly. However, for age-specific prevalence, the higher point estimate for females than for males, which was observed in all age groups of "recent workers," was not the rule for "nonrecent workers," with the exception of the 35–44, and 65+ age groups. For other age groups, the gender-specific prevalence estimates were close to each other between females and males.

Gender-race specific prevalences of SR-CTS are presented in Table II. Among "recent workers," whites reported significantly higher prevalence of SR-CTS than

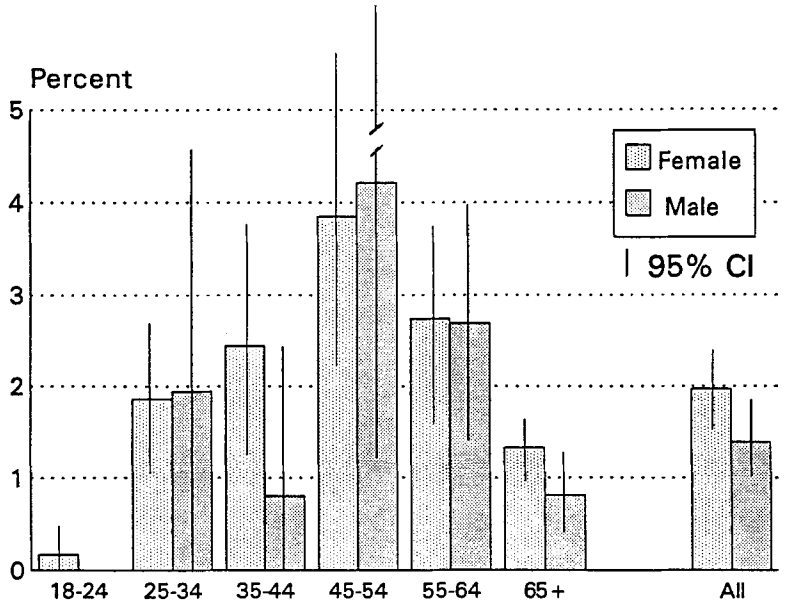

Fig. 2. Age-gender specific prevalence of self-reported carpal tunnel syndrome (SR-CTS) among "non-recent workers."

TABLE II. Gender- and Race-Specific Frequency (in thousands), Prevalences (and 95% CI) of Self-Reported Carpal Tunnel Syndrome (SR-CTS) Among "Recent Workers" and "Nonrecent Workers"

	Females		Males		All	
	Number ($\times 10^3$)	Prevalence and (95% CI)	Number ($\times 10^3$)	Prevalence and (95% CI)	Number ($\times 10^3$)	Prevalence and (95% CI)
Recent workers						
White	1,003	2.02% (1.75; 2.29)	747	1.25% (1.00; 1.51)	1,750	1.60% (1.41; 1.80)
Nonwhite	69	0.77% (0.41; 1.13)	55	0.61% (0.23; 0.99)	124	0.69% (0.43; 0.96)
All	1,072	1.83% (1.59; 2.08)	802	1.17% (0.95; 1.40)	1,874	1.47% (1.30; 1.65)
Nonrecent workers						
White	509	2.02% (1.67; 2.36)	171	1.37% (0.92; 1.81)	680	1.80% (1.51; 2.09)
Nonwhite	59	1.65% (0.46; 2.83)	32	1.53% (0.33; 2.74)	91	1.61% (0.52; 2.69)
All	568	1.97% (1.62; 2.32)	203	1.39% (0.99; 1.79)	771	1.78% (1.48; 2.07)

nonwhites (Table II). The prevalence for white females was highest, and their 95% CI was clearly separated from those of white males, nonwhite females, and nonwhite males.

Among "nonrecent workers," significant differences of SR-CTS prevalence were not observed between females and males, or between whites and nonwhites, although white females still had the highest prevalence among the four gender-race categories. This narrowing of the difference was due to the higher prevalences among nonwhites in "nonrecent workers," whereas the prevalences among whites remained unchanged between "recent workers" and "nonrecent workers."

TABLE III. Top 15 (of 42) Occupation Categories with High Prevalence Rates of Self-Reported CTS in the Past 12 Months (Among Those Who Worked and Experienced Some Hand Discomfort Anytime in the 12-Month Period)

Rank order[a]	Occupation title	Female		Male		All		
		Freq. $\times 10^3$	Rate %	Freq. $\times 10^3$	Rate %	Freq. $\times 10^4$	Rate %	S.E.* %
1	Mail/message distributing occup.	26.5	6.68	8.0	1.20	34.5	3.24	1.18
2	Health assessment/treating occup.	66.8	3.25	—	—	66.8	2.74	0.65
3	Construction/extractive trades	—	—	135.6	2.30	150.7	2.49	0.54
4	Fabricators/assemblers/inspectors	42.7	3.49	31.0	1.73	73.7	2.44	0.65
5	Precision production occup.	37.6	3.40	55.4	1.79	93.0	2.22	0.54
6	Machine operators excl. precision	63.1	2.56	56.7	1.51	119.8	1.93	0.42
7	Secretaries/stenographers/typists	82.6	1.57	—	—	82.6	1.54	0.35
8	Farm operators/managers	—	—	20.4	1.50	25.9	1.53	0.64
9	Mechanics/repairers	—	—	55.1	1.28	64.2	1.41	0.37
10	Financial records processing occup.	35.9	1.50	—	—	35.9	1.34	0.57
11	Other administrative support occup.	123.7	1.75	8.9	0.31	132.6	1.33	0.24
12	Cleaning/building services	26.3	1.90	16.4	0.89	42.7	1.33	0.44
13	Writers/artists/entertainers, etc.	19.2	1.64	12.4	1.02	31.6	1.33	0.50
14	Food service occup.	46.7	1.38	20.8	1.12	67.5	1.28	0.37
15	Health technologists/technicians	18.4	1.47	—	—	18.4	1.28	0.59
	All[b]	950.8	1.63	668.2	0.97	1,619.0	1.27	0.09

*Standard error.
[a]Rank-ordered by prevalence rate for both sexes.
[b]Numbers in this row are slightly lower than those in Table II, due to inclusion of a condition of reporting "hand discomfort for one or more days."
— Statistically unreliable due to raw counts (unweighted) of 3 or less.

CTS and Occupation/Industry

The top 15 occupation and industry subgroups with the highest prevalences of SR-CTS among "recent workers" are listed in Tables III and IV, respectively. Among the occupation subgroups, those reporting the highest prevalences of SR-CTS were mail and message distributing occupations, health assessment and treating occupations, construction and extractive trades, and fabricators, assemblers, inspectors, and samplers. Among the industry subgroups, food products (including meat), manufacturing, repair services, transportation, construction, and transportation equipment manufacturing industries showed the highest prevalences.

Hand Discomfort and Carpal Tunnel Syndrome

Of 127 million "recent workers," 21.6% (27 million) reported experiencing one or more days of "hand discomfort" during the 12 months prior to the survey (Table I, level C). These 27 million "recent workers" with hand discomfort were classified into three subcategories: 42.4% (11.6 million) experienced the "prolonged hand discomfort," and 1.1 million within this group self-reported CTS (Table I, D2); and 33.1% (9.1 million) had fewer days of hand discomfort, and 0.3 million within this group self-reported CTS (D2, left). The remaining 24.5% (6.7 million) reported that the hand discomfort (of unspecified duration) was due entirely to injury, and 0.2 million within this group self-reported CTS (D1, left). We could not determine from the data how many of these persons with hand discomfort due to injury actually developed acute CTS from that injury, or the work-relatedness of such an injury.

TABLE IV. Top 15 (of 42) Industry Categories with High Prevalence Rates of Self-Reported CTS in the Past 12 Months (Among Those Who Worked and Experienced Some Hand Discomfort Anytime in the 12-Month Period)

		Female		Male		All		
Rank order[a]	Industry title	Freq. $\times 10^3$	Rate %	Freq. $\times 10^3$	Rate %	Freq. $\times 10^3$	Rate %	S.E.* %
1	Food/kindred products	12.7	1.81	35.7	2.82	48.4	2.46	0.88
2	Repair services	—	—	33.2	2.35	40.0	2.40	0.97
3	Transportation, excl. railroad/trucking	32.9	3.10	38.5	1.94	71.4	2.34	0.64
4	Construction	16.2	2.05	159.2	2.12	175.4	2.11	0.47
5	Transportation equipment	26.1	3.51	38.7	1.63	64.8	2.08	0.57
6	Other nondurable goods	11.1	2.11	28.9	2.07	40.1	2.08	0.89
7	Health services excl. hospitals	89.1	2.36	—	—	89.1	1.93	0.47
8	Furniture/lumber/wood	—	—	14.7	1.18	26.2	1.66	0.67
9	Hospitals	74.9	2.07	—	—	77.0	1.63	0.39
10	Personal services, excl. private households	50.9	1.90	12.0	0.93	62.8	1.58	0.50
11	Chemicals/allied products	—	—	13.7	1.42	21.1	1.52	0.68
12	Machinery, excl. electrical	—	—	31.6	1.61	41.0	1.50	0.50
13	Agriculture	16.4	2.01	32.7	1.22	49.1	1.41	0.44
14	Textile mill/finished products	22.6	1.69	—	—	26.6	1.39	0.62
15	Auto dealers/services	—	—	20.6	1.10	32.1	1.38	0.52
	All[b]	950.8	1.63	668.2	0.97	1,619.0	1.27	0.09

*Standard error.
[a]Rank-orderd by prevalence rate for both sexes.
[b]Numbers in this row are slightly lower than those in Table II.
— Statistically unreliable due to raw counts (unweighted) of 3 or less.

"Medically Called" Carpal Tunnel Syndrome (MC-CTS)

As seen in Table I, the analysis of MC-CTS was limited to "recent workers" who had "prolonged" hand discomfort that was not due entirely to an injury. Approximately 5% of "recent workers" with "prolonged hand discomfort" saw a medical person for that condition. Among the 1.1 million people who reported both "prolonged" hand discomfort and SR-CTS, 675,000 (95% CI: 530,000; 830,000) stated that the condition was called carpal tunnel syndrome by a medical person (Table I, level E). This corresponds to a prevalence of 0.53% (95% CI: 0.42; 0.65) among "recent workers." No comparable data were sought for among "nonrecent workers."

Age-gender specific prevalences of MC-CTS are presented in Figure 3. Overall, prevalence of MC-CTS was higher for females (0.67%; 95% CI: 0.51; 0.82) than for males (0.42%; 95% CI: 0.26; 0.57) and the difference was statistically significant. Among age groups, females had significantly higher prevalence than males only in the age groups 25–34 and 55–64. The 95% CIs tended to become larger due to a small number of responses in each cell.

In ~ 52.8% of cases of MC-CTS (95% CI: 43.7; 62.0), the respondents reported that the medical person said the CTS was work-related. However, since it is not known what criteria were used for determination of "work-relatedness" by the health care providers, it is difficult to estimate its reliability. Despite this uncertainty, if this 52.8% figure is applied to 0.53% MC-CTS in the above, the national prevalence of work-related MC-CTS is estimated to be 0.28% among 127 million "recent workers" or 356,000 cases (possible range from a low of 0.184%, or 233,000 cases, to a high of 0.403%, or 512,000 cases).

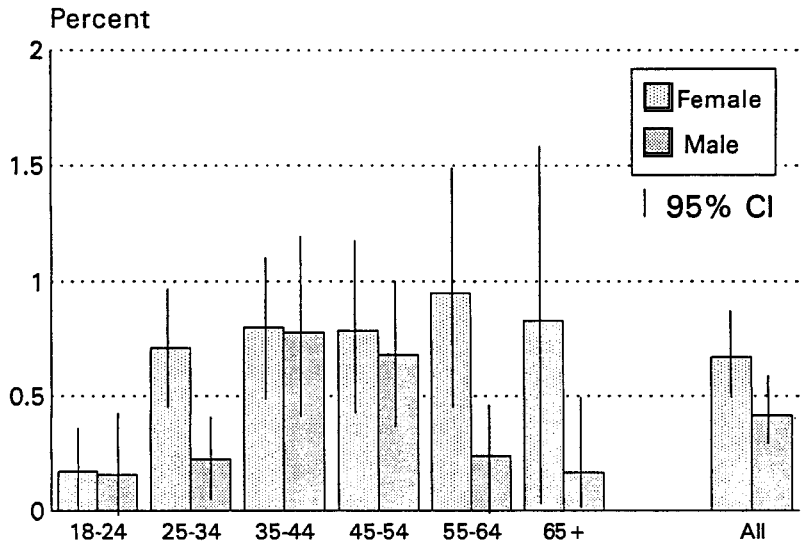

Fig. 3. Age-gender specific prevalence of "medically called" carpal tunnel syndrome (MC-CTS) among "recent workers" with prolonged hand discomfort.

Exposure to Manual Work and Carpal Tunnel Syndrome

The proportion of workers exposed to "bending/twisting of the hands and wrists" and/or "hand vibration" was first calculated among "recent workers," and prevalences of SR-CTS and MC-CTS were examined relative to the exposure. Overall, just one-half of the workers were exposed to "bending/twisting," but only 18% were exposed to hand vibration (Table V). The majority of those reporting SR-CTS were exposed to either bending/twisting or hand vibration, or both, except for the age 65+ group (Fig. 4).

Workers exposed to bending/twisting of the hands/wrists reported significantly higher prevalence of SR-CTS, when compared to those who were not exposed (Table V). The prevalence of SR-CTS was also significantly higher among those exposed to hand vibration but to a lesser degree than with exposure to bending/twisting. When the analysis was limited to MC-CTS (Table V, lower half), the effect of bending/twisting remained statistically significant, but the effect of hand vibration became not significant.

The gender-specific analysis of exposure to bending/twisting of the hands on the prevalence of SR-CTS is shown in Table VI. The percentage of female workers reporting exposure to bend/twist was slightly lower than that of male workers. Regardless of gender, however, the exposed workers reported a significantly higher prevalence of SR-CTS than those not exposed. A similar analysis for exposure to hand vibration showed that the proportion of female workers reporting exposure to vibration was only 8%. Further, the prevalences of SR-CTS for the exposed and the nonexposed women were not significantly different. In contrast, 26% of male workers reported exposure to hand vibration, and the exposed male workers were three times more likely to report SR-CTS than nonexposed male workers.

TABLE V. Proportion of Workers Exposed to "Bending or Twisting of the Hands/Wrists Many Times an Hour" or "Use of Vibrating Hand Tools" and Effect of Such Exposures on Prevalences (and 95% CI) of SR-CTS and MC-CTS*

	Exposed	Not exposed
SR-CTS (among "recent workers")		
Bend/twist		
% workers [row %]	[49.7%]	[50.3%]
SR-CTS yes	1,411,000	463,000
CTS % (95% CI)	2.23% (1.94; 2.52)	0.73% (0.57; 0.89)
Vibration		
% workers [row %]	[18.0%]	[82.0%]
SR-CTS yes	519,000	1,355,000
CTS % (95% CI)	2.28% (1.73; 2.83)	1.30% (1.12; 1.48)
MC-CTS (among "recent workers" who had "prolonged" hand discomfort)		
Bend/twist		
% workers [row %]	[70.0%]	[30.0%]
MC-CTS yes	631,000	117,000
CTS % (95% CI)	7.75% (6.15; 9.36)	3.34% (2.05; 4.63)
Vibration		
% workers [row %]	[25.7%]	[74.3%]
MC-CTS yes	237,000	511,000
CTS % (95% CI)	7.92% (5.23; 10.61)	5.91% (4.66; 7.17)

*SR-CTS = self-reported carpal tunnel syndrome; MC-CTS = medically called carpal tunnel syndrome.

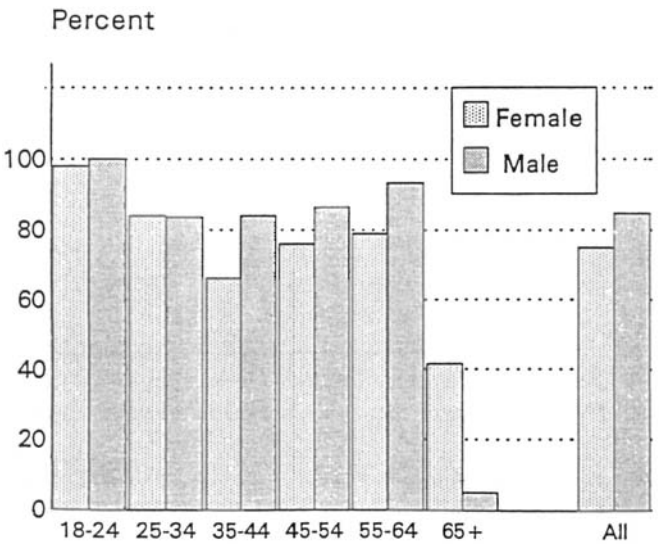

Fig. 4. Age-gender specific proportion of people who were exposed to bending/twisting of the hands/wrists and/or hand vibration among "recent workers" who had self-reported carpal tunnel syndrome (SR-CTS).

Similar comparisons by race are presented in the lower half of Table VI. For bending/twisting, the percentages of workers reporting exposure are about the same for both whites and nonwhites. The prevalence of SR-CTS was significantly higher

TABLE VI. Gender- and Race-Specific Prevalences (and 95% CIs) of SR-CTS* Between Those Exposed to "Bending or Twisting of the Hands/Wrists Many Times an Hour" or "Use of Vibrating Hand Tools" and Those Not Exposed

	Exposed	Not exposed
By gender:		
Bend/twist		
Female		
% workers [row %]	[46.5%]	[53.5%]
CTS yes	2.82% (2.39; 3.25)	0.97% (0.74; 1.21)
Male		
% workers [row %]	[52.4%]	[47.6%]
CTS yes	1.79% (1.38; 2.20)	0.49% (0.31; 0.67)
Vibration		
Female		
% workers [row %]	[8.2%]	[91.8%]
CTS yes	2.48% (1.56; 3.40)	1.77% (1.51; 2.02)
Male		
% workers [row %]	[26.3%]	[73.7%]
CTS yes	2.22% (1.61; 2.83)	0.80% (0.60; 1.00)
By race:		
Bend-twist		
White		
% workers [row %]	[49.9%]	[50.1%]
CTS yes	2.41% (2.06; 2.75)	0.80% (0.63; 0.98)
Non-white		
% workers [row %]	[48.6%]	[51.4%]
CTS yes	1.16% (0.67; 1.65)	0.25% (0.08; 0.42)
Vibration		
White		
% workers [row %]	[17.9%]	[82.1%]
CTS yes	2.46% (1.84; 3.07)	1.42% (1.22; 1.61)
Non-white		
% workers [row %]	[18.4%]	[81.6%]
CTS yes	1.20% (0.23; 2.17)	0.58% (0.34; 0.81)

*Self-reported carpal tunnel syndrome.

for those reporting the exposure to bending/twisting, an observation consistently found for each gender-race category. In contrast, exposure to hand vibration was reported by ~ 18% of workers for either whites or nonwhites. A difference of SR-CTS prevalence by exposure to vibration was observed for both whites and nonwhites but was significant only for whites.

Multiple logistic regression analyses (Table VII) showed that whether for SR-CTS or MC-CTS, exposure to repetitive bending/twisting of the hands/wrists at work had the highest adjusted odds ratio for reporting CTS (compared to those without such exposure), followed in descending order by race (whites higher than nonwhites), gender (females higher than males), use of vibrating hand tools, and age (risk increasing with age).

It was also noted that in case of SR-CTS, the adjusted odds ratio for bend/twist was 3.35 when vibration was not included in the model, whereas it was 3.01 when

TABLE VII. Adjusted Odds Ratios Based on Multiple Logistic Regression Analysis of SR-CTS and MC-CTS Among "Recent Workers"*

	Adjusted			
	SR-CTS		MC-CTS[a]	
Variable	Odds ratio	(95% CI)	Odds ratio	(95% CI)
Bend/twist[b]	3.013	(2.368; 3.835)	5.233	(3.440; 7.960)
Race[c]	2.353	(1.575; 3.518)	4.202	(1.775; 9.919)
Gender[d]	1.919	(1.553; 2.372)	2.228	(1.520; 3.265)
Vibration[e]	1.581	(1.213; 2.060)	1.808	(1.270; 2.572)
Age[f]	1.020	(1.014; 1.026)	1.026	(1.016; 1.036)
Bend/twist[g]	3.35		5.99	
Vibration[h]	2.32		3.00	

*SR-CTS = self-reported carpal tunnel syndrome; MC-CTS = medically called carpal tunnel syndrome.
[a]Comparing MC-CTS to those who reported hand discomfort but no MC-CTS.
[b]1 = exposure yes for bend/twist; 0 = no exposure.
[c]1 = white; 0 = nonwhite.
[d]1 = female; 0 = male.
[e]1 = exposure yes for vibration; 0 = no exposure.
[f]For each year of age increment.
[g]When vibration is not included in the model.
[h]When bend/twist is not included in the model.

vibration was included, a difference of only ~ 10%. In contrast, the adjusted odds ratio for vibration was 2.32 when bend/twist was not included in the model, compared to 1.58 when bend/twist was included, a differene of ~ 32%. A very similar observation was made in case of MC-CTS in that the supplemental effect of vibration to bend/twist was small compared to the supplemental effect of bend/twist to vibration. The combined effect of vibration and bend/twist was not significantly more than we would expect from knowing the individual effects of these two factors, as shown by the insignificant p values for the interaction terms between bending/twisting and vibration ($p = 0.56$ for SR-CTS and $p = 0.60$ for MC-CTS).

We also examined the interaction terms between gender (a major personal factor) and bending/twisting of the hand/wrist (a major exposure factor) and found no significant interactions as shown by the insignificant p values ($p = 0.53$ for SR-CTS and $p = 0.77$ for MC-CTS).

DISCUSSION

This report, based on a supplement to a nationwide household survey, is the first to provide national estimates of prevalence of self-reported carpal tunnel syndrome (SR-CTS) and "medically called" CTS (MC-CTS) by age, gender, race, occupation/industry, and exposure to potential risk factors such as bending/twisting of the hands/wrists and use of vibrating hand tools at work. From this analysis, it is estimated that in 1988, ~675,000, or 0.53% of 127 million "recent workers," were told by a health care provider that they had CTS, and roughly one-half of these cases (356,000 or 0.28%) might be work-related. (Here, we use the term "work-related" rather than "occupational" as defined by the World Health Organization [Armstrong et al., 1993].)

Whereas CTS is a well-defined clinical entity, its surveillance for public health purposes has been limited [Baker and Ehrenberg, 1990]. Reporting of work-related CTS to the public health authority is not required in most jurisdictions, with a few exceptions such as California and Massachusetts. Nationally, employers are required to keep record of "disorders associated with repeated trauma" (DART) by the Occupational Safety and Health Administration (OSHA). Included in this category are CTS, bursitis, tendinitis, tenosynovitis, noise-induced hearing loss, and perhaps some of the back pain cases. Although the OSHA-200 logs have a column to record these disorders, the BLS Annual Survey report does not include body parts or diagnosis. It reported that in 1988 there were 10 cases of DART per 10,000 full-time workers (0.1%) among the private sector industry, and it increased to 0.24% in 1990 [BLS, 1992]. However, the proportion of CTS within the published DART figures is not known. Thus to date, surveillance for work-related CTS has been largely limited to sporadic efforts, such as a review of workers' compensation claims for CTS in a state or a special telephone survey in a county.

Based on the analysis of workers' compensation claims data in Washington State, an incidence rate of occupational CTS was ~ 0.2% of full-time equivalent workers (FTEs) in 1988 [Franklin et al., 1991]. Also, as part of the NIOSH's Sentinel Event Notification System for Occupational Risks (SENSOR) program, California conducted a CTS survey in Santa Clara County in 1987. Health care providers reported 7,214 cases of carpal tunnel syndrome, of which it was estimated that ~ 47% were work-related [Cummings et al., 1989]. Using the adult population of the county as a denominator, the prevalence of work-related CTS was estimated to be 0.29%. Although "nonrecent workers" were not excluded from the denominator of the county in this extrapolation, this estimate is similar in magnitude to our finding that the prevalence of MC-CTS cases "thought to be job-related by a medical person" was 0.28%.

These findings seem to indicate that the overall prevalence of "work-related" CTS in the late 1980s was in the range of 0.2–0.4% among "recent workers," although such an estimate can be readily challenged by the lack of universal definition of work-relatedness and the absence of medical validation in our analysis. Nonetheless, this estimate seems to provide an overall magnitude of the problem in the United States, which has not been available before. Part of the disparity among these estimates may be explained by the difference in study populations and methods, including whether the incidence or the prevalence was measured. The prevalence of MC-CTS in this report was based on unconfirmed reports of evaluations by various health care providers, and the report from the State of Washington was based on the workers' compensation claims data. Surveillance based on the existing records (such as OSHA-200 logs and workers' compensation claims) is apt to detect fewer number of cases compared to surveillance based on collection of new health data by inquiry (such as by administering a symptom questionnaire and conducting physical examinations) [Fine et al., 1986].

Age- and gender-specific prevalences of SR-CTS among "recent workers" in our analysis agree with previous reports in that females are at a higher risk of experiencing CTS than males [Kimura and Ayyar, 1985; Stevens et al., 1988]. The age group with the highest prevalence varies somewhat among different reports. However, there seems to be general agreement that carpal tunnel syndrome is most frequently reported among people in their 40s, 50s, and 60s [Kimura and Ayyar,

1985; Stevens et al., 1988]. Either for SR-CTS or MC-CTS, increasing age is a risk factor as shown by the multiple logistic regression analysis (Table VII). Whether this age effect [Stetson et al., 1992] is solely due to the biological aging effect or related to the length of exposure years is difficult to determine. Health surveys of workers in specific industries or occupations produced varying results, probably due to different types of population, exposure, and a possible "healthy worker effect" [Harber et al., 1992; Osorio et al., 1994]. Based on their review of studies through 1990, Hagberg et al. [1992] argue that age has not been shown to be a risk factor for CTS when the duration of exposure was controlled. In another study, an interaction between age and duration of exposure was reported [Morgenstern, 1991]. One limitation of our study is that in the 1988 survey, duration of exposure to workplace risk factors was not assessed.

Within "nonrecent worker" population, however, the peak prevalences of SR-CTS were observed in the age 45–54 group for both female and male. The significantly higher prevalence of SR-CTS for females was not observed for all age groups, contrary to the expectation that females' higher prevalence would remain among "nonrecent workers" because of the diseases and conditions specific to the female sex [Cannon et al., 1981; Spinner et al., 1989].

Among various exposure factors (such as force, repetition, wrist angle, etc.) of manual work, the 1988 NHIS/OHS examined the effects of occupational exposure to vibration and to repetitive bending/twisting of the hands/wrists. Ergonomically, the repetition and bend/twist are separate factors, but they were combined into one question in the 1988 survey. Such combination would be justified in view of a theory that the product of these factors is probably more critical than each factor being considered separately [Tanaka and McGlothlin, 1993].

Our analysis has shown that between the two exposure factors examined, repeated bending/twisting of the hand/wrist was by far the much more significant risk factor than exposure to vibration. As shown in Table VII, although the effect of bend/twist on CTS prevalence was not much influenced by vibration, the effect of vibration was strongly influenced by bend/twist. This result can be explained by an ergonomic observation that most of the tasks that require use of vibrating hand tools would also involve repetitive bending/twisting of the hand/wrist. Also, to hold a vibrating hand tool steady would require much more force at the hand/wrist (one of the stress factors of manual work) than holding a nonvibrating tool of the same size, shape, and weight. In other word, "pure" exposure of the hand to vibration only is rare in most industrial situations. Also, many cases of CTS are known to occur without any vibratory exposure.

This is in agreement with other reports in that although the exposure to hand vibration is clearly associated with CTS [Cannon et al., 1981], vibration per se is unlikely to cause CTS, even though it is considered to augment the action of other factors that lead to CTS [Chatterjee et al., 1982; Baumgartner and Krueger, 1984; Tanaka and McGlothlin, 1993]. The practical implication of this argument would be that whereas the reduction of vibration of tools and machinery is still important to reduce work-related CTS (as well as noise and other vibration-induced disorders such as vibration white finger), such reduction of vibration alone may not prevent work-related CTS, unless other stress factors such as repetitive bending/twisting of the hand/wrist are addressed.

With regard to the gender effect of bending/twisting (of the hands/wrists) or the use of vibrating tools, the overall proportion of females exposed to bending/twisting was slightly less than that of males, and the proportion of females exposed to vibration was much smaller than that of males. Nonetheless, given the reported population of the exposed, the prevalence of SR-CTS or MC-CTS was significantly higher among females than males. These findings seem to counter the speculation that females have a higher CTS prevalence simply because more women than men tend to work in repetitive manual jobs. Previous on-site studies of CTS have reported varying results on the effect of gender on CTS; in some there was no gender difference in CTS incidence if the exposures were similar [Silverstein et al., 1986], and in others greater CTS risk for females controlling for measures of exposure [Castorina et al., 1990]. Our analysis did not find a significant interaction between gender and exposure to bending/twisting of the hand/wrist.

This study also revealed that among "recent workers," whites had a significantly higher prevalence of SR-CTS than nonwhites. What accounts for this difference is not known and only speculative at this time, including differences in the degree of awareness of CTS, in the tolerance of hand discomfort, in the readiness or hesitancy of reporting CTS, or some other factors. However, among "nonrecent workers" the difference of prevalence by race was insignificant among females and disappeared among males, suggesting that the significant difference of SR-CTS prevalence by race was observed only among "recent workers." Possible explanations for this may include a smaller sample size of "nonrecent workers," particularly for nonwhites, random chance, or reporting bias. Our analysis has also shown that nonwhites had a significantly lower proportion of MC-CTS compared to SR-CTS than whites. Some part of the difference may be explained by differential access to health care.

A major limitation of this study is that it is based on self-reports of CTS without medical validation. The prevalence of SR-CTS in this report may be an overestimate of CTS, since hand discomfort may readily be equated with CTS in a society in which this condition has often been presented in the news media [Payan, 1988]. In contrast, the prevalence of MC-CTS (0.53%) was only about one-third of SR-CTS (1.47%) among "recent workers." Although no validation of medical diagnosis was attempted, the MC-CTS estimate was probably closer to the true CTS prevalence than the SR-CTS estimate, since the question for MC-CTS was limited to people who sought medical care for "prolonged" hand discomfort, and the respondents mentioned CTS diagnosis without a leading question. However, it was also possible that MC-CTS in this report might be an underestimate, if some individuals with CTS did not seek medical attention for their hand discomfort.

Despite these limitations, we analyzed the SR-CTS data for the major portion of this report, since the inclusion of self-reported cases would help us define the possible upper boundary of the magnitude of this problem. Also, restriction of the analysis to only MC-CTS would have reduced the scope and statistical power of the analysis due to smaller response size.

Another limitation of the data was that no definite temporal association could be established between the reported CTS and the reported occupation/industry or exposure to bending/twisting of the hand/wrist. This was likely to result in an overestimate of work-related CTS.

Although this analysis has confirmed that bending/twisting of manual work was a significant CTS risk factor among "recent workers," what can be said about SR-CTS cases among "nonrecent workers"? In Table II, it was noted that the point estimate of prevalence of SR-CTS among "nonrecent workers" was higher than that of "recent workers," although the difference between these estimates was not statistically significant. Superficially, this may mean that whether the individual merely worked or not had no influence on his or her self-report of CTS, or "having worked" was shown to be marginally protective of SR-CTS. At least two reasons can be considered for this result: nonoccupational causes of CTS and the healthy worker effect.

Since CTS is caused by entrapment of the median nerve within the carpal tunnel, any condition that sufficiently increases the intratunnel pressure to interfere with the microcirculation of the nerve may lead to this syndrome [Gelberman et al., 1981; Eversmann, 1988; Pfeffer et al., 1988; Spinner et al., 1989]. Nonetheless, further examination of our results seems to suggest that, theoretically, the pathophysiologic mechanisms leading to the median nerve entrapment are likely to be different between the working and nonworking populations, or to be more precise, between people who perform repetitive manual work and those who do not. Based on the literature on the pathogenesis of CTS, which includes both occupational and nonoccupational etiologies [Spinner et al., 1989; Cannon et al., 1981], a Venn diagram such as shown in Figure 5, can be proposed to consider the universe of CTS and to address the controversy that surrounds the work-relatedness issue of CTS [Hadler, 1991]. In the diagram, each CTS case can be placed in one of four etiologic circles:

1. Intrinsic: secondary to some underlying disease/condition [Cannon et al., 1981; Spinner et al., 1989]
2. Use-related (exertional or dynamic) [Braun et al., 1989]: secondary to edema/inflammation of the tenosynovium in the carpal tunnel [Faithfull et al., 1986; Eversmann, 1988; Braun et al., 1989; Tanaka and McGlothlin, 1993]
   (a) avocational use of the hand (art, hobbies, or sports) [Hoffman and Hoffman, 1985]
   (b) occupational use of the hand in manual work [Brain et al., 1947; Tanzer, 1959; Birkbeck and Beer, 1975; Gainer and Nugent, 1977; Falck, 1983; Masear et al., 1986; Silverstein et al., 1986; Barnhart and Rosenstock, 1987; Feldman et al., 1987; Stock, 1991]
3. Injury-related: occupational or nonoccupational [Bauman et al., 1981]

Cases of CTS that are caused by some underlying diseases or conditions, such as those due to fluid retention during pregnancy or use of estrogens, are expected to be in the intrinsic circle. In contrast, exertional CTS, whether avocational or occupational, is likely the result of tenosynovial inflammation caused by the friction in the carpal tunnel [Faithfull, et al., 1986; Tanaka and McGlothlin, 1993]. An acute case of CTS due to a trauma to the wrist is a clear-cut case of entrapment, whether the injury is caused by an accident on the job, in one's home, or while playing sports.

Theoretically, intrinsic CTS may develop without repetitive manual work, although multiple etiologies may often coexist [Armstrong et al., 1993]. As in the case of an individual who is located in the overlapping area of the Venn diagram, etiologic factors can add up. For example, a woman who is taking oral contraceptive pills and performing repetitive manual work would be at an increased risk of developing CTS than one with a single factor [Cannon et al., 1981]. Such a person with added risk

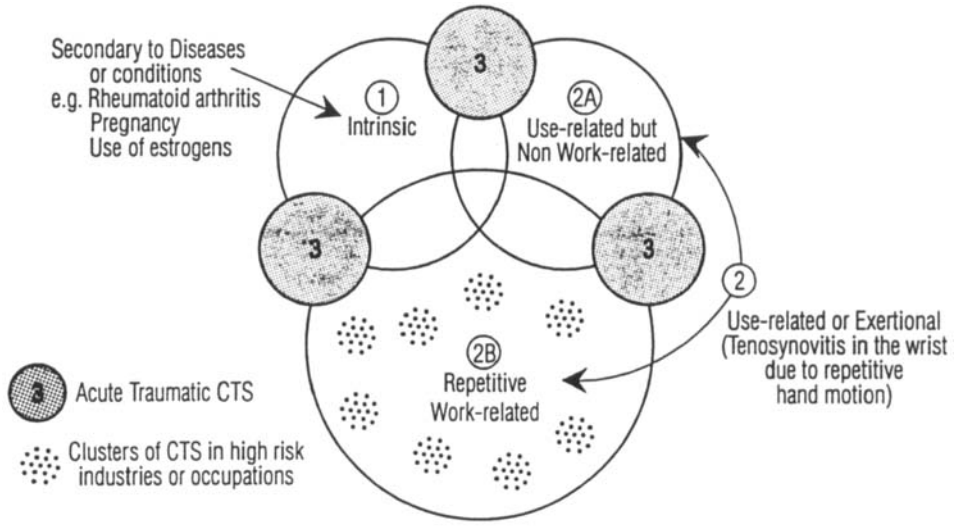

Fig. 5. A Venn diagram to explain some possible differences as well as overlapping in the pathogenesis of carpal tunnel syndrome. (The size of the circles is not proportional to the actual case frequency.)

factors may find it difficult to stay on a job with repetitive manual work, thus exiting the circle of exertional CTS (a healthy worker effect). In this respect, CTS among "nonrecent workers" may include some work-related CTS cases that had left the workplace.

Within the circle of work-related CTS, clusters of CTS cases such as those found in some of meatpacking plants are depicted. For example, specific investigations of alleged clusters (including NIOSH's Health Hazard Evaluations) reported markedly a high incidence rate of CTS [Masear et al., 1986; Hales, et al., 1989]. In contrast, our analysis did not detect such extraordinary prevalence of CTS in any particular occupation or industry, since the sampling scheme of NHIS was targeted toward general population. Also, reporting prevalence by the most recent job, rather than by the job at first occurrence of hand discomfort, could lead to misclassification, if some workers had left the workforce or changed jobs due to CTS.

For the purpose of arriving at a national estimate of CTS at one point in time and examining the roles of potential ergonomic risk factors, the 1988 NHIS/OHS has achieved its objectives. In contrast, as far as CTS is concerned, NHIS may not have been as effective a surveillance tool as the BLS' Annual Report, in that the latter could identify industries with high incidence rates of DART to the 4-digit level. Within the 1–2% range of nationwide prevalence, the estimated number of SR-CTS cases was large, and yet the raw counts of 650 SR-CTS or 145 MC-CTS did not give much statistical power when the responses were spread over hundreds of occupational or industrial categories at the 3-digit level (which therefore is not presented in this report). One important exception was that, at the top of the list of high risk occupations was "mail and message distribution," which is largely comprised of postal service workers. Although there have been reports of CTS among U.S. mail workers [Castorina et al., 1990], this occupation category has not been included in the BLS Annual Survey, which is limited to the private sector.

An estimated prevalence of 0.28% for "work-related" MC-CTS among U.S. workers translates to ~ 356,000 (possibly ranging from a quarter million to a half million) individuals with CTS requiring medical care and being disabled at least temporarily. This is a large loss in terms of national economy as well as individual suffering and deprivation.

The results of the 1988 NHIS/OHS, combined with those of the BLS' Annual Report, indicate the areas where intervention and research efforts for prevention of CTS should be directed. In addition to the identification of high risk occupations and industries, our analysis has shown that, among the various factors examined, repetitive bending/twisting of the hands and wrists at work is the most important one for SR-CTS and MC-CTS. Future research on CTS and other CTDs in the workplace should include concerted ergonomic and epidemiologic investigations focusing on various work stress factors of manual tasks within high risk occupations and industries [Tanaka and McGlothlin, 1993].

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