Physical Examination Has a Low Yield in Screening for Carpal Tunnel Syndrome

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Background *Physical examination is often used to screen workers for carpal tunnel syndrome (CTS). In a population of newly hired workers, we evaluated the yield of such screening.*

Methods *Our study population included 1,108 newly hired workers in diverse industries. Baseline data included a symptom questionnaire, physical exam, and bilateral nerve conduction testing of the median and ulnar nerves; individual results were not shared with the employer. We tested three outcomes: symptoms of CTS, abnormal median nerve conduction, and a case definition of CTS that required both symptoms and median neuropathy.*

Results *Of the exam measures used, only Semmes–Weinstein sensory testing had a sensitivity value above 31%. Positive predictive values were low, and likelihood ratios were all under 5.0 for positive testing and over 0.2 for negative testing.*

Conclusion *Physical examination maneuvers have a low yield for the diagnosis of CTS in workplace surveillance programs and in post-offer, pre-placement screening programs.* Am. J. Ind. Med. 54:1–9, 2011. *© 2010 Wiley-Liss, Inc.*

KEY WORDS: carpal tunnel syndrome; post-offer pre-placement examinations; physical examination; screening; clinical epidemiology

INTRODUCTION

Carpal Tunnel Syndrome (CTS) is a common and costly disease among working-aged adults, with a prevalence between 1% and 5% among the general population [de Krom et al., 1992; Atroshi et al., 1999; Armstrong et al., 2008a]. It is a leading cause of work-related disability, resulting in a median of 27 days away from work per reported case in the United States [U.S. Department of Labor, 2006]. The public health importance of CTS has led to efforts to define screening and surveillance strategies as well as epidemiological case definitions.

Surveillance programs for work-related CTS have been instituted both in the United States and abroad [Lalich and Sestito, 1997; Davis et al., 2001; Bland and Rudolfer, 2003; Roquelaure et al., 2008]. Screening programs have also been implemented for early detection of CTS [Lundstrom et al., 1992; Murata et al., 1996]. A variety of physical exam procedures involving inspection, palpation, provocation maneuvers, and tests of strength and resistance have been used for the diagnosis of this disease [Phalen, 1966; Szabo et al., 1999; D'Arcy and McGee, 2000; Sesto et al., 2003; Graham et al., 2006; Boland and Kiernan, 2009]. Most of these measures address one or more characteristics of the syndrome, such as sensory or motor loss. Physical

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examination measures, like those that were used for the current study, have shown usefulness in some clinical settings [Marx et al., 1999; Massy-Westropp et al., 2000; MacDermid and Wessel, 2004; Graham et al., 2006]. However, in a general population with a low prevalence of CTS, previous literature has questioned whether the physical exam should be relied upon for worker screening and surveillance. In such a population, these measures tend to have a low positive predictive value and poor validity compared to median nerve conduction testing [de Krom et al., 1992; Franzblau et al., 1993]. Despite the reported low yield of physical examination maneuvers, such maneuvers continue to be used as part of employer-mandated screening programs. Both peer-reviewed literature and employer newsletters have discussed and advocated the use of post-offer, pre-placement employment screens as well as ongoing employee health surveillance screening for the past two decades [Growing nerve-test industry, 1993; Bingham et al., 1996; Special Report, 1997; Homan et al., 1999; Sluiter et al., 2001]. Though, no national statistics exist about the frequency of such employment screening, many providers offer physical testing programs with the aim of lowering injury costs among newly hired workers. In fact, one national company alone has conducted over 400,000 such screenings [WorkSTEPS Inc, 2009]. Employment screens commonly include the use of physical examination testing as part of their protocol. But in populations of healthy workers, who may be expected to have mild symptom severity and low prevalence of the disease, clinical tests for CTS may lead to a large portion of workers testing falsely positive and undergoing unnecessary further examination or inappropriate job placement [Franzblau et al., 2004]. Considering the apparent widespread use of physical exam measures in employment screening, it is important to study how well the physical exam performs in a population representative of those currently undergoing employment screening nationwide. The purpose of this study was to determine the yield of commonly used physical examination screening measures for CTS in a large group of newly hired workers.

METHODS

Subject Recruitment and Eligibility

We analyzed the baseline data from the Predicting CTS study in St. Louis, MO (PrediCTS study) [Armstrong et al., 2008b]. Subjects were recruited from eight employers and three construction trade union apprenticeship programs between July 2004 and October 2006. Subjects were eligible if they were over the age of 18 years and starting a new full-time job (over 30 hr per week) or changing their work benefits status. Subjects were excluded if they had a current or previous diagnosis of CTS or peripheral neuropathy, if they reported a contraindication to nerve conduction studies, or were pregnant. Recruitment occurred during employee orientations, classes at apprenticeship programs, or at the time of employer mandated post-offer, pre-placement screening, depending on the individual company or employer involved. Industries represented included manufacturing, construction, biotechnology, and healthcare. The Washington University School of Medicine and University of Michigan's Institutional Review Boards approved this study, and all subjects provided written informed consent prior to participation. A certificate of confidentiality was obtained to better protect the confidentiality of subjects' information, so that subjects would be more confident that their personal information would not be shared with their employers and thus be more likely to disclose the presence of symptoms.

Data Collection

Subjects were tested at the time of enrolment in the study. Testing consisted of a self-administered questionnaire, a physical examination, and nerve conduction studies. All examiners were members of the research team and included an occupational physician, three occupational therapists, two physical therapy assistants, an occupational therapy assistant, and two senior medical students. Each examiner was instructed in a standardized physical examination testing procedure and demonstrated proficiency before collecting study data. Periodic re-evaluation of examiners' performance was assessed over the course of the study.

Symptom Definition

Symptoms of the hand and wrist were assessed in the self-administered questionnaire (''In the past YEAR, have you had RECURRING (repeated) symptoms in your HANDS, WRISTS, or FINGERS more than three times or lasting more than ONE week?''). To clarify the localization and types of symptom, a modified Katz hand diagram was also completed by each subject [Katz et al., 1990]. A team of three health professionals (two physicians and an occupational therapist) independently rated each Katz hand diagram as ''Unlikely,'' ''Possible,'' ''Probable,'' or ''Classic'' for CTS [Franzblau et al., 1994]; disagreement between the reviewers was resolved by consensus. We have previously shown high rates of agreement for these Katz hand diagram ratings [Dale et al., 2008].

Physical Examination Testing

The physical exam included Semmes–Weinstein sensory testing (tested with a 2.83 and 3.61 mm monofilament), Tinel's test, and Phalen's maneuver following recommended procedures [Stone, 1992; Palumbo and Szabo, 2002].

Nerve Conduction Testing

Examiners performed median and ulnar sensory and motor nerve conduction studies at the wrist bilaterally using the NC-Stat automated nerve conduction testing device (NEUROMetrix, Inc., Waltham, MA). This clinical tool has been found to have reliability and criterion validity similar to traditional methods of nerve conduction testing [Rempel et al., 1998; Leffler et al., 2000; Kong et al., 2006; Armstrong et al., 2008b]. Prior to data collection, all examiners demonstrated proficiency in use of the device following the standard testing procedures recommended by the manufacturer. The NC-Stat required placement by the examiner of self-adhesive electrodes at the wrist and fingers using anatomic landmarks; the distance in centimeters between the wrist and the finger electrodes was measured as part of the testing protocol. The NC-State device then followed an automated testing protocol to measure median and ulnar distal motor latencies (wrist-thenar eminence and wrist-hypothenar eminence) and distal sensory latencies (wrist-third finger and wrist-fifth finger). Because the NC-Stat sensory electrodes are placed by reference to anatomic landmarks (the distal wrist crease and the finger crease of the proximal interphalangeal joint), the distance between the wrist and finger electrodes for median nerve measurements varied between 10.2 and 17.4 cm in our subjects. We normalized the measured sensory latencies for each subject to standard 14 cm latencies using the measured nerve conduction velocity. We calculated median-ulnar sensory latency difference (MUDS).

Data Analysis

We defined three different CTS outcomes, based on different case definitions used in epidemiologic studies [Katz et al., 1990; Rempel et al., 1998]:

1. CTS symptoms of the hand defined as a ‘‘classic’’ or ‘‘probable’’ rating on the modified Katz hand diagram.
2. Abnormal median nerve conduction, defined as sensory latency >3.5 ms (14 cm) or motor latency >4.5 ms or MUDS of >0.5 ms (14 cm).
3. A CTS case definition drawn from the consensus criteria of Rempel et al. [1998] requiring both symptoms (a ‘‘classic’’ or ‘‘probable’’ rating on a modified Katz hand diagram) and abnormal median nerve conduction (as defined above).

Using these outcomes as referents, we calculated the sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), likelihood ratios (LRs) for positive and negative testing, and the ratio of LR+/LR− for each physical exam measure to illustrate their yield when compared to symptoms, nerve conduction studies, or their combination [Deeks and Altman, 2004; Haynes et al., 2006]. The ratio of LR+ to LR− may be used to note the separation of the positive and negative test results. Desirable tests show large positive LR values and small negative LR values, producing a large ratio. According to Jekel et al. [1996], a score of 50 or higher indicates desirable test performance. LR were considered statistically significant if the confidence interval did not include a value of one. We collected data for both the right and left hands. In comparing the physical exam measures and nerve conduction results, data were segregated by hand in order to ensure independence of the observations. We also described the yield of the physical examination in those workers who reported symptoms in the hand or fingers (excluding those who reported symptoms only in the wrist) [Gerr and Letz, 1998]. Statistical Analysis Software (SAS v8.2; SAS institute Inc, Cary, NC) and Statistical Package for Social Science (SPSS v11.0; SPSS Inc, Chicago, MC) were used for all analyses.

RESULTS

This population of 1,108 newly hired workers was predominately male gender (65%), young, with mean age of 30.3 years (SD 10.3), and had a mean body mass index (BMI) of 28.4 kg/m^2 (SD 6.5), reflecting the characteristics of the US population. As expected for a population of young workers, the prevalence of chronic diseases was low for diabetes, degenerative arthritis, and thyroid disease (2.4%, 2.1%, 2.3% respectively). Subjects came from three main occupational groups: construction apprentices (41.3%), office and laboratory workers (35.0%), and service workers/housekeepers (23.7%). Table I summarizes the frequency of abnormal findings for each physical exam measure. The number of subjects varied slightly for each procedure because of missing data for a small number of cases. The percent of cases with missing data ranged from 0% to 0.9%.

A large proportion of subjects (n = 449, 40.8% in the right hand) had one or more abnormal physical examination findings, though all three tests were abnormal in very few subjects (n = 20, 1.8% in the right hand). Semmes–Weinstein sensory testing, defined as abnormal for subjects who failed to respond to the 2.83 mm diameter monofilament, was the most frequent finding (n = 343, 31.2% in the right hand). Using the 3.61 mm monofilament to determine abnormal findings produced much lower rates (n = 16, 1.5% right hand). Abnormal median nerve conduction was seen frequently (n = 306, 28.7% in the right hand), though many fewer subjects had symptoms typical of CTS, or met the CTS case definition of symptoms plus median nerve conduction abnormalities (2.3% right hand, 1.0% left hand). Figure 1 illustrates the frequency of positive physical exam findings for Tinel's test, Phalen's test, and Semmes–Weinstien's test. The Venn diagram shows that for the right hand, 20 of the 1,108 subject (1.8%) had positive findings of all three tests,

TABLE I. Distribution of Abnormal Findings and Cases for Each Study Outcome

	Abnormal (% abnormal) n = 1,108	
	Right hand	Left hand
Semmes–Weinstein	345 (31.2%)	289 (26.1%)
Tinel's test	129 (11.7%)	119 (10.8%)
Phalen's test	105 (9.5%)	101 (9.2%)
One or more tests abnormal[a]	451 (40.7%)	421 (38.0%)
Tinel's test and Semmes–Weinstein	59 (5.3%)	38 (3.4%)
Phalen's test and Semmes–Weinstein	52 (4.7%)	31 (2.8%)
Phalen's test and Tinel's test	37 (3.3%)	26 (2.4%)
All three tests abnormal[b]	20 (1.8%)	7 (0.6%)
Katz hand diagrams[c]	38 (3.4%)	26 (2.4%)
Median nerve conduction[d]	306 (28.7%)	263 (24.4%)
Consensus criteria CTS definition[e]	24 (2.3%)	11 (1.0%)
Any hand or finger symptom	113 (10.2%)	76 (6.9%)

[a]Positive in one or more of Semmes–Weinstein sensory testing, Phalen's test, or Tinel's test.
[b]Positive in all of Semmes–Weinstein sensory testing, Phalen's test, and Tinel's test.
[c]We defined abnormal Katz hand diagram as a "probable" or "classic" rating.
[d]We defined abnormal median nerve conduction as a sensory latency >3.5 ms OR motor latency of >4.5 ms or MUD of >0.5 ms.
[e]A case of CTS according to the consensus criteria [Rempel et al., 1998] consists of a "probable" or "classic" hand diagram rating combined with abnormal median nerve conduction.

few cases had positive results on two tests but 34% of the cohort had positive findings on only one physical test. Left hand results were similar. Abnormal physical findings frequently occurred in isolation, with only one of the three findings abnormal. Figure 2 illustrates the low prevalence of CTS cases by definition based on symptoms of CTS and median neuropathy (0.7% right hand, 0.4% left hand) or when physical exam test results are included (1.4% right hand, 0.6% left hand). There is a higher proportion of physical exam findings that overlap with nerve conduction abnormalities (13.5% right hand, 10.9% left hand).

Tables II–IV summarize the agreement between physical exam measures, alone and in combination, compared to

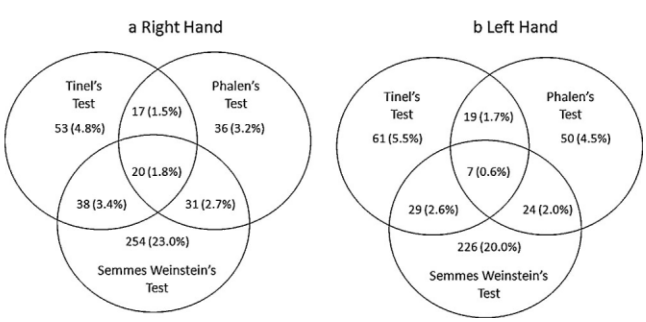

FIGURE 1. Frequency of positive physical exam findings for three tests of the right and left hands.

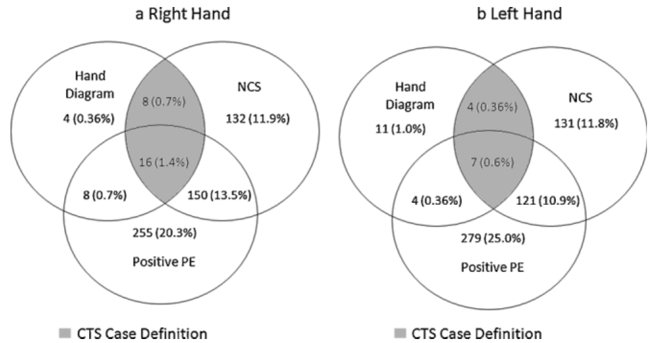

FIGURE 2. Frequency of overlap of positive symptoms, physical exam results and abnormal nerve conduction studies of the right and left hands.

our three CTS outcomes of CTS hand symptoms, abnormal median nerve conduction, and consensus case definition of CTS.

Although there was some variability within the results, the physical examination tests, alone and in combination, agreed poorly with our three case definitions of CTS. Some maneuvers had good specificity (they were usually normal in subjects without CTS); they all showed poor sensitivity (they were frequently normal in subjects with CTS). The difference in prevalence of positive exam findings between the right and left hands had little effect on the PPV and NPV. Using a more conservative criteria for the Semmes–Weinstein monofilament testing (lack of response to the 3.61 mm) provided few cases but better specificity and much poorer sensitivity (specificity = 99.5%; sensitivity = 3.2%) for the outcome of abnormal nerve conduction, with similar results for the other case definitions. Although some of the LR for positive and for negative tests were statistically significant, most had relatively small values and did not demonstrate clinically meaningful test performance [Jekel et al., 1996]. When compared to the consensus case definition of CTS (symptoms plus median neuropathy—Table IV), physical examination maneuvers had poor positive predictive values (3.7–14.3%), indicating that the likelihood of CTS was low following an abnormal physical examination finding. Modest LR were seen for some combinations of two or more abnormal tests, indicating that the post-test odds of disease were altered in those subjects having two or more abnormal physical examination tests.

Contrary to our expectation, the LRs were lower when physical examination maneuvers were examined in those subjects with hand and finger symptoms, though the PPV increased due to the higher prevalence of CTS in this population (Table V). When analyzing subjects with hand and finger symptoms, physical exam sensitivities and PPVs increased, although specificities and NPVs decreased across the board. Further, positive LRs decreased and negative LRs increased, with little change to confidence intervals,

TABLE II. Validity of Physical Exam Measures Using the Modified Katz Hand Diagram as a Gold Standard*

Katz hand diagram		Sensitivity (%)	Specificity (%)	PPV[a] (%)	NPV[a] (%)	LR+	LR−	LR+/LR−
Semmes–Weinstein	R	57.9	69.8	6.4	97.9	1.9 (1.44–2.53)	0.6 (0.41–0.88)	3.2
	L	34.6	74.1	3.1	97.9	1.3 (0.78–2.27)	0.9 (0.67–1.17)	1.5
Tinel's test	R	29.7	89.0	8.5	97.3	2.7 (1.59–4.43)	0.8 (0.64–0.98)	3.4
	L	19.2	89.4	4.2	97.9	1.8 (0.81–4.01)	0.9 (0.75–1.09)	2.0
Phalen's test	R	27.0	91.1	9.5	97.3	3.0 (1.73–5.17)	0.8 (0.66–0.98)	3.8
	L	8.0	90.8	2.0	97.7	0.9 (0.23–3.28)	1.0 (0.90–1.14)	0.9
One or more tests abnormal[b]	R	68.4	60.3	5.8	98.2	1.7 (1.37–2.16)	0.5 (0.33–0.84)	3.3
	L	42.3	62.1	2.6	97.8	1.1 (0.71–1.76)	0.9 (0.67–1.30)	1.2
Tinel's test and SW	R	21.1	95.2	13.6	97.1	4.4 (2.26–8.20)	0.8 (0.70–0.98)	5.3
	L	11.5	96.8	7.9	97.9	3.6 (1.17–10.36)	0.9 (0.80–1.05)	3.9
Phalen's test and SW abnormal	R	21.1	95.9	15.4	97.2	5.1 (2.59–9.50)	0.8 (0.70–0.97)	6.2
	L	7.7	97.3	6.5	97.8	2.9 (0.72–10.88)	0.9 (0.85–1.06)	3.0
Phalen's test and Tinel's test	R	7.9	96.8	8.1	96.7	2.5 (0.80–7.37)	1.0 (0.87–1.04)	2.6
	L	3.8	97.7	3.8	97.7	1.7 (0.23–11.39)	1.0 (0.91–1.06)	1.7
All three tests abnormal[c]	R	5.3	98.3	10.0	96.7	3.1 (0.75–12.07)	1.0 (0.89–1.04)	3.2
	L	3.8	99.4	14.3	97.7	6.9 (0.87–47.45)	1.0 (0.90–1.04)	7.2

NPV, Negative predictive value; PPV, Positive predictive value; LR, likelihood ratio, SW, Semmes–Weinstein.
*We defined abnormal Katz Hand diagram as a "probable" or "classic" rating.
[a]These calculations used the observed prevalence for the right and left hands shown in Table I.
[b]Positive in one or more of Semmes–Weinstein sensory testing, Phalen's test, or Tinel's test.
[c]Positive in all of Semmes–Weinstein sensory testing, Phalen's test, and Tinel's test.

TABLE III. Validity of Physical Exam Measures Using Abnormal Nerve Conduction as a Gold Standard*

Hand median neuropathy		Sensitivity (%)	Specificity (%)	PPV[a] (%)	NPV[a] (%)	LR+	LR−	LR+/LR−
Semmes–Weinstein	R	45.2	74.8	41.9	77.3	1.8 (1.51–2.07)	0.7 (0.66–0.82)	2.5
	L	35.7	76.8	33.2	78.7	1.5 (1.25–1.83)	0.8 (0.76–0.92)	1.8
Tinel's test	R	16.8	90.5	41.5	73.2	1.8 (1.27–2.30)	0.9 (0.87–0.97)	1.9
	L	13.4	89.9	29.9	76.3	1.3 (0.91–1.82)	1.0 (0.91–1.02)	1.4
Phalen's test	R	12.1	91.7	37.0	72.1	1.5 (0.99–1.99)	1.0 (0.91–1.00)	1.5
	L	11.5	91.6	30.6	76.2	1.4 (0.91–1.93)	1.0 (0.92–1.01)	1.4
One or more tests abnormal[b]	R	54.2	65.4	38.7	78.0	1.6 (1.36–1.78)	0.7 (0.61–0.80)	2.2
	L	48.7	65.3	31.1	79.8	1.4 (1.20–1.62)	0.8 (0.69–0.89)	1.8
Tinel's test and SW	R	9.5	96.2	50.0	72.5	2.5 (1.51–3.54)	0.9 (0.91–0.98)	2.6
	L	5.3	97.1	36.8	76.1	1.8 (0.95–3.02)	1.0 (0.95–1.01)	1.9
Phalen's test and SW abnormal	R	8.2	96.7	50.0	72.3	2.5 (1.45–3.64)	0.9 (0.92–0.98)	2.6
	L	4.6	97.7	38.7	76.0	2.0 (0.96–3.42)	1.0 (0.95–1.01)	2.0
Phalen's test and Tinel's test	R	4.2	97.2	38.2	71.6	1.5 (0.78–2.63)	1.0 (0.96–1.01)	1.6
	L	2.3	97.7	24.0	75.6	1.0 (0.39–2.16)	1.0 (0.98–1.02)	1.0
All three tests abnormal[c]	R	2.3	98.4	36.8	71.4	1.4 (0.58–3.02)	1.0 (0.97–1.01)	1.5
	L	0.4	99.3	14.3	75.5	0.5 (0.06–3.66)	1.0 (0.99–1.01)	0.5

NPV, Negative predictive value; PPV, Positive predictive value; LR, likelihood ratio, SW, Semmes–Weinstein.
*We defined abnormal Katz Hand diagram as a "probable" or "classic" rating.
[a]These calculations used the observed prevalence for the right and left hands shown in Table I.
[b]Positive in one or more of Semmes–Weinstein sensory testing, Phalen's test, or Tinel's test.
[c]Positive in all of Semmes–Weinstein sensory testing, Phalen's test, and Tinel's test.

TABLE IV. Validity of Physical Exam Measures Using the Consensus Criteria CTS Case Definition (CTS Symptoms Plus Abnormal Median Nerve Conduction) as a Gold Standard

CTS case definition hand		Sensitivity (%)	Specificity (%)	PPV[a] (%)	NPV[a] (%)	LR+	LR−	LR+/LR−
Semmes–Weinstein	R	66.7	69.9	4.9	98.9	2.2 (1.64–2.96)	0.5 (0.27–0.84)	4.6
	L	54.5	74.0	2.1	99.4	2.1 (1.21–3.61)	0.6 (0.32–1.17)	3.4
Tinel's test	R	26.1	88.8	4.9	98.2	2.3 (1.14–4.63)	0.8 (0.65–1.06)	2.8
	L	27.3	89.3	2.6	99.2	2.5 (0.95–6.69)	0.8 (0.57–1.17)	3.1
Phalen's test	R	29.2	91.0	7.0	98.2	3.3 (1.69–6.09)	0.8 (0.60–1.01)	4.2
	L	18.2	90.9	2.0	99.1	2.0 (0.56–7.03)	0.9 (0.68–1.19)	2.2
One or more tests abnormal[b]	R	66.7	60.4	3.7	98.7	1.7 (1.26–2.25)	0.6 (0.31–0.97)	3.0
	L	63.6	62.1	1.7	99.4	1.7 (1.07–2.64)	0.6 (0.27–1.28)	2.9
Tinel's test and SW	R	25.0	95.0	10.3	98.2	5.0 (2.39–10.04)	0.8 (0.63–0.99)	6.3
	L	18.2	96.6	5.3	99.1	5.4 (1.48–18.90)	0.8 (0.64–1.12)	6.4
Phalen's test and SW abnormal	R	29.2	95.9	14.0	98.3	7.1 (3.55–13.22)	0.7 (0.57–0.96)	9.6
	L	18.2	97.3	6.5	99.1	6.7 (1.82–23.47)	0.8 (0.64–1.11)	8.0
Phalen's test and Tinel's test	R	8.3	96.9%	5.9	97.9	2.7 (0.69–10.24)	0.9 (0.84–1.07)	2.9
	L	9.1	97.8	4.0	99.1	4.0 (0.60–26.22)	0.9 (0.77–1.12)	4.3
All three tests abnormal[c]	R	8.3	98.4	10.5	97.9	5.1 (1.25–19.28)	0.9 (0.83–1.05)	5.5
	L	9.1	99.4	14.3	99.1	16.2 (2.12–104.87)	0.9 (0.76–1.10)	17.7

NPV, Negative predictive value; PPV, Positive predictive value; LR, likelihood ratio, SW, Semmes–Weinstein.
[a]These calculations used the observed prevalence for the right and left hands shown in Table I.
[b]Positive in one or more of Semmes–Weinstein sensory testing, Phalen's test, or Tinel's test.
[c]Positive in all of Semmes–Weinstein sensory testing, Phalen's test, and Tinel's test.

TABLE V. Validity of Physical Exam Measures Using the CTS Consensus Case Definition as a Gold Standard Among Subjects Who Reported Hand Symptoms (Right hand: n = 113; Left hand: n = 76)

CTS definition symptoms		Sensitivity (%)	Specificity (%)	PPV[a] (%)	NPV[a] (%)	LR+	LR−	LR+/LR−
Semmes–Weinstein	R	66.7	51.6	24.1	87.0	1.4 (0.95–1.99)	0.6 (0.34–1.22)	2.1
	L	54.5	62.5	20.0	88.9	1.5 (0.78–2.63)	0.7 (0.37–1.43)	2.0
Tinel's test	R	25.0	76.9	19.2	82.4	1.1 (0.46–2.38)	1.0 (0.74–1.29)	1.1
	L	27.3	82.8	21.4	86.9	1.6 (0.53–4.29)	0.9 (0.60–1.28)	1.8
Phalen's test	R	28.6	75.6	21.4	81.9	1.2 (0.54–2.37)	0.9 (0.70–1.27)	1.2
	L	18.2	73.0	10.5	83.6	0.7 (0.18–2.42)	1.1 (0.82–1.54)	0.6
One or more tests abnormal[b]	R	66.7	36.3	19.4	82.5	1.0 (0.74–1.51)	0.9 (0.47–1.78)	1.1
	L	63.6	43.8	16.3	87.5	1.1 (0.69–1.88)	0.8 (0.36–1.91)	1.4
Tinel's test and SW	R	23.8	86.8	29.4	83.2	1.8 (0.71–3.99)	0.9 (0.68–1.13)	2.1
	L	18.2	90.6	25.0	86.6	1.9 (0.45–6.96)	0.9 (0.68–1.21)	2.1
Phalen's test and SW abnormal	R	28.6	85.7	31.6	83.9	2.0 (0.86–4.05)	0.8 (0.63–1.11)	2.4
	L	18.2	90.6	25.0	86.6	1.9 (0.45–6.96)	0.9 (0.68–1.21)	2.1
Phalen's test and Tinel's test	R	9.5	92.3	22.2	81.6	1.2 (0.28–4.70)	1.0 (0.84–1.14)	1.3
	L	9.1	92.2	16.7	85.5	1.2 (0.15–7.66)	1.0 (0.81–1.20)	1.2
All three tests abnormal[c]	R	9.5	96.7	40.0	82.2	2.9 (0.51–10.97)	0.9 (0.81–1.08)	3.1
	L	9.1	98.4	50.0	86.3	5.8 (0.39–38.31)	0.9 (0.76–1.12)	6.3

NPV, Negative predictive value; PPV, Positive predictive value; LR, likelihood ratio, SW, Semmes–Weinstein.
[a]These calculations used the observed prevalence for the right and left hands shown in Table I.
[b]Positive in one or more of Semmes–Weinstein sensory testing, Phalen's test, or Tinel's test.
[c]Positive in all of Semmes–Weinstein sensory testing, Phalen's test, and Tinel's test.

indicating poorer test performance in both directions (both ruling out and ruling in CTS).

DISCUSSION

Our results emphasize that physical examination tests are poor predictors of CTS in a general working population. No single physical exam procedure showed a high sensitivity or high PPVs, even among subjects with hand symptoms. Thus, if workers were classified as having CTS based on physical examination alone, or based on physical examination plus symptoms, the majority of such classifications would have been incorrect in our worker population when compared to case definition of CTS that includes typical symptoms and median nerve conduction abnormalities.

The physical examination has been widely used for the diagnosis of CTS in the clinical setting, with a number of studies evaluating the reliability and validity of physical examination maneuvers in this setting [Marx et al., 1999; Massy-Westropp et al., 2000]. Phalen's and Tinel's tests were judged to have "moderately acceptable" reliability and validity for use in clinical practice; Semmes–Weinstein sensory testing was deemed to have "acceptable" validity for clinical practice if appropriate expertise is available, but does not show acceptable reliability between different examiners [Marx et al., 1999]. However, studies that may be useful in a clinical setting often have lower yield in a general population setting, as demonstrated by previous studies of the physical examination for detecting CTS in general working populations. Franzblau et al. [1993] compared vibrometry, pinch and hand grip strength, Phalen's test, Tinel's test, and two-point discrimination to a combination of CTS symptoms and median nerve electrodiagnostic testing in a large worker population. Each of these measures was found to have poor PPV and sensitivity. Franzblau et al. concluded that the physical exam would contribute little to screening efforts for CTS. A later study by Homan et al. [1999] found mixed results when it examined the overlap between physical exam measures, symptoms, and median nerve conduction in 824 workers from six different workplaces. Their physical exam consisted of Phalen's test, Tinel's test, a carpal canal compression test, and two-point discrimination. They found that there was little agreement between the three different criteria in the diagnosis of CTS. The physical exam in particular had a very poor overlap with abnormal median nerve conduction.

Our study does not address the utility or yield of physical examination maneuvers in a clinical setting. Physical examination has long been used by physicians to diagnose CTS in clinical settings, where the prevalence and severity of disease are likely to be much higher than in a general working population. Other clinical studies have reported that combinations of physical exam measures have greater predictive validity than seen in our study, especially when symptoms of CTS were also included. Graham et al. [2006] analyzed 256 selected case histories to determine the diagnostic validity of a combination of physical exam measures and symptoms and compared them to the judgment of clinicians. The three physical exam measures included in the model were Tinel's test, Phalen's test, and two-point discrimination. This combination had a correlation of 0.71 with the estimates of clinical experts who reviewed the same cases. In contrast, Wainner et al. [2005] developed a clinical prediction rule for CTS consisting of a symptom relief with hand shaking, wrist ratio > 0.67, the hand symptom severity scale, diminished sensation, and age greater than 45 years. In applying this rule to 82 patients at four different medical facilities, the combination was reported to have had a sensitivity of 98% if two or more of the criteria were abnormal. In this study, however, physical exam measures other than diminished sensation (including Phalen's, Tinel's, and the carpal compression test) had relatively poor performance, and were not included in the prediction rule.

Importantly, both of the above studies combined their physical exam with symptoms of CTS in arriving at a diagnosis, whereas we examined the yield of physical exam alone. In fact, symptoms alone can show good test performance for CTS as long as they are assessed by properly validated surveys or questionnaires [Katz et al., 1990; Levine et al., 1993; Szabo et al., 1999; D'Arcy and McGee, 2000; Descatha et al., 2007]. Since the PPV for all our physical exam findings alone or in combination remained low, a positive finding would make little difference in clinical decision making if combined with symptom data.

Post-offer pre-placement screening for CTS and other upper extremity disorders is currently used by many employers in an effort to prevent disease and reduce workers' compensation costs. Though there is a legitimate concern that workers may not accurately report symptoms in the setting of an examination where employment may be contingent on the findings, it appears from our data that physical examination findings do not accurately predict CTS at the time of hire, regardless of symptom reporting. Our exam results were not reported to employers and were protected by a certificate of confidentiality, thus increasing the likelihood that workers correctly reported the presence of symptoms.

Limitations

One limitation of our study is the lack of widely accepted case definitions for CTS. Most research case definitions rely on a combination of symptoms and nerve conduction testing and/or physical exam measures, but do not agree on what specific criteria should be used. We relied on an international consensus research case definition of CTS requiring typical symptoms and nerve conduction abnormalities [Rempel et al., 1998]. We also included referent case definitions based on abnormal median nerve conduction abnormality regardless of symptoms, and on symptoms of CTS regardless of nerve conduction, in an attempt to provide other clinically relevant outcomes against which physical exam measures could be correlated.

Because multiple examiners performed the physical exam and nerve conduction testing, there may have been differences in the way each examiner performed testing. The effect of this possible measurement bias was reduced by standardized training and demonstration of proficiency, as well as by periodic re-evaluation of the examiners. For light touch sensory measurements, we used the absence of response to the ‘‘normal’’ monofilament (2.83 mm) to define an abnormal response. The dry or calloused skin often present in the hands of manual workers may cause an inability to detect touch by the 2.83 mm monofilament. However, we had very few abnormal tests when using the stricter criteria of absence of response to a larger diameter monofilament (3.61 mm).

CONCLUSION

In a diverse sample of workers, we found little overlap between symptoms, nerve conduction testing, and physical examination tests commonly used to define CTS. None of the physical exam measures studied individually or in combination showed PPVs or sensitivities high enough to be effective in screening worker populations for the disease prior to or during employment. Screening or surveillance strategies based on these physical exam measures would lead to many false positive and negative test results, potentially leading to unnecessary further examinations or inappropriate job placement. Current evidence does not support the practice of basing employment decisions on physical examination screening for CTS.

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