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Nested Case-Control Study of Hand and Wrist Work-Related Musculoskeletal Disorders in Carpenters

Margaret R. Atterbury, MD, Janet C. Limke, MD, Grace K. Lemasters, PhD, Yuhua Li, PhD, Christy Forrester, BA, Rick Stinson, MA, and Harriet Applegate, MA

Unionized carpenters (n = 522) participated in a telephone interview regarding their jobs and musculoskeletal symptoms. From this group, a nested case-control study was conducted on 25 symptomatic carpenters who met a hand or wrist work-related musculoskeletal disorder (WMD) case definition and on 35 asymptomatic carpenters who were of similar, age, sex, height, and weight. The purpose of the study was to determine if questionnaire symptom data could be used to estimate the prevalence of hand/wrist WMDs. To test this hypothesis, a subset of subjects underwent physical examination and electrodiagnostic testing to determine if these symptom-derived cases had findings of carpal tunnel syndrome or other hand or wrist musculoskeletal disorders. Standardized upper extremity physical examinations and unilateral ulnar and median nerve conduction studies were administered. Physical examination findings of CTS were significantly increased among WMD cases. Mean median sensory and motor distal latencies were significantly longer ($P < 0.05$) and median sensory amplitudes smaller in cases compared to controls. Median relative to ulnar sensory and motor latencies also were longer in cases. A median mononeuropathy at the wrist was found in 78% of the cases. These findings suggest that symptom-derived WMD data are useful in estimating the prevalence of CTS among carpenters.

KEY WORDS: carpal tunnel syndrome, median mononeuropathy, symptom validation, electrodiagnostic nerve studies, cumulative trauma disorders, asymptomatic findings

INTRODUCTION

Past studies have associated carpal tunnel syndrome (CTS) and other musculoskeletal disorders of the hands and wrists with occupational exposure to force, repetition, awkward posture, and vibration [Silverstein et al., 1986; Armstrong et al., 1987; Kuroinka and Forcier, 1994]. In these studies, work-related musculoskeletal disorders (WMDs) have been defined by the presence of symptom and/or physical exam criteria. In the diagnosis of CTS (entrapment of the median nerve at the wrist), physical examination techniques lack sensitivity and specificity [Katz et al., 1990]. Nerve conduction studies (NCS), however, provide an objective measure of median nerve function and have been found to be highly sensitive and specific in the diagnosis of CTS [AAEM, 1993]. Several recent studies have incorporated NCS results in the evaluation of case definitions of CTS [Barnhart et al., 1991; Bernard, 1993; Franzblau et al., 1993] among manufacturing workers or keyboard users. None have evaluated hand/wrist WMDs and nerve conduction measurements among carpenters or other building trade workers. Carpenters frequently use hand-held vibratory power tools, exposing them to a combination of forceful hand motion, vibration, and awkward postures and putting them at risk for the development of CTS and other WMDs.

Symptom questionnaires provide the least expensive, most accessible, noninvasive method of estimating preva-

Greater Cincinnati Occupational Health Center, Cincinnati, OH 45241 (M.R.A., Y.L., C.F., R.S., H.A.). University of Cincinnati, Cincinnati, OH 45221 (J.L., G.K.L.).
Address reprint requests to Dr. Margaret R. Atterbury, Greater Cincinnati Occupational Health Center, 10475 Reading Road, Suite 405, Cincinnati, OH 45241.

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lence of disease. However, whether or not symptom-derived data reflect muculoskeletal disorders may be contested due to their subjectivity. The purpose of this study is to determine if hand/wrist WMDs defined in a symptom questionnaire are validated by abnormal physical examination and electrodiagnostic findings and are therefore useful estimators of the prevalence of WMDs. This study is part of a larger one designed to determine the prevalence of musculoskeletal disorders in carpenters and to begin an ergonomic intervention program among unionized carpenters.

MATERIALS AND METHODS

Questionnaire

From 2,074 members of the Southwest Ohio District Council of Carpenters, 660 carpenters were randomly selected to participate in a telephone interview regarding their jobs and musculoskeletal symptoms. All union members who had performed carpentry work during the last year were eligible to participate. Thirty-three carpenters had either retired or left the trade for a year or longer; of 627 eligible carpenters, 522 (84%) participated. Of the nonparticipants, 37 (6%) refused and 68 (11%) were not located. Eight carpenters were excluded from the analysis because of reporting either incomplete or unreliable information as judged by the interviewer. Data for a total of 514 carpenters were available for analysis. Topics covered in the questionnaire included: demographics; prior medical conditions predisposing to the development of WMDs (diabetes, hypothyroidism, rheumatoid arthritis, lupus, gout); work history including specialties worked during carpentry career; and work organization and psychosocial factors. Carpenters were asked if they had recurring symptoms such as pain, aching, numbness or any other symptom in their neck, shoulders, elbows, hands or wrists, back, hips, knees, or ankles. If a positive response was given, they were then asked date of onset, symptom quality (any combination of pain, aching, burning, numbness or tingling, fingers turning white or blue) symptom severity, frequency, duration, whether or not they sought treatment, days missed, change in job tasks, nocturnal symptoms, and sudden injuries.

Case Selection

The case definition for a hand/wrist WMD was similar to one previously used by NIOSH in their Health Hazard Evaluation studies of musculoskeletal disorders [Bernard, 1993]. Those with hand and/or wrist symptoms were classified as a WMD "case" if they met the following criteria: (1) self-reported pain, aching, burning, numbness or tingling in the hands and/or wrists during the past one year, (2) onset of these symptoms after starting work as a carpenter; (3) symptoms occurring at least once a month or lasting at least 1 week; (4) no history of injury; (5) pain reported as "moderate," "severe," or "the worst pain in your life."

In order to examine subjects relatively soon after the interview, recruitment was initiated prior to completion of the interviews of the entire cohort (N = 522), which took ~7 months. Two months after the interviews were begun, a subset of hand/wrist cases were recruited by phone to have a physical examination and nerve conduction testing. The intent was to examine a total of 50 carpenters, approximately half of whom were asymptomatic and half of whom met the hand/wrist case definition. To be eligible for participation, the hand/wrist case subjects had to report continued pain at the time of phone recruitment without having had a new hand/wrist injury. Of the total 38 hand/wrist cases identified and recruited, six (16%) reported no longer having pain and hence were ineligible. Of the 32 recruited, 25 (78%) participated and seven (22%) refused. Two case subjects underwent physical examination but did not tolerate the complete nerve conduction testing procedure and therefore could not be included in that part of the analysis due to insufficient data.

Carpenters who reported being asymptomatic in all body parts on the initial phone interview were used as a control group. Of 134 carpenters who reported being asymptomatic, 60 were randomly recruited until a total of 35 had participated. Three individuals were ineligible because they had stopped doing carpentry work or sustained a new injury. Ten carpenters refused, seven had work schedule conflicts, and five were not located.

Symptom Survey and Physical Examination

On the day physical examinations and nerve conduction studies were performed, carpenters underwent an updated musculoskeletal symptom survey. Standardized musculoskeletal examinations of the neck and upper extremities were performed by two physician examiners who were unaware of either the carpenters' symptoms or work history. The hand/wrist portion of the examination included range of motion, passive and resisted wrist and finger extension and flexion. A positive finding for wrist tendinitis was distal forearm pain reported as 1 (mild) or greater on a 5-point scale. A positive Tinel's or Phalen's test was required for physical exam diagnosis of carpal tunnel syndrome. Tinel's test was performed by gently tapping over the distal wrist crease in the area of the transverse carpal ligament. Phalen's test was performed by having the subject hold both wrists in full flexion for 1 minute. A positive response for either Tinel's or Phalen's tests was tingling in the hand including the median nerve distribution. A positive Finkelstein's test for the diagnosis of DeQuervain's tenosynovitis was pain with passive ulnar deviation of the wrist with fingers fully flexed around the thumb.

Nerve Conduction Measurements

A single electromyographer, unaware of the individuals' symptoms, physical examination findings, or work history, performed nerve conduction studies on the symptomatic hands of case subjects and a single upper extremity of asymptomatic noncases. The hand tested was matched for dominance in cases vs. noncases. Hand temperature was measured by surface thermistor at the distal palmar crease between the fourth and fifth digits. Hands were warmed to greater than or equal to 32°C when necessary. Nerve conduction studies were performed with a Teca Neurostar electromyograph (Pleasantville, NY). A bipolar surface stimulator delivered supramaximal stimulations at durations from 0.05 to 0.5 ms. Sensory responses were recorded by ring electrodes with at least a 4 cm separation. Ten mm disc electrodes recorded motor responses. Latency and amplitude measurements were taken by cursor after gain was adjusted for full viewing of the evoked response. Filter settings were 20 Hz to 2 KHz for sensory and 2 Hz to 10 KHz for motor nerve conduction studies. Antidromic sensory latencies were measured to the negative peak and motor latencies to the start of the negative deflection.

Antidromic median sensory latencies were recorded at the third digit with stimulation 7 and 14 cm proximal at the midpalm (MPL) and wrist (MSL), respectively. Monga et al. [1982] found that testing of the more medially placed nerve fibers was more sensitive in picking up changes in patients with CTS. Thus digit three was used instead of the ring finger. Ulnar sensory distal latency (USL) was recorded at the fifth finger with stimulation 14 cm proximal. Median motor distal latency (MML) and ulnar motor distal latency (UML) were recorded over the abductor pollicis brevis and abductor digiti minimi, respectively, with stimulation 8 cm proximal.

If either of the two following tests were positive, the findings were said to be consistent with median mononeuropathy at the wrist: MSL minus USL $\geq$ 0.5 ms [Pease et al., 1989] 126, or MML minus UML $\geq$ 1.8 ms [Thomas et al., 1967] 30. Single limb comparison studies between median and ulnar nerves were chosen in order to control for individual variations in the speed of nerve conduction due to age and genetic differences [Felsenthal, 1977; Stevens, 1987] and was the method with the least error when examining false positive rates of CTS in a normal population [Redmond and Rivner, 1988]. Carpenters who met the hand/wrist case definition and electrodiagnostic criteria for median mononeuropathy at the wrist were diagnosed as having CTS.

Statistics

Statistical analysis was performed on the data using the student's test or Chi square analysis where appropriate.

TABLE I. Demographic and Physical Characteristics of the Hand/Wrist WMD Carpenter Case and Control Groups

	WMD cases (N = 25)	Controls[a] (N = 35)
% Male	92.0	100
Age (years) mean ± Standard Deviation (SD)	43.8 (± 9.32)	39.9 (± 9.92)
Height (inches) Mean (± SD)	5'10.1 (± 2.6")	5'10.4 (± 2.25")
Weight (lbs) Mean (± SD)	189.2 (± 29.8)	187.4 (± 25.1)
% Rt. hand dominant	92.0	82.9
Years as carpenter mean (± SD)	19.7 (± 8.9)	15.7 (± 9.9)
% Who worked as carpenter last week	64.0	82.9
Interval from original Interview to physical exam (Weeks) Mean (± SD)	9.7 (± 1.95)	13.5 (± 6.35)

[a]Reported being asymptomatic on phone interview.

NCS data were inversely transformed prior to performing student's t-test since these data were not normally distributed.

RESULTS

There was no significant difference between cases and controls with respect to mean age, gender, height, weight, or years worked as a carpenter (Table I). The mean time between the phone interview and physical examination was significantly longer for the asymptomatic group compared to the symptomatic group. The primary carpentry specialties performed during their carpentry careers were: form, frame, finish, and drywall (Table II).

Prior medical conditions relevant to hand/wrist musculoskeletal disorders reported among cases and controls included: rheumatoid arthritis, diabetes mellitus, hypothryoidism, and ruptured cervical disc. Only a history of CTS was significantly increased among cases (36%), compared to controls (0%). No one reported a history of lupus, gout, thoracic outlet syndrome, or Raynaud's syndrome.

Based on the updated symptom survey, 19 of the 25 cases continued to meet the case definition on the day of examination. The remaining six continued to report some hand/wrist symptoms, but they no longer met the case definition. The repeat symptoms survey on the day of physical examination identified new symptoms in seven (20%) of the previously asymptomatic carpenters, but only two of these met the case definition. Since one purpose of this substudy was to validate the questionnaire results in the primary analysis, the original classification was not altered.

With respect to type of symptoms reported among the

TABLE II. Carpentry Specialties Reported Among Hand/Wrist WMD Cases and Controls

	WMD cases (N = 25)	Controls (N = 35)
Form	8 (32%)	10 (29%)
Frame/finish	8 (32%)	10 (28%)
Drywall/ceiling	5 (20%)	7 (20%)
Other[a]	4 (16%)	8 (23%)

[a]Includes flooring, welding, supervision, fixtures, piledriving.

25 carpenter cases in the past 1 year: 18 (72%) reported bilateral symptoms, 24 (92%) had numbness or tingling, 13 (56%) reported pain, 13 (56%) reported aching, 4 (24%) reported burning, and 2 (8%) reported their fingers turning white or blue. There were 17 (68%) cases who reported awakening with nocturnal symptoms.

The hand and wrist physical examination results are reported in Table III. Five (20%) cases and four (11.4%) control carpenters had physical examination findings of wrist tendinitis. Phalen's was positive in nine (36%) of cases and two (6%) of control carpenters. Tinel's test was positive in seven (28%) of cases and three (8.6%) of controls. Physical examination findings consistent with CTS (positive Phalen's or Tinel's test) were significantly increased among cases compared to controls ($p < .05$).

Mean median sensory and motor distal latencies were significantly longer and median sensory amplitude significantly smaller in cases compared to controls (Table IV). Median relative to ulnar sensory and motor latencies also were longer in cases. The ratio of distal latency across the palm to distal latency across the wrist was significantly smaller in cases compared to controls. This last test is a form of midpalm study, measuring latency distal to the wrist to the total distal latency across the wrist. A decreasing ratio is indicative of slowing across the carpal tunnel [Pease et al., 1989]. There was no difference in ulnar sensory and motor distal latencies and amplitudes between the groups.

A median mononeuropathy was defined by median minus ulnar sensory latency ≥ 0.5 ms *or* median minus ulnar motor latency ≥ 1.8 ms. The prevalence of a median mononeuropathy among cases was 78%, and among controls was 34% (Table V).

Although all cases continued to have symptoms at the time of examination/testing, seven previously asymptomatic controls reported hand wrist symptoms on the day nerve conduction studies were performed. Therefore, the frequency of a median mononeuropathy among those who remained asymptomatic was determined, Of the 28 asymptomatic controls, however, 21% still met the criteria for median mononeuropathy (Table V).

TABLE III. Hand/Wrist Physical Examination Results Among Carpenters with Work-Related Musculoskeletal Disorders and Controls

	WMD cases (N = 25)	Controls (N = 35)
Wrist tendinitis	5 (20%)	4 (11.4%)
Carpal tunnel syndrome[a] (positive Phalen's *or* Tinel's)	12 (48%)	5 (14.3%)
Phalen's	9 (36%)	2 (6.0%)
Tinel's	7 (28%)	3 (8.6%)
DeQuervain's tenosynovitis	1 (4%)	0 (0.0%)

[a]$p<0.05$.

TABLE IV. Comparison Of Distal Nerve Conduction Among Carpenter Hand/Wrist Cases and Controls* (mean ± standard deviation)

Nerve conduction measure	WMD Cases[a] (N = 23)	Controls (N = 35)	p value
Median sensory			
amplitude (uV)	14.43 ± 8.3	21.23 ± 8.3	<0.01
distal latency (ms)	4.32 ± 0.8	3.69 ± 0.7	<0.01
Median motor			
amplitude (mV)	6.48 ± 2.9	7.68 ± 2.0	0.07
distal latency (ms)	4.82 ± 0.9	4.35 ± 0.9	0.05
Ulnar sensory			
amplitude (uV)	18.61 ± 7.9	18.00 ± 7.1	NS
distal latency (ms)	3.22 ± 0.3	3.30 ± 0.4	NS
Ulnar motor			
amplitude (mV)	10.25 ± 1.9	10.21 ± 2.1	NS
distal latency (ms)	3.10 ± 0.4	3.19 ± 0.4	NS
Median to ulnar comparison measures			
median-ulnar sensory latency (ms)	1.09 ± 0.87	0.38 ± 0.54	<0.01
median-ulnar motor latency (ms)	1.76 ± 0.98	1.16 ± 0.67	0.01
Median sensory midpalmar latency at 7 cm divided by MSL[b] at 14 cm	0.47 ± 0.05	0.51 ± 0.05	0.02

*Those who reported being asymptomatic on the phone interview.
[a]Two cases could not tolerate nerve conduction studies.
[b]Median sensory distal latency.
NS = not significant. All values reported <.10.

DISCUSSION

Assignment as a case (the case definition) was defined by symptoms derived from a telephone interview for the purpose of estimating the prevalence of both muscle-tendon and nerve-related WMDs among union carpenters. The case definition was similar to that used in NIOSH Health Hazard Evaluation studies [Bernard, 1993] and equivalent to a case

TABLE V. Prolonged Median-Ulnar Sensory (MSL-USL) and Motor Distal Latencies (MML-UML) Among Carpenter Hand/Wrist WMD Cases and Asymptomatic Controls

	MSL-USL ≥ 0.5 ms		MML-UML ≥ 1.8		Either test	
	ms				Positive	
	n	% positive	n	% positive	n	% positive
WMD cases (N = 23)	14	(61%)	13	(57%)	18	(78%)
Controls[a] (N = 35)	12	(34%)	4	(11%)	12	(34%)
Asymptomatic controls[b] (N = 28)	6	(21%)	2	(7%)	6	(21%)

[a]Identified as asymptomatic on phone interview.
[b]Remained asymptomatic on day of NCS, i.e., excluding seven controls who reported new hand/wrist symptoms.

definition (number three) used in a study of auto manufacturing workers [Franzblau et al., 1993]. For the validation study, a restrictive definition was used, only including those reporting moderate or severe symptoms. Cases with persistant symptoms were examined.

The control group were carpenters exposed to similar ergonomic stressors, identified as asymptomatic on the telephone interview. The controls had about a 4-week longer period between time of interview and examination, and this may have allowed for new symptom development in this group. However, if this time lag resulted in development of new musculoskeletal disorders in the reference group, this would effectively underestimate true differences between cases and controls.

Neurologic symptoms (numbness or tingling) were reported by most cases. Physical exam findings of CTS (positive Phalen's and Tinel's tests) were more frequent than findings of tendinitis among cases. Of hand/wrist cases, 78% had electrodiagnostic confirmation of a median mononeuropathy (CTS) at the wrist. Other studies of WMDs, however, have found symptoms of pain and cases of tendinitis more frequently than nerve-related symptoms and disorders such as CTS [Moore, 1992; Bernard, 1993]. The preponderance of neurologic symptoms and frequent findings of CTS in this study may reflect the increased severity of median nerve dysfunction in carpenters in the case group. For instance, two cases had unobtainable median nerve sensory responses, both of whom had a median mononeuropathy determined by prolonged motor latencies. Since carpenters are exposed to a combination of ergonomic stressors, including vibration, it can be alternatively postulated that these neurologic hand/wrist symptoms may represent vibration effects other than CTS. In addition to CTS [Cannon et al., 1981; Wieslander et al., 1989; Brismar and Ekenvall, 1992; Nilsson et al., 1994], the use of hand-held vibratory tools has been associated with Raynaud's phenomenon [NIOSH, 1989], a diffuse polyneuropathy of the hands [Brammer and Pyyko, 1987]. Only two (8%) of cases reported their fingers turning white or blue, suggestive of Raynaud's phenomenon. Ulnar nerve sensory and motor conductions were not significantly different between cases and control carpenters, arguing against the diagnoses of polyneuropathy or diffuse digital neuritis. Both physical examination and nerve conduction findings of a median mononeuropathy at the wrist indicate that the majority of symptoms were due to CTS.

CTS is a clinical diagnosis that usually includes electrodiagnostic confirmation of a median mononeuropathy at the wrist. Although there is no one electrophysiologic test established as a "gold standard" for this diagnosis, nerve conduction studies provide objective measures of median nerve function. Both median to ulnar sensory and median to ulnar motor comparisons were included to screen for a median mononeuropathy, since median sensory conductions may be unobtainable in severe cases of CTS. Thus each of these comparison studies was used as a primary validity measure. In fact, two carpenter cases had unobtainable median sensory latencies and relative prolongation of median to ulnar motor distal latencies.

Carpenters are predisposed to multiple cumulative trauma disorders. Just as median nerves may be affected at the wrist, ulnar nerves may be affected by trauma or stretch at the elbow. Thus this study originally included a median midpalm test that was independent of ulnar nerve function for a diagnosis of median mononeuropathy. Analysis showed that the median midpalm study was unobtainable in five (23%) case subjects: two had no detectable median sensory conduction with stimulation at the wrist, and three had unobtainable midpalm latencies. Consequently, this test was less useful in this population with relatively severe median nerve dysfunction. Ulnar nerve conduction studies also were not significantly different between the two groups, minimizing the need for an independent study of median nerve function. Cases were more likely to have electrodiagnostic findings of a median mononeuropathy than physical examination findings of CTS. This finding is consistent with the wide range of reported sensitivities and specificities for Phalen's and Tinel's tests [Katz et al., 1990;

Moore, 1992]. In another study comparing various CTS case definitions, symptoms alone were found to have a higher positive predictive value in determining a median mononeuropathy than symptoms and physical exam findings [Franzblau et al., 1993].

An unexpected finding was that 21% of totally asymptomatic carpenters had electrodiagnostic findings of a median mononeuropathy at the wrist. The significance of prolonged median sensory distal latencies among asymptomatic carpenters is unclear since nerve conduction abnormalities among asymptomatic populations have not been well researched. One study compared median sensory distal amplitude and latencies between nonexposed workers, and asymptomatic and symptomatic industrial workers with exposure to hand/wrist ergonomic stressors [Stetson et al., 1993]. Mean median and ulnar sensory amplitudes were smaller, motor and sensory distal latencies significantly longer in the asymptomatic industrial group compared to the nonexposed control group. Likewise, median relative to ulnar latencies and midpalmar latency comparison measures were significantly longer in the industrial group. Most notable, however, was that the difference between asymptomatic exposed and nonexposed workers was more significant than that between symptomatic and asymptomatic exposed workers, suggesting that ergonomic stressors may be associated with prolongation of median nerve distal latencies prior to the development of symptoms. Our control group had similar ergonomic exposures as our hand/wrist case group. Longitudinal studies need to be initiated in order to further investigate whether or not these asymptomatic referents with median nerve dysfunction will eventually develop clinical disease.

In summary, 78% of carpenters with a hand or wrist WMD as defined by a symptom questionnaire had nerve conduction study findings consistent with a median mononeuropathy at the wrist, i.e., CTS. This finding suggests that (telephone) interview symptom data are useful in estimating the prevalence of CTS among a skilled professional trade, such as journeymen carpenters. The preponderance of neurologic symptoms and severity of electrodiagnostically confirmed CTS among cases, and the prevalence of median mononeuropathy among asymptomatic carpenters, suggest that this case definition may, in fact, underestimate the true prevalence of CTS in the population.

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