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Workplace Surveillance for Carpal Tunnel Syndrome Using Hand Diagrams

Alfred Franzblau,[1,5] Robert A. Werner,[1,2] James W. Albers,[1,3] Christin L. Grant,[4] Denise Olinski,[1] and Elizabeth Johnston[1]

Four hundred and eleven workers from 4 different companies participated in a worksite screening program designed, in part, to estimate the prevalence of carpal tunnel syndrome (CTS). Each worker completed a discomfort survey and underwent limited nerve conduction testing of the median and ulnar sensory nerves in both wrists. The discomfort survey included a hand diagram which allowed subjects to shade in area(s) affected by numbness, burning, tingling, or pain. The discomfort survey also asked each worker to indicate whether she or he had experienced neuropathic symptoms (i.e., numbness, burning, tingling, or pain) in the wrist, hand or fingers of each hand, without regard to localization (i.e., median versus ulnar versus radial distribution), and also nocturnal occurrence of symptoms. Analyses involved comparing hand diagram scores and non localized wrist/hand/finger symptoms with electrodiagnostic test results. All configurations of hand diagram scores of the dominant hands had a statistically significant association with electrophysiologically determined median nerve dysfunction, but so did non localized symptom reports. The sensitivity, specificity, and positive predicted values of hand diagrams were poorer than those reported previously. While some test performance characteristics of hand diagrams were better than those for non localized distal extremity symptoms consistent with CTS, some were worse. Overall, our data suggest that hand diagrams are no better than using a questionnaire to determine if workers have experienced symptoms consistent with CTS in their wrists, hands or fingers without regard to localization. The choice of screening tool would depend on

[1]Department of Environmental and Industrial Health, University of Michigan School of Public Health, 1420 Washington Heights, Ann Arbor, Michigan 48109-2029.
[2]Physical Medicine and Rehabilitation Service, Ann Arbor Veterans Administration Hospital, Ann Arbor, Michigan 48105; Department of Physical Medicine and Rehabilitation, University of Michigan School of Medicine, Ann Arbor, Michigan 48109-0042.
[3]Department of Neurology, University of Michigan School of Medicine, Ann Arbor, Michigan 48109-0322.
[4]Center for Ergonomics, University of Michigan School of Engineering, Ann Arbor, Michigan 48109-2117.
[5]Correspondence should be directed to Department of Environmental and Industrial Health, University of Michigan School of Public Health, 1420 Washington Heights, Ann Arbor, Michigan 48109-2029 Dr. Franzblau (telephone number: 313-936-0758)

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the goal of screening, in particular, whether it is more desirable to have slightly higher sensitivity or positive predictive value.

KEY WORDS: carpal tunnel syndrome, screening, hand diagrams, nerve conduction velocity testing, median mononeuropathy, cumulative trauma disorders.

INTRODUCTION

The reported incidence of cumulative trauma disorders, and carpal tunnel syndrome (CTS) in particular, has increased dramatically among industrial and office workers over the last decade[1,2]. NIOSH has identified work-related musculoskeletal disorders as among the ten most important occupational safety and health concerns in the United States[3].

Active surveillance is one potential way to identify cases, or to monitor trends in occupational illness and injury among workers[4,5]. In particular, active surveillance may provide a more accurate estimate of incidence or prevalence of CTS among workers, and, in theory, may also provide a basis for referral of individual workers for further medical evaluation. In conjunction with appropriate ergonomic assessment of jobs, active surveillance may help to achieve a better understanding of the relationship between ergonomic stress and CTS. Active surveillance may also allow for better targeting of interventions, and may facilitate assessment of workplace interventions to reduce the incidence of CTS. Self-administered hand diagrams are one potential way of performing active surveillance for CTS among workers.

A number of previous studies report that hand diagrams are able to discriminate patterns of hand and wrist symptoms related to CTS from other upper extremity diagnoses[6,7]. Based on these results, the authors suggest that the hand diagram "holds promise" as a diagnostic tool for population studies of CTS. However, these previous studies have only included patients referred to hospital-based clinics with upper extremity complaints. Such a sample of patients may not be representative of an active worker population, and the test performance of hand diagrams used in the workplace may differ from previous reports.

Our research has involved field surveys of active workers at a number of industrial and office sites. The focus of these field studies has been to estimate the prevalence of upper extremity cumulative trauma disorders in general and carpal tunnel syndrome in particular, to evaluate worksite-screening methods for upper extremity cumulative trauma disorders, and to gain a better understanding of how ergonomic stressors in the workplace may contribute to these medical problems. As a part of the medical screening protocol used in these field studies, subjects were asked to complete a self-administered questionnaire that included a discomfort survey of recent upper extremity symptoms. The questionnaire also included a self-administered hand diagram. In addition, each subject completed median and ulnar sensory nerve conduction testing in both wrists. The present report describes and compares the discomfort survey results, the hand diagram results, and electrodiagnostic test results as they pertain to carpal tunnel syndrome. The primary focus of

the present study is to assess the test performance characteristics of self-administered hand diagrams among active industrial workers as a possible workplace screening tool for CTS.

METHODS

Recruitment of Subjects

Participants in this study were recruited from 4 unrelated companies in the midwest. Company 1 is a small automotive parts manufacturing plant. Company 2 is a large office furniture manufacturer with multiple plant sites. Company 3 is a large insurance company with offices located in many states. Company 4 is a multinational manufacturer of industrial containers. Company 1 has only one plant site. All study participants from Company 2 were recruited from 2 plant sites. All subjects from Company 3 were recruited from a single insurance claims processing center. Study participants from Company 4 were recruited from a single plant site. Workers at Company 4 were represented by a union. Workers at the other study sites did not have union representation.

The procedures used to determine the eligibility of workers differed among the companies. For Companies 1 and 3, essentially all workers at the plant sites under study were invited to participate. Companies 2 and 4 were studied as part of a larger ongoing investigation of the relationship between workplace ergonomic exposures and upper extremity cumulative trauma disorders. At these companies, certain jobs were selected on the basis of the frequency of repetitive hand movements ("low", "medium" and "high"), and all workers with at least 6 months tenure in those jobs were invited to participate. Subjects from Companies 1, 2 and 4 were industrial/blue collar workers, while subjects from Company 3 were office/white collar workers.

Study participants provided written informed consent which had been approved by the University of Michigan School of Public Health Human Subjects Review Committee. The medical screening surveys were performed during normal work hours. No personally identifiable results were provided to the companies or union. Each participant was sent a confidential summary of their personal test results (including electrodiagnostic findings), an interpretation of the results, and recommendations for medical follow-up, if indicated.

Clinical Procedures

Medical survey procedures included a self-administered questionnaire, a physical examination focused on the upper extremities, and ulnar and median sensory nerve conduction studies in both wrists. Examiners were masked to data collected

by other members of the study team. The physical examination procedures are described elsewhere[8]; these results were not used in the present analyses.

The self-administered questionnaire focused on demographic information, prior medical conditions, occupational history, current health status, and symptoms potentially related to upper extremity cumulative trauma disorders. Subjects were instructed to report a symptom if it had been present on at least 3 separate episodes, or one episode had lasted more than one week, in the 12 months preceding the survey. The survey queried subjects about 9 symptoms (burning, stiffness, pain, cramping, tightness, aching, soreness, tingling and numbness) in each of 15 body locations (neck, right or left shoulder, right or left upper arm, right or left elbow, right or left forearm, right or left wrist, right or left hand and right or left fingers). This portion of the questionnaire did not ask subjects to distinguish symptoms in the distribution of the median nerve from symptoms elsewhere in the fingers, hands, or wrists. For the purposes of this study, symptoms consistent with CTS consisted of numbness, burning, tingling or pain in the wrist, hand or fingers. In addition, if subjects reported wrist, hand or finger symptoms, they also were asked to indicate if they had experienced nocturnal occurrence of symptoms (i.e., "nocturnal symptoms"). In previous studies it has been shown that inclusion of nocturnal occurrence of symptoms increases the positive predictive value without much reduction in sensitivity[8,9].

Each subject also completed a hand diagram. The hand diagram and accompanying instructions were similar to the diagram and instructions used by Katz et al[6]. If a subject had experienced numbness, tingling, burning or pain in the wrists, hands or fingers on at least 3 separate episodes, or one episode had lasted more than one week in the 12 months preceding the survey, then she/he was instructed to shade in the distribution of such symptoms on the hand diagram.

Hand diagrams were scored for likelihood of underlying CTS. Scoring was performed independently by AF and RW without knowledge of other test results. Scores were then compared. Discrepancies usually were related to minor interpretative errors on the part of one scorer, or confusing or ambiguous shading of hand diagrams by subjects. The few discrepancies were resolved by consensus. The rating system used was essentially identical to Katz et al.[6], except for substitution of "burning" for "decreased sensation":

Classic. Tingling, numbness, burning or pain in at least 2 of digits 1, 2 or 3. Palm and dorsum of the hand excluded; wrist pain or radiation proximal to the wrist allowed.

Probable. Same as for classic, except palmar symptoms allowed unless confined solely to ulnar aspect.

Possible. Tingling, numbness, burning or pain in at least one of digits 1, 2 or 3.

Unlikely. No symptoms in digits 1, 2 or 3.

Interrater agreement of dominant hand diagram scores was very high (399 out of 411, or 97.1%), and the overall Kappa statistic was indicative of near perfect agreement ($\kappa = 0.927$; p-value of less than 0.001). Interrater agreement of results for the non dominant hands was similar. These findings suggest that scoring of hand diagrams in this study was a very reliable procedure.

Electrophysiologic testing included median and ulnar sensory conduction studies in the wrists using surface electrodes and fixed distances (14 centimeters, antidromic stimulation). Nerve conduction tests were performed by physicians certified in electrodiagnostic medicine (RAW and JWA), or certified electrodiagnostic technicians working under their direct supervision. Measurements included amplitude, onset latency and peak latency in each nerve tested[10]. Criteria for median mononeuropathy at the wrist include: a difference of at least 0.5 milliseconds between median and ulnar sensory peak latencies in the same wrist, or a difference of at least 0.8 milliseconds between median and ulnar sensory peak latencies in the same wrist. The threshold difference of 0.5 milliseconds has been used in a number of previous workplace studies[8,11], and is above the 95th percentile of an asymptomatic, ergonomically unexposed population[12]. The criterion of 0.5 milliseconds has also been shown to minimize false positive electrodiagnostic test results when evaluating patients for suspected CTS[13]. The higher threshold difference of 0.8 milliseconds represents the 99th percentile of an asymptomatic, ergonomically unexposed population[12].

Mid-palm temperatures were monitored during nerve conduction studies. If the hand temperature was below 32°C, the hand was warmed to increase the temperature, however dominant hand temperatures still varied from 29.0°C to 35.0°C, with mean of 33.0°C, and from 29.0°C to 35.2°C with mean of 32.9°C in non dominant hands. Although it has been suggested that temperature correction can be applied to an absolute latency[10], no studies have investigated the impact of temperature on the sensory latency differences used in the present study. In a univariate analysis, hand temperature (as an independent variable) was not correlated with the median-minus-ulnar sensory peak latency difference in the dominant hands in our data ($r^2 = 0.003$; $p = 0.255$), and the relationship in the non dominant hands, though significant, was negligible ($r^2 = 0.020$; $p = 0.004$). Therefore, no correction for temperature was applied to latency differences.

Statistical Analyses

Data were collected for both hands on all subjects. Electrodiagnostic results for dominant and non dominant hands are significantly correlated ($r^2 = 0.479$, $p < 0.001$ for correlation of dominant versus non dominant median sensory peak latencies in our data). We chose to analyze results separately for dominant and non dominant hands, rather than combining results of all hands into a single analysis. This approach assures the independence of each observation. Analyses were performed using SYSTAT version 5.01[15]. Most analyses involved descriptive statistics. Cross-tabs, Pearson correlation, ANOVA, paired t-tests and independent t-tests were also performed, and were considered statistically significant if $p < 0.05$. Interrater agreement was analyzed using the Kappa statistic. The Kappa statistic, the standard error of Kappa, the 95% confidence interval of Kappa, and the p-value of the z-statistic for Kappa ($z = \kappa/SE(\kappa)$) were calculated according to Fleiss[16].

RESULTS

Overall, 528 workers were eligible to participate in the 4 worksite screenings, and 411 volunteered (77.8%—see Table 1). The participation rates varied from 70.6% to 87.8%. The mean age of study participants varied significantly among the 4 study sites ($F = 2.942$, df = 3, $p = 0.033$). Post-hoc testing revealed that the mean age at sites 1 and 3, and sites 2 and 4 were similar, and that other pairwise comparisons differed significantly. The distribution of hand dominance was similar among Companies 1, 2 and 3; workers at Company 4 reported right hand dominance slightly less often, although a cross-tabs test was not statistically significant ($\chi^2 = 2.205$; 3 df; $p = .531$). The most striking difference among participants from the different study sites pertains to the gender distribution. Overall, 41.6% of subjects were male, however, there was considerable variation in the percentage of male subjects, ranging from 13.4% to 72.7% ($\chi^2 = 102.4$, 3 df, $p < 0.001$).

The nerve conduction test results are summarized in Table 2. The number of subjects varies among the listed parameters for a variety of reasons (e.g., one subject did not indicate hand dominance, and so is not included in analyses; one subject did not complete nerve conduction testing in the median nerve of the dominant hand; one subject did not complete nerve conduction testing in the ulnar nerve of the dominant hand; 2 subjects did not complete testing in the non dominant hand, etc.). All statistical comparisons (i.e., paired t-tests) of results for dominant and non dominant hands differed significantly (e.g., median sensory amplitude in dominant and non dominant hands: $t = -8.705$; $p < 0.001$).

Overall, 19.6% of subjects (80 of 408) met the threshold criterion of 0.5 milliseconds for median mononeuropathy in the dominant hands. If the more stringent

Table 1. Demographic Description of Study Participants

Plant site	Total number eligible	Number of participants (%)	Mean[a] age (SD)	Males[a] (%)	Right hand dominant[a] (%)
Company 1	119	84 (70.6)	33.8 (10.6)	38 (45.2)	74 (88.1)
Company 2	98	86 (87.8)	37.2 (10.9)	55 (64.0)	77 (89.5)
Company 3	221	164 (74.2)	35.0 (10.6)	22 (13.4)	146 (89.0)
Company 4	90	77 (85.6)	37.4 (9.6)	56 (72.7)	64 (83.1)
Totals/summary	528	411 (77.8)	35.7 (10.5)	171 (41.6)	361 (87.8)

[a]For study participants only; SD = standard deviation.

Table 2. Summary of Nerve Conduction Measurements[a]

	Dominant hands			Non-dominant hands			
	N	Mean	Range	*N*	Mean	Range	*p*-values*
Nerve conduction parameter							
Median sensory amplitude (μv)	407	35.5	6.0–109	408	39.3	3.9–104	<0.001
Median sensory onset latency (ms)	407	2.6	2.1–5.5	408	2.6	1.9–5.0	<0.001
Median sensory peak latency (ms)	407	3.4	2.7–7.1	408	3.3	2.6–6.1	<0.001
Ulnar sensory amplitude (μv)	407	32.6	4.0–85.9	408	34.8	4.0–86.9	<0.001
Ulnar sensory onset latency (ms)	407	2.4	1.8–3.6	407	2.5	1.9–3.7	0.028
Ulnar sensory peak latency (ms)	407	3.1	2.6–4.6	408	3.2	2.6–4.5	0.013
	N	Cases	%	*N*	Cases	%	*p*-values**
Median mononeuropathy							
Median mononeuropathy—0.5	408	80	19.6	408	63	15.4	0.118
Median mononeuropathy—0.8	408	42	10.3	408	33	8.1	0.276

[a]μv = microvolts; ms = milliseconds.
*Paired *t*-tests.
**Independent *t*-tests.

threshold criterion of 0.8 milliseconds is applied, then only 10.3% of subjects (42 of 408) had median mononeuropathy in the dominant hands. The corresponding prevalences of median mononeuropathy were slightly lower in the non dominant hands. The proportion of cases with median mononeuropathy in the dominant hands did not differ significantly from the non dominant hands (t = 1.566, p = .118 for 0.5 ms criterion; t = 1.090, p = .276 for 0.8 ms criterion). Interestingly, the proportion of cases of median mononeuropathy did not differ significantly across study sites in the dominant hands (χ^2 =6.047, 3 df, p = .109 for 0.5 ms criterion; χ^2 =1.706, 3 df, p = 0.636 for 0.8 ms criterion; data not shown). For the non dominant hands, the proportion of cases meeting the 0.5 ms criterion for median mononeuropathy differed significantly across study sites (χ^2 = 8.666, 3 df, p = .034; data not shown), but this relationship was not significant using the more conservative 0.8 ms threshold for defining median mononeuropathy (χ^2 =3.500, 3 df, p = .321; data not shown).

The categorization of hand diagram scores and non localized symptoms by electrodiagnostic outcomes are shown in Tables 3 and 4. Eighty subjects (19.6%) had hand diagrams of the dominant extremity scored as 'classic', 'probable' or 'possible' (see Table 3), and 70 subjects (17.3%) reported (non localized) symptoms of numbness, burning, tingling or pain in the dominant fingers, hand or wrist with nocturnal occurrence (see Table 4). Cross-tabs analyses were statistically significant for all dominant hand analyses, indicating that self-reported symptoms potentially consistent with CTS, whether localized to the distribution of the median nerve or not, had statistically significant associations with median mononeuropathy regardless of threshold criterion (χ^2 = 20.3, 3 df, $p < 0.001$ for 0.5 ms criterion using hand diagrams; χ^2 = 29.7, 3 df, $p < 0.001$ for 0.8 ms criterion using hand diagrams; χ^2 = 16.1, 1 df, $p < 0.001$ for 0.5 ms criterion using non localized symptoms; χ^2 = 21.4, 1 df, $p < 0.001$ for 0.8 ms criterion using non localized symptoms).

There were 79 subjects (19.4%) with hand diagrams of the non dominant extremity scored as 'classic', 'probable' or 'possible' (see Table 3). In contrast to the dominant hands, there were only 36 subjects (8.9%) who reported (non localized) symptoms of numbness, burning, tingling or pain in the non dominant fingers, hand or wrist with nocturnal occurrence in the non dominant hands (see Table 4). Cross-tabs analyses were statistically significant in all cases except for the analysis of hand diagrams using the 0.8 ms criterion for median mononeuropathy (χ^2 = 9.69, 3 df, p = 0.021 for 0.5 ms criterion using hand diagrams; χ^2 = 1.596, 3 df, p = 0.660 for 0.8 ms criterion using hand diagrams; χ^2 = 7.037, 1 df, p = 0.008 for 0.5 ms criterion using non localized symptoms; χ^2 = 4.145, 1 df, p = 0.042 for 0.8 ms criterion using non localized symptoms). The values of the non dominant χ^2 statistics were less than the values for the corresponding analyses of the dominant hands. These results suggest that self-reported symptoms potentially consistent with CTS in the non dominant hands, whether reported via hand diagrams or otherwise, have a weaker statistical association with electrophysiologically determined median nerve function than in the dominant hands.

Table 3. Association Between Hand Diagram Ratings and Electrodiagnostic Test Results for Median Mononeuropathy in Dominant and Nondominant Hands[a]

Hand diagram ratings	Fulfills 0.5 ms criterion for median mononeuropathy		Fulfills 0.8 ms criterion for median mononeuropathy		
	Yes D/ND	No D/ND	Yes D/ND	No D/ND	Totals D/ND
Classic	15/10	16/18	12/4	19/24	31/28
Probable	3/2	14/13	2/1	15/14	17/15
Possible	9/6	23/30	3/3	29/33	32/36
Unlikely	53/45	275/284	25/25	303/304	328/329
Totals	80/63	328/345	42/33	366/375	408/408

[a]D = dominant hands; ND = nondominant hands; ms = milliseconds; χ^2 for 0.5 ms criterion for median mononeuropathy for dominant hands = 20.3; 3 degrees of freedom; $p < 0.001$; χ^2 for 0.8 ms criterion for median mononeuropathy for dominant hands = 29.7; 3 degrees of freedom; $p < 0.001$; χ^2 for 0.5 ms criterion for median mononeuropathy for nondominant hands = 9.69; 3 degrees of freedom; $p < 0.021$; χ^2 for 0.8 ms criterion for median mononeuropathy for nondominant hands = 1.596; 3 degrees of freedom; $p < 0.660$.

Table 4. Association Between Distal Extremity Symptoms Consistent with Carpal Tunnel Syndrome with Nocturnal Symptoms and Electrodiagnostic test Results in the Dominant and Non Dominant Hands[a]

Distal extremity symptoms *with* nocturnal symptoms	Fulfills 0.5 ms criterion for median mononeuropathy		Fulfills 0.8 ms criterion for median mononeuropathy		
	Yes D/ND	No D/ND	Yes D/ND	No D/ND	Totals D/ND
Present	26/11	44/25	18/6	52/30	70/36
Absent	54/51	281/317	24/26	311/342	335/368
Totals	80/62	325/342	42/32	363/372	405/404

[a]See text for explanation; D = dominant hands; ND = nondominant hands; ms = milliseconds; χ^2 for 0.5 ms criterion for median mononeuropathy for dominant hands = 16.1; 1 degree of freedom; $p < 0.001$; χ^2 for 0.8 ms criterion for median mononeuropathy for dominant hands = 21.4; 1 degree of freedom; $p < 0.001$; χ^2 for 0.5 ms criterion for median mononeuropathy for nondominant hands = 7.037; 1 degree of freedom; $p = 0.008$; χ^2 for 0.8 ms criterion for median mononeuropathy for nondominant hands = 4.145; 1 degree of freedom; $p = 0.042$.

The sensitivity's, specificity's, positive predictive values and negative predictive values for hand diagram scores and non localized distal extremity symptoms are shown in Table 5. In order to ensure direct comparability of results, all predicted values have been calculated assuming a prevalence of median mononeuropathy of 15%. Hand diagram scores are grouped and analyzed according to 'any positive hand diagram', 'classic or probable hand diagram', and only 'classic hand diagram'.

The sensitivity's for hand diagrams of the dominant hands range from 0.19 to 0.40, and the positive predictive values range from 0.27 to 0.49 (see Table 5). For all 3 hand diagram groupings (for dominant hands), the sensitivity's and positive predictive values were slightly higher when using the more stringent electrodiagnostic criterion. The specificity's and negative predictive values of hand diagrams were high in all cases. Comparisons of the hand diagram results with non localized distal extremity symptoms consistent with CTS indicate that hand diagrams tend to have similar or lower sensitivity's; the positive predictive values of hand diagrams straddled the positive predictive values for non localized symptoms consistent with CTS. The specificity and negative predictive value of distal extremity symptoms with nocturnal occurrence were high, and similar to the values obtained for hand diagrams.

The analogous results for non dominant hands are also shown in Table 5. Overall, the results for the non dominant hands are similar to those for the dominant hands, except that the positive predictive values for the non dominant hands are less than the corresponding positive predictive values of the dominant hands in all cases. Also, when using the 0.8 millisecond criterion to define median mononeuropathy, the sensitivity's of hand diagrams and non localized symptoms consistent with CTS in the non dominant hands were much less than those for the dominant hands.

Table 5. Sensitivity's, Specificity's, and Predictive Values of Hand Diagrams, and Distal Extremity Symptoms with Nocturnal Symptoms in Dominant and Nondominant Hands[a]

	Median mono.—0.5				Median mono.—0.8			
	Sen D/ND	Spec D/ND	PPV[b] D/ND	NPV[b] D/ND	Sen D/ND	Spec D/ND	PPV[b] D/ND	NPV[b] D/ND
Any positive hand diagram	.34/.23	.84/.86	.27/.23	.88/.86	.40/.10	.83/.92	.29/.19	.89/.85
"Classic" *or* "probable" hand diagram	.23/.28	91/.86	.30/.26	.87/.87	.33/.12	.91/.92	.39/.21	.89/.86
Only "classic" hand diagram	.19/.36	.95/.86	.40/.31	.87/.88	.29/.14	.95/.92	.49/.25	.88/.86
Distal extremity Sx *with* nocturnal Sx	.33/.31	.86/.86	.30/.28	.88/.88	.43/.17	.86/.93	.35/.29	.90/.86

[a]See text for explanation; D = dominant hands; ND = nondominant hands; PPV = positive predictive value; NPV = negative predictive value; Sen = sensitivity; Spec = specificity.
[b]PPV and NPVs have been calculated assuming 15% prevalence of median mononeuropathy.

DISCUSSION

We present test performance characteristics of hand diagrams in comparison to median mononeuropathy in dominant and non dominant extremities. In addition, the test performance of non localized distal upper extremity symptoms potentially consistent with CTS are also compared to the same electrodiagnostic criteria. The 'gold standards' employed in this study are the electrophysiological measurements. While median mononeuropathy, as defined in this study, is not intended to be held absolutely equivalent to CTS, electrophysiological testing is considered to be the most accurate procedure for detecting CTS[17], and it has the advantage of being an objective test. The blinded nature of the screening evaluations performed during the field surveys did not permit full clinical evaluations and diagnoses in the usual sense.

Overall, in the dominant hands the positive predictive values of hand diagram scores appeared to be somewhat higher than positive predictive values of non localized symptom reporting, while the sensitivity's of the latter were somewhat higher than the former. The negative predictive values were essentially the same. The specificity of non localized symptoms with nocturnal occurrence was in the same range as the various hand diagrams scoring schemes. Analyses using the two different electrodiagnostic criteria for defining median mononeuropathy did not produce very different results: overall, the performance of hand diagrams was not much different from that of non localized symptoms potentially consistent with CTS in the dominant hands.

The results for non dominant hands demonstrate that hand diagrams and non localized symptoms potentially consistent with CTS have a weaker statistical relationship with electrophysiologically determined median nerve dysfunction than that found for dominant hands. Also, the sensitivity's and positive predictive values of the various configurations of self-reported symptoms were lower in the non dominant hands compared to the dominant hands. Therefore, symptoms potentially consistent with CTS, whether recorded on hand diagrams or non localized to the distribution of the median nerve in the hand, are even less predictive of electrophysiologically determined median nerve dysfunction in the non dominant hands.

There are a number of differences between this study and previous reports using essentially the same hand diagram instrument. Most important, the earlier studies involved patients referred for medical evaluation of wrist and/or other upper extremity complaints[6,7]. In a prospective study, 41% of the subjects were disabled because of their upper extremity condition, or they were unemployed or retired[7].

In previous studies, hand diagram scores were compared to clinical diagnoses of CTS[6] or to nerve conduction studies[7]. These gold standards' differ from the electrophysiologic criteria used to define median mononeuropathy in the present study. The sensitivity's, specificity's, and predictive values from the previous studies are summarized in Table 6. The previously reported sensitivity's for hand diagrams are much higher than results in the present study (compare Table 6 to Table 5). It is possible that some of the differences in sensitivity's, specificity's, and predictive val-

ues are attributable to differences in the 'gold standards' utilized in these different reports.

In addition, the markedly higher hand diagram sensitivity's reported in previous studies may, in part, reflect better performance of this tool among subjects with more severe median nerve lesions at the wrist, or in populations with greater prevalence of median nerve dysfunction. To test this latter hypothesis using our current data, we excluded subjects without any upper extremity complaints, and then repeated the analyses shown in Table 5 for hand diagrams (N = 257). The sensitivity's increased in all cases when comparing this 'symptomatic' subset of the study cohort to the entire study group (data not shown), which would be consistent with improved test performance of hand diagrams in settings with more prevalent distal extremity symptoms.

Subjects referred for medical evaluation in previous studies had a very high prevalence of CTS or median nerve dysfunction (88.2%[6] and 36.6%[7]). We recalculated the predictive values in the previous studies assuming a 15% prevalence of CTS, or median nerve dysfunction, to permit direct comparison to results in the present study. Reducing the prevalence of disease to 15% serves to reduce most

Table 6. Sensitivity's, Specificity's, and Predictive Values of Previously Published Studies of Hand Diagram Results[a]

	As published				Re-calculated[b]	
	Sensitivity	Specificity	PPV	NPV	PPV	NPV
Reference 6[c]						
Any positive hand diagram	.99	.50	.94	.83	.26	~1.00
"Classic" *or* "probable" hand diagram	.80	.90	.98	.38	.59	.96
Only "classic" hand diagram	.43	1.00	1.00	.19	1.00	.91
Reference 7[d]						
Any positive hand diagram	.96	.23	.42	.91	.18	.97
"Classic" *or* "probable" hand diagram	.64	.73	.58	.78	.29	.92
Only "classic" hand diagram	.34	.87	.60	.70	.32	.88

[a]PPV = positive predictive value; NPV = negative predictive value.
[b]PPVs and NPVs have been recalculated assuming 15% prevalence of CTS or median nerve abnormalities.
[c]Prevalence of CTS in original study population was 88.2%.
[d]Prevalence of median nerve dysfunction in original study population was 36.6%.

positive predictive values to the range of values found in the present study (see original and recalculated values in Table 6).

The present study involved active workers, and therefore provides a better indication of the expected test performance of hand diagrams as a workplace screening tool for median nerve dysfunction and/or CTS. The present study also included workplaces with a wide range of potential ergonomic stressors, which we believe would tend to enhance the generalizability of the results. It is possible that the type of work/ergonomic stressors, presence or absence of union representation, age, gender, or other unmeasured variables may have produced confounding that influenced the findings. However, the internal consistency of our results, and the similarity of our results with those of Katz et al[6,7] (when recalculated as in Table 6), would suggest that any confounding produced by such factors is unlikely to be significant. Therefore, we believe that the present findings are robust.

The portion of the hand diagram including the fingers, hands and wrists was the same in this study as in previous reports. However, some changes were made to the overall diagram and to the instructions to subjects. We chose not to include the additional diagram of the entire arm up to the shoulder, as did Katz et al.,[6] since this portion of the diagram has no impact on scoring. In addition, the instructions given to subjects differed slightly from those of Katz et al[6]. Specifically, there was no reference to "decreased sensation"[6], and we added 'burning' as a symptom. Also, subjects were not instructed to use different shading schemes for each symptom (e.g., stippling for tingling, cross-hatches for numbness, etc.)[6] since such differential shading has no impact on scoring. We believe that the changes we introduced are minor, and would not account for much of the apparent difference in test performance.

Not all configurations of hand diagram scores had a statistically significant association with median mononeuropathy (see Table 3). The sensitivity's and positive predicted values of hand diagrams were poorer than had been reported previously, particularly for the non dominant hands. While some test characteristics of hand diagrams were better than those for non localized distal extremity symptoms consistent with CTS, some were worse. Overall, our data suggest that hand diagrams are no better than a questionnaire which queries subjects for (non localized) symptoms consistent with CTS in the wrists, hands or fingers (with nocturnal occurrence of symptoms). The choice of screening tool may depend on the goal of screening, in particular, whether it is more desirable to have slightly higher sensitivity or positive predictive value, and whether the focus is on both hands or only the dominant extremity.

In our opinion, use of questionnaire or hand diagram results as the sole basis of referral of workers for full diagnostic evaluation for possible CTS would result in a considerable number of false-positive work-ups, and so caution should be exercised if these tools are applied in this manner. Clearly, this is a limitation of the possible goals achievable with active workplace surveillance for CTS. The other potential goals of active workplace surveillance mentioned earlier (estimation of prevalence of CTS, better targeting of interventions, and assessment of impact of workplace interventions) may still be achievable with questionnaire instruments.

Workplace surveillance programs for CTS, and cumulative trauma disorders in general, need to be designed with clear goals in mind, and with an awareness of potential limitations.

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