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Evaluation of a symptom diagram for identifying carpal tunnel syndrome

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Background Hand symptom diagrams (HSDs) for rating the distribution of paraesthesias are proposed for use in epidemiological studies of carpal tunnel syndrome (CTS).

Aim To assess the validity of HSDs in a working population of manufacturing and service workers participating in a prospective study of musculoskeletal disorders.

Methods Assessment of each subject involved completing a HSD, a heath assessment and electrodiagnostic studies (EDSs). HSDs were rated for CTS blinded to the health assessment and EDS results. The validity assessments of HSD used EDS as the sole confirmatory standard for CTS.

Results A total of 733 subjects (65% of those eligible) participated in the study and 720 underwent EDSs. Dominant hand prevalence of a positive HSD and delayed nerve conduction studies in this working population was 9.2 per 100 workers. The sensitivity of a positive HSD for all workers was 0.28. By restricting the population to those workers with any current hand symptoms or to any worker with neuropathic hand symptoms, the sensitivities of HSD improved to 0.61 and 0.79, respectively. The positive predictive value of a HSD, with our study prevalence, was 0.48.

Conclusions The HSD classification schema has poor validity when applied to a general working population but improves when applied to workers with current neuropathic symptoms. The high number of false-negative HSDs in the general study population is most likely to be due to the inadequacies of using EDS as the confirmatory test. With a low prevalence of CTS, the positive predictive value for HSDs is poor.

Key words Carpal tunnel syndrome; epidemiological studies; musculoskeletal; screening.

Introduction

Hand diagrams characterizing the distribution of neuropathic hand symptoms are an enticing tool to screen for and aid in the diagnosis of carpal tunnel syndrome (CTS). Hand symptom diagrams (HSDs) have the advantages of being low cost, easy to administer and acceptable in almost all populations within which they are used [1].

Published estimates of the validity of CTS HSDs for screening and the diagnosis of CTS have used electrodiagnostic studies (EDSs) as the sole confirmatory test [1–3]. The published consensus epidemiological case definition for CTS requires a combination of HSD ratings and EDSs in view of limitations associated with EDS and HSD alone as diagnostic standards [4]. Accepting the case definition of CTS as requiring the combination of HSD and EDS precludes the individual assessment of HSD or EDS alone against the other. Consequently, although not ideal, evaluating the validity of HSD almost certainly requires confirmation by EDS alone or in combination with physical examination or other CTS assessment tests [5].

Reported estimates of the sensitivity and specificity of CTS diagnostic tests vary across populations and are related to the selection of diseased and non-diseased subjects [6,7]. Likewise, broad application of a diagnostic test to a clinically unselected population may influence validity estimates based on the inadequacies of both the test under evaluation and possibly the inadequacies of the confirmatory test. With these considerations in mind, the published validity estimates vary for CTS HSD ratings systems when evaluated in both working and clinical populations [1,2].

Katz *et al.* [2] developed a HSD rating system categorizing the distribution of current neuropathic hand symptoms (numbness, tingling, pain and decreased sensation) into classic, probable, possible and unlikely categories for CTS. When the HSD rating system was applied to

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a symptomatic clinical population referred to a hospital-based electrodiagnostic laboratory for evaluation of upper extremity discomfort, a positive rating using EDS as the gold standard had a sensitivity of 0.96, a specificity of 0.23, a positive predictive value of 0.42 and a negative predictive value of 0.91. The prevalence of CTS based on a positive hand diagram and an abnormal EDS was 35 per 100 patients.

Franzblau *et al.* [1] rated hand diagrams in an active working population in the manufacturing and insurance services sector using a classification system similar to Katz. Subjects with hand symptoms occurring at least three times in the past 12 months or with symptoms lasting 1 week or longer completed hand diagrams. For those subjects with positive hand diagram ratings indicating classic, probable or possible CTS, the sensitivity, specificity, positive predictive value and negative predictive values for the dominant hand were 0.34, 0.84, 0.27 and 0.88, respectively. The prevalence of CTS in this population as defined by a positive HSD and an abnormal EDS was seven per 100 workers.

The intent of this work is to assess the Katz HSD rating system in an additional distinct working population, to consider the validity estimates of the HSD rating diagram within selected symptomatic working populations and to further consider the CTS consensus epidemiological case definition in the context of a research study focusing on identifying CTS risk factors.

Methods

Subjects were recruited as part of a prospective study designed to assess the incidence and risk factors for upper extremity musculoskeletal disorders. Worksite selection criteria, detailed study design information and study procedures are described in Silverstein *et al.* [8]. Twelve different worksites in the manufacturing (electronics, automotive parts, windows, cabinets, medical and fitness equipment) and health care (hospitals excluding direct patient care and health research) sectors in Washington State participated in the research study. Part-time workers, temporary workers, workers in a mobile job, such as a forklift driver, or with more than four job tasks, which constrained the methods for exposure assessment were excluded [8].

Study procedures included a health assessment (including hand diagrams) and electrodiagnostic tests at the wrist. Health assessment included a structured questionnaire interview by trained interviewers. Information on demographics (age, gender, race, ethnicity and education), medical history (physician-diagnosed diseases, injuries and presence of musculoskeletal symptoms), work history (current job, time on job and change in job) and non-occupational activities (smoking status, hobbies, e.g. home repair, video games, knitting and sewing and weightlifting) was obtained.

Workers were asked to complete a body map describing the distribution of pain or discomfort, in the neck, shoulder, elbow/forearm and hand/wrist if they had problems in the past year which either lasted a week or more or had occurred at least ≥3 times. Each study participant completed a hand diagram to illustrate the distribution of hand symptoms, if any. Hand symptom categories were aching, burning, loss of colour, numbness/tingling, pain, pain/numbness/tingling, stiffness, swelling and other. Subjects with symptoms in the last 7 days rated the severity of their hand symptoms on a five-point scale (none, mild, moderate, severe and very severe). Hand diagrams were rated for all subjects with or without hand symptoms in the last 7 days (Figure 1).

HSDs were rated independently by two reviewers according to the hand diagram rating system described by Katz *et al.* [2]. One of four ratings was assigned: classic—tingling, numbness or decreased sensation with or without pain in at least two of digits 1, 2 or 3; symptoms in palm and dorsum of hand excluded; probable—same as classic, except palmar symptoms allowed unless confined solely to the ulnar aspect; possible—tingling, numbness, decreased sensation and/or pain in at least one of digits 1, 2 or 3 and unlikely—no symptoms in digits 1, 2 or 3.

Of the 253 hand diagrams with symptoms, the initial interrater agreement was high (242 out of 253 or 96%). Almost all the disagreements were due to slight differences in the interpretation of the shading of the hand diagram. There were three hand diagrams where the disagreement was likely to have been due to individual rater error from either skipping the record or an incorrect recording of the rating. This was probably due to the coding of a large number of symptomatic and asymptomatic records. If there was a disagreement in initial coding, a consensus determination was made collaboratively with review of the hand diagram. A classic/probable/possible HSD rating was considered a 'positive'.

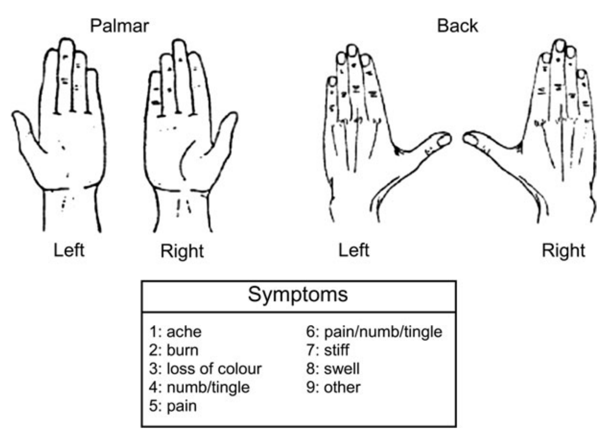

Figure 1. Hand symptom diagram.

All subjects received nerve conduction studies in their dominant hand. Nerve conduction studies were performed using standard techniques of supramaximal percutaneous nerve stimulation and surface recording using a Cadwell Laboratories, Inc. Sierra II® Wedge. Hands were warmed in an electric heating pad or in hot water to an initial temperature of 32°C. The EDS criterion used for a diagnosis of CTS in this study was that workers had at least one of the following findings: median motor latency >4.0 ms and/or median sensory latency >3.7 ms [2]. Nerve conduction technicians, certified by the American Association of Electrodiagnostic Technologists and blinded to the health assessment, performed the electrodiagnostic tests. Electrodiagnostic tests were not adjusted for age and height in order to achieve comparability to previously published validity estimates. A board certified neurologist-reviewed test printouts.

Analysis was restricted to the dominant hand (92% were right handed) [9]. Sensitivity, specificity, positive predictive values and negative predictive values were calculated [10].

The study design, consent form and procedures were reviewed and approved by the Washington State Institutional Review Board (IRB) and the IRBs of participating health care facilities. All analyses were conducted using SPSS (version 15) and SAS statistical software (version 9.1).

Table 1. Individual characteristics of study subjects undergoing electrodiagnostic tests of the median nerve at the carpal tunnel

	All subjects (n = 720), n (%)
Age (years), mean ± SD	39.5 ± 10.9
Age group (years)	
18–35	260 (36)
36–50	324 (45)
>50	136 (19)
Male	374 (52)
BMI group	
Normal: <25.0	293 (41)
Overweight: ≥25.0 to <30.0	237 (33)
Obese: ≥30.0	190 (26)
BMI, mean ± SD	27.3 ± 5.8
Caucasian	428 (59)
With at least high school education	599 (83)
Diabetes, hypertension, gout or thyroid	140 (19)
Smoking	
Current smokers	216 (30)
Past smokers	146 (20)
Never	358 (50)
Having hobbies or sports requiring high hand force	290 (40)
Having hobbies or sports requiring high repetitive hand activities	248 (34)
Years in current job, median (Q1–Q3)	2.4 (0.7–5.4)

Results

A total of 733 subjects (65% of those eligible) participated in the study. Of these, 720 had EDSs at baseline. The study population's age, gender, race, body mass index (BMI), educational attainment, smoking status and medical co-morbidities (per cent with at least one of the following medical conditions: diabetes, hypertension, gout or a thyroid disorder) are shown in Table 1. Compared to the Washington State population as a whole, our study population contained a greater proportion of current smokers (30% versus 21% Washington State population), was more racially diverse (59% white versus 82% Washington State population) and was more obese (26% with BMI ≥30.0 versus 18% Washington State population) [11].

The HSD ratings for all study participants are presented in Table 2. The study population prevalence estimate of a dominant hand positive:

- HSD was 17.6 per 100 workers.
- EDS was 32.6 per 100 workers.
- EDS combined with a positive HSD was 9.2 per 100 workers.
- EDS combined with a positive HSD with current hand symptoms was 26.1 per 100 workers.

The validity measures for the entire study population and two subgroups of symptomatic workers are presented in Table 3. The sensitivity and specificity of the HSD rating system for the entire study cohort using EDS as the confirmatory test were 0.28 and 0.87, respectively. By restricting the study population to those with current hand symptoms, the HSD sensitivity improved to 0.61 and specificity decreased to 0.58. Further restricting the working population to those with neuropathic symptoms improved the HSD sensitivity to 0.79 but decreased the specificity to 0.40. Since there was no change in the HSD rating for the symptomatic populations selected, as each is a subgroup of the previous group, the positive predictive value did not change. The negative predictive value did change, due to the elimination of HSDs rated as unlikely within the symptomatic subgroups, but remained relatively constant at ~0.7. HSD validity measures for the manufacturing sector worker population were not significantly different from those in the service sector (data not shown).

Our EDS criteria are meant to be consistent with the study by Katz *et al.* [2]. The validity measures varied little when CTS criteria for median and ulnar sensory latency differences were used (data not shown) [1]. More

Table 2. Katz hand diagram ratings for study subjects

Group (*n*)	CTS EDS[b]	Hand diagram rating[a]			
		Classic	Probable	Possible	Unlikely
All subjects (720)	(+)	15	12	39	169
	(−)	9	20	32	424
All subjects with current hand symptoms (253)	(+)	15	12	39	42
	(−)	9	20	32	84
All subjects with numbness, tingling or pain (179)	(+)	15	12	39	18
	(−)	9	20	32	40

[a]Rating system is per Katz *et al.* [2].

[b]CTS EDSs were considered positive if the motor latency >4.0 ms and/or sensory latency >3.7 ms as per Katz *et al.* [2].

Table 3. Validity measures for Katz hand diagram ratings[a] for study subjects

Group (*n*)	Sensitivity for hand diagrams rated		Specificity for hand diagrams rated		Positive predictive value		Negative predictive value	
	Classic or probable	Classic, probable or possible	Unlikely or possible	Unlikely	Classic or probable	Classic, probable or possible	Unlikely or possible	Unlikely
All subjects (720)	0.11	0.28	0.94	0.87	0.48	0.52	0.69	0.72
All subjects with current hand symptoms (253)	0.25	0.61	0.80	0.58	0.48	0.52	0.59	0.67
All subjects with numbness, tingling or pain (179)	0.32	0.79	0.71	0.40	0.48	0.52	0.56	0.69

[a]Rating system and CTS EDSs criteria per Katz *et al.* [2].

stringent EDS criteria decreased the positive predictive value estimate in our study and only slightly altered the sensitivity and specificity measures. For example, if the EDS criteria were changed to a median motor latency >4.5 ms and/or median sensory latency >4.0 ms, the sensitivity, specificity, positive predictive value and negative predictive values for a positive HSD in the entire study population were 0.43, 0.86, 0.29 and 0.91, respectively. There was no statistically significant difference in the distribution of Katz HSD ratings when those who rated their hand symptoms as mild were compared to those who rated their symptoms as moderate to severe. Including burning as a symptom did not identify additional symptomatic subjects above those reporting either numbness or tingling.

Discussion

In this epidemiological study of a working population, the HSD rating symptom developed by Katz performed poorly in differentiating those workers with abnormal EDSs from those with normal EDSs. When restricted to subpopulations of workers with current hand symptoms, there was an improvement in the sensitivity of the HSD rating system due to selective elimination of those workers with a false-negative HSD.

The strength of this study was the heterogeneity of the study population's physical and psychosocial exposures and the epidemiological methods to maintain blinding of the health assessment, nerve conduction testing and hand diagram rating measures [8]. Our study results are consistent with those reported in the existing literature where the HSD rating system was evaluated with EDS as the sole confirmatory test [1–3]. When the HSD rating system is used in a working population, potential inadequacies of EDS as the confirmatory test for CTS possibly inflate the number of false-negative HSDs and the sensitivities are poor.

Differences in HSD validity estimates between study populations referred for medical evaluation and those involved in epidemiological studies of working populations can be partly explained by the selection of those subjects included for testing. Patients seeking medical evaluation may differ from those in a working population in symptom severity, duration and quality which are likely to influence the HSD validity estimates [12–14]. Carefully selected clinical populations may fail to represent the spectrum of clinical disorders necessary to estimate the validity of a test in other clinical populations, such as a general medical clinic [6,7]. The restriction of our study population to those workers with neuropathic symptoms may provide the validity estimates for a working population that may most closely resemble that of a clinical population.

Further research is necessary to understand the value of HSD and EDSs in CTS. Through the process of developing the consensus epidemiological case definition for CTS, the participants provided an ordinal likelihood of CTS based on combinations of HSD and EDS results [4].

There is broad concurrence, including the authors of this study, that the combination of a positive hand diagram and abnormal EDS results clearly identifies a case of CTS and is the best available CTS case definition [15]. Similarly, there is concurrence that an asymptomatic person with a normal EDS does not have CTS. The two groups of workers where the likelihood of CTS is less straightforward are those with a positive EDS and a normal HSD (in our study a false-negative HSD) and those with a classic/probable HSD and a normal EDS (in our study a false-positive HSD). For the epidemiological study of risk factors predictive of CTS, a potential misclassification of a diseased subject into the non-diseased group may lead to bias in the estimation of exposure response relationships. Approximately 21% of our study population belongs to one of these two groups.

Homan *et al.* [16] described the relationship between CTS physical examination findings, hand symptoms and EDSs in a working population. Poor overlap was noted for the three types of CTS assessments with only 5% meeting all three criteria present (HSD, EDS and physical examination). In the study population of 824 workers in manufacturing, office and computer-related jobs, 9% had an isolated finding of a median mononeuropathy on EDS, 8% had isolated CTS on physical examination and 22% had hand symptoms consistent with CTS. There were statistically significant associations between symptoms, or symptoms combined with physical exam findings, and positive EDS findings. The association was noted in those workers with recurring or persistent symptoms and not in those with current symptoms. Therefore, incorporating frequency and duration of symptoms into HSD rating may improve the validity of HSD as a tool for estimating the prevalence of CTS.

More interesting is the possible longitudinal variation in the development or resolution of false-positive HSDs and false-negative HSDs in our study. Bonfiglioli *et al.* [17] observed resolution, development and persistence of CTS symptoms and EDS measurements at a 2-year follow-up of assembly line workers who had a 5-month reduction in workload prior to follow-up. Werner *et al.* [18,19] reported that workers with initially abnormal EDS and no hand symptoms had on a 70-month follow-up a statistically significant increased risk of developing hand symptoms. Conversely, a long-term study of workers with initially abnormal EDS and CTS hand symptoms showed a significant resolution of CTS hand symptoms and persistence of EDS findings [20].

Our cross-sectional observations of the poor validity of the HSD rating system using EDS as the sole confirmatory test are consistent with those observed by others. The consensus epidemiological case definition for CTS provides a meaningful and appropriate rationale for the inclusion of both symptoms and EDS. The prospective evaluation of the development of CTS symptoms either with abnormal EDS results or with normal ones may provide more clarity on the natural history of the disease and consequently the utility of HSDs for screening populations of workers.

Key points

- The prevalence of both an abnormal HSD and nerve conduction studies for CTS in a working population was 9.2%.
- Validity measures for a CTS HSD rating system are poor.
- Using HSDs to screen workers for CTS will lead to a large number of unnecessary evaluations for CTS.

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Conflicts of interest

None declared.

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