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What is the role of Semmes-Weinstein monofilament testing in the diagnosis of electrophysiologically graded carpal tunnel syndrome?

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Abstract. [Purpose] The aim of the study was to investigate the ability of Semmes-Weinstein Monofilament testing to detect carpal tunnel syndrome, as well as moderate-to-severe carpal tunnel syndrome using varying thresholds and methods. [Subjects] Clinical and electrophysiological data of 62 patients (124 hands) with a mean age of 49.09±10.5 years were evaluated in this study. [Methods] Sensitivity and specificity were calculated according to two threshold values (2.83 and 3.22) and two methods, a conventional method and an internal comparison method. A threshold value of 3.22 was also used to determine sensitivity and specificity in the diagnosis of electrophysiologically moderate-to-severe carpal tunnel syndrome. Data of the first three digits were averaged to reveal the mean strength value of the monofilaments for each hand. [Results] The criteria of 2.83-conventional method yielded a sensitivity of 98% and a specificity of 17% in the diagnosis of carpal tunnel syndrome. The threshold value of 3.22 using a conventional method was found to detect moderate-to-severe carpal tunnel syndrome with high sensitivity (80%) and excellent specificity (93%). A statistically significant difference was observed in the mean strength values of the monofilaments in moderate-to-severe carpal tunnel syndrome hands and hands without carpal tunnel syndrome. [Conclusion] The current study demonstrated that Semmes-Weinstein monofilament testing might be a valuable quantitative method for detecting moderate-to-severe carpal tunnel syndrome.
Key words: Semmes-Weinstein monofilaments, Sensitivity and specificity, Carpal tunnel syndrome

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INTRODUCTION

Carpal tunnel syndrome (CTS) is a common and well-known entrapment neuropathy. A variety of physical exams involving clinical examinations and tests have addressed one or more characteristics of the syndrome, such as sensory or motor loss[1, 2)]. The Semmes-Weinstein monofilament (SWM) testing is one of the clinical tests that measures the response to a touching sensation of the monofilaments using a numerical quantity. This testing was developed for the detection of patients at risk of neuropathic ulceration, and it is a clinical tool used in the evaluation of peripheral nerve injuries and compression syndromes before and/or after recovery[3, 4)].

Previous studies comparing clinical standards in diagnosing CTS provided inconsistent results, and there is no consensus on the sensitivity and specificity of the SWM testing[5–9)]. It is generally accepted that CTS is diagnosed by clinical and electrodiagnostic examinations; however, there is still controversy about how valuable some of the clinical examination tools are, such as sensory testing[10, 11)]. Gellman et al. suggested that SWM testing would be a beneficial part of the sensory examination to diagnose CTS patients with high sensitivity and specificity[12)]. On the other hand, Pagel et al. reported that SWM testing was useless as a screening tool in patients with CTS-compatible symptoms[13)].

A systematic review reported that additional studies detailing test methodologies are required to define the role of SWM testing in the clinical assessment of CTS[14)]. However, to our knowledge, studies describing the methods and threshold abnormalities of SWM testing for the diagnosis of CTS, as compared with electrophysiological severity, are not yet available.

Thus, the aim of this study was to determine the value of SWM testing as a clinical examination tool using two different threshold abnormalities and two different methods, as well as the relationship between threshold abnormality and electrophysiological CTS grade.

SUBJECTS AND METHODS

Clinical data of patients who applied to the outpatient

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clinic of a university with symptoms suggesting CTS were assessed retrospectively. Two physicians independently performed the clinical and electrophysiological evaluations of the patients. The first physician performed clinical assessments and routine physical examinations, including Tinel's sign, Phalen's maneuver, and SWM testing. The patients were then referred to a second physician (unaware of the physical exam results) for electrodiagnostic testing. The exclusion criteria were the presence of a neurologic disease; prior nerve injuries, trauma, or a surgical procedure in the upper extremities; thenar atrophy; pregnancy; or acute/subacute cervical radiculopathy. Patients who had clinical or electrophysiological findings suggesting other pathologies, such as polyneuropathy, ulnar, and/or radial neuropathy, were also excluded. All of the patients were informed about the study, and their written informed consent was obtained. The research protocol was reviewed and approved by the Clinical Research Ethics Committee of the university, and it was carried out in accordance with the principles of the Declaration of Helsinki.

The electrodiagnostic measures were performed in the electrophysiology laboratory at a university hospital. All electrophysiological examinations were conducted at room temperature with a skin temperature of >31 °C. The instrument used was a Medelec Sapphire 4 ME. The filter settings were 3 Hz–5 kHz for the motor nerve conduction study (NCS) and 20 Hz–2 kHz for the sensory NCS. The sweep durations were 50 ms for the motor NCS and 20 ms for the sensory NCS. The sensitivity was 1 mV and 20 μV for the motor and sensory NCSs, respectively. Supramaximal stimulation was used in the motor NCS. Bilaterally median motor and sensory nerve conduction potentials were recorded using standard techniques according to the practice parameters for the electrodiagnosis of CTS outlined by the American Academy of Neurology, the American Association of Neuromuscular and Electrodiagnostic Medicine, and the American Academy of Physical Medicine and Rehabilitation[15]. Bilaterally motor/sensory ulnar and radial nerve conduction studies were also performed for the differential diagnosis. Abnormal electrophysiological findings suggesting CTS were categorized into three grades according to Stevens' classification: mild, prolonged median sensory distal latency (>3.5 ms); moderate, abnormal median sensory latency (>3.5 ms) and prolonged median motor distal latency (>4.2 ms); and severe, the absence of median sensory nerve action potential or low amplitude of thenar compound muscle action potential (<5 mV)[16]. After removing the data for SWM testing from the clinical data, the patients were considered to have CTS if they had both clinical and electrophysiological findings. The electrophysiological data of these patients for each hand were then grouped into mild CTS and moderate-to-severe CTS groups according to the electrophysiological grades described.

Measurements were obtained through the application of a force-calibrated SWM to each digit except the ring finger, with the wrist in a neutral position. Testing was performed in a silent room using a standard technique: the monofilaments were applied three times to the tip of each finger. The heaviest monofilament that a patient could feel was used; thus, a numeric value was recorded that the logarithm of 10 times the force in milligrams require to bow the monofilament[17].

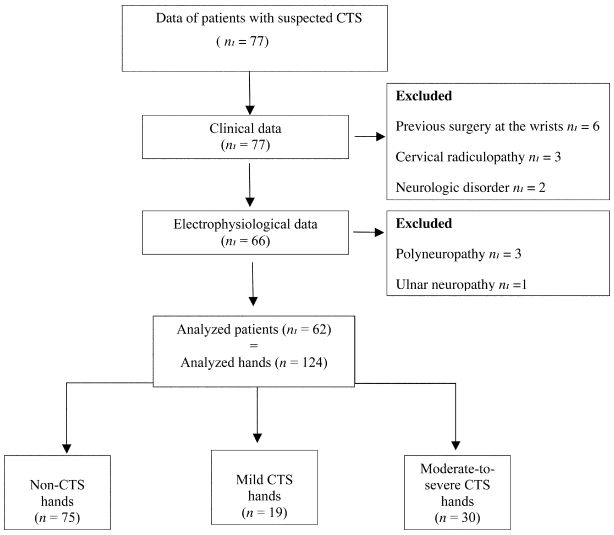

Fig. 1. Flowchart of the study population

Sensitivity and specificity were calculated according to two threshold values (2.83 and 3.22) and two methods, a conventional method (CM) and an internal comparison method (IM). A test was considered positive if the recorded threshold value of any radial digit was higher than 2.83 (2.83-CM), the recorded threshold value of digit 3 was higher than both 2.83 and the threshold value of digit 5 (2.83-IM), the recorded threshold value of any radial digit was higher than 3.22 (3.22-CM), the recorded threshold value of digit 3 was higher than both 3.22 and the threshold value of digit 5 (3.22-IM).

All these criteria were used in the calculations to determine the sensitivities and specificities of non-CTS and CTS hands. The last two criteria (3.22-CM and 3.22-IM) were also investigated to determine sensitivity and specificity using the recorded data of non-CTS and moderate-to-severe CTS hands.

Mean monofilament value of each hand: The threshold value for each digit corresponded to a theoretical monofilament strength in SWM testing. These logarithms were converted into actual pressure applied, and the strength values of the monofilament for the first three digits of the patients were averaged to reveal the mean strength value of each hand. These data were used to compare non-CTS and CTS hands, as well as non-CTS and moderate-to-severe CTS hands. The highest monofilament strength value for the first three digits of the patients was used for the receiver operating characteristic (ROC) curve.

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL, USA) version 15.0. The data were analyzed using two by two tables to determine the sensitivity, specificity, positive predictive value, and negative predictive value. The Kolmogorov-Smirnov test was used to test the normality of the data distribution. The Mann-Whitney U test was used for between-group comparisons due to the data not showing a normal distribution. The ROC curve was used to determine

Table 1. Positive and negative tests in total CTS hands

		Positive	Negative	Total
		(No.)	(No.)	(No.)
2.83-CM	CTS (+)	48	62	110
	CTS (–)	1	13	14
2.83-IM	CTS (+)	19	13	32
	CTS (–)	30	62	92
3.22-CM	CTS (+)	24	5	29
	CTS (–)	25	70	95
3.22-IM	CTS (+)	14	2	16
	CTS (–)	35	73	108
Total		49	75	124

CTS: carpal tunnel syndrome; CM: conventional method; IM: internal comparison method

Table 2. Sensitivity and specificity of criteria for CTS

	Sensitivity	Specificity	Accuracy	PPV	NPV
	(%)	(%)	(%)	(%)	(%)
2.83-CM	98	17	49	44	93
2.83-IM	39	83	65	59	67
3.22-CM	49	93	76	83	74
3.22-IM	29	97	70	88	68

CTS: carpal tunnel syndrome; CM: conventional method; IM: internal comparison method; PPV: positive predictive value; NPV: negative predictive value

Table 3. Positive and negative tests in moderate-to-severe CTS hands

		Positive	Negative	Total
		(No.)	(No.)	(No.)
3.22-CM	CTS (+)	24	5	29
	CTS (–)	6	70	76
3.22-IM	CTS (+)	14	2	16
	CTS (–)	16	73	89
Total		30	75	105

CTS: carpal tunnel syndrome; CM: conventional method; IM: internal comparison method

Table 4. Sensitivity and specificity of criteria for moderate-to-severe CTS

	Sensitivity	Specificity	Accuracy	PPV	NPV
	(%)	(%)	(%)	(%)	(%)
3.22-CM	80	93	90	83	92
3.22-IM	47	97	83	88	82

CTS: carpal tunnel syndrome; CM: conventional method; IM: internal comparison method; PPV: positive predictive value; NPV: negative predictive value

the accuracy. Accordingly, the optimal cutoff point was calculated for diagnosis of CTS and for diagnosis of moderate-to-severe CTS. Significance was set at $p<0.05$.

RESULTS

In total, data of 62 patients (57 females, 5 males) with a mean age of 49±10.5 (20–72) years were evaluated in this study. Figure 1 shows a flowchart of the study population.

Of 124 hands in 62 patients, 49 hands (39%) had abnormal clinical and electrophysiological findings related to CTS. According to electrophysiological severity, 19 patients had mild CTS, 18 patients had moderate CTS, and 12 patients had severe CTS.

It was observed that the criteria of 2.83-CM yielded a sensitivity of 98% and a specificity of 17%. When the criterion of 2.83-IM was used, a sensitivity of 39% and a specificity of 83% were achieved. Specificities of 93% (CM) and 97% (IM) were obtained when the threshold value was increased to 3.22. Using the criteria of 3.22-CM and 3.22-IM, the sensitivity results were found to be 49% and 29%, respectively. The numbers of positive and negative tests and the positive and negative predictive values are shown in Tables 1 and 2.

The criterion of 3.22-CM was found to detect moderate-to-severe CTS with a sensitivity of 80% and a specificity of 93%. The positive predictive value was 83%, and the negative predictive value was 92%. When the criterion of 3.22-IM was used, the sensitivity was 47%, and the specificity was 97% (Tables 3 and 4).

Data for the strength values of each hand demonstrated statistically significant differences in moderate-to-severe CTS hands compared with non-CTS hands. The median strength value of the monofilament was 407.3 mg (133.2–2041.7 mg) in moderate-to-severe CTS hands, and 166 mg (27.5–1309.3 mg) in non-CTS hands ($p<0.001$). There was no significant difference between non-CTS hands and mild CTS hands for these assessment values ($p=0.566$). The median strength value of the monofilament was 166 mg (67.6–166 mg) in mild CTS hands. A strength value of the monofilament > 288.4 mg had 80% sensitivity and 93.3% specificity for diagnosis of moderate-to-severe CTS, as identified by the ROC curve. The area under the ROC curve was 0.889 (95% confidence interval=0.810–0.968).

DISCUSSION

There is a lack of studies exploring the relationship between SWM testing outcomes and electrodiagnostically classified CTS. A characteristic feature of our study is that we investigated the capability of not only the threshold values of 2.83 and 3.22 but also the threshold value of 3.22 in diagnosing moderate-to-severe CTS, as well as the correlation between SWM testing and the severity of CTS. The main results of the present study showed that SWM testing using the criterion of 3.22-CM could be a valuable quantitative method for detecting moderate-to-severe CTS.

It has been demonstrated that limb ischemia significantly increases paresthesia, and SWM testing outcomes are one of the earliest manifestations of changes in nerve function[4–18]. Although SWM testing is theoretically identified as a part of the clinical examination for patients with suspected CTS, the sensitivity and specificity of the test measurements vary widely among studies, which may be attributed to

the variations in testing techniques and the disagreement regarding the abnormality of the threshold value. Pagel et al. performed a study to investigate the value of SWM testing in patients with electrophysiologically confirmed CTS using two criteria similar to ours with a threshold value of 2.83[13]. The sensitivity and specificity ratios in their study were very close to our results. They obtained sensitivities of 98% and 13% and specificities of 15% and 88% for the CM and IM, respectively. Based on these results, the authors concluded that SWM testing lacks utility in the diagnosis of CTS.

Similarly, Szabo et al. evaluated the utility of clinical tests including SWM testing with a threshold of 2.83 for CTS[19], whereas they calculated 65% sensitivity and 42% specificity. Although, sensitivity would be higher (83%) if SWM testing were combined with Phalen's maneuver, they suggested that SWM testing alone failed to diagnose CTS. One interpretation of their findings, including lower sensitivity and higher specificity, that is different from our study is that Szabo et al. considered the test was positive if any of the radial 3 and 1/2 digits had abnormal sensations (>2.83). Distinctively, the ring finger was not tested in the present study because it has a dual innervation from the median and ulnar nerves. Additionally, Szabo et al. used a monofilament kit containing 2.83 and 3.61 monofilaments, but the kit did not include a 3.22 monofilament.

Our results showed a sensitivity of 49% and a specificity of 93% for the criterion of 3.22-CM and a sensitivity of 29% and a specificity of 97% for the criterion of 3.22-IM. However, Mac Dermid et al. found a higher sensitivity (79% and 70%, respectively) and a lower specificity (64% and 70%, respectively) for both methods at these thresholds, and they suggested that accuracy was highest when a threshold of 2.83 was used in the long finger along with the small finger (sensitivity of 82% and specificity of 86%)[5]. In addition, they concluded that further studies must determine which protocol and threshold abnormality is the best method for diagnosing CTS. Other studies have shown conflicting results related to the sensitivity and specificity of SWM testing[6–9].

No clinical test to diagnose CTS has both high sensitivity and high specificity. The data related to sensitivity and specificity to detect CTS are in agreement with the findings reported in many earlier studies. The value of 2.83-CM had excellent sensitivity (98%) but low specificity (17%), whereas the value of 3.22-CM had high specificity (93%) but low sensitivity (49%). Therefore, we think that SWM testing is not useful as a screening tool in diagnosing CTS.

In our study, the relationship between the threshold value and electrophysiologically graded CTS was investigated. Although patients with CTS have been graded electrophysiologically in some of previous studies, to our knowledge, this is the first study to assess their relationship with monofilament values. Our results showed statistically significant differences in the mean monofilament value of the first three digits between moderate-to-severe CTS hands and non-CTS hands. In addition, the threshold value of 3.22 using CM detected moderate-to-severe CTS with high sensitivity and specificity. According to the ROC curve, a strength value of 288.4 mg as a cutoff is found between the strength value for the 3.22 monofilament and the strength value for the 3.61 monofilament and is very close to the strength value for the 3.22 monofilament. Taken together, the data available from both analyses reveal that SWM testing is likely a beneficial part of the clinical exam in the presence of moderate-to-severe CTS. Our data suggests there were no statistically significant differences in terms of the mean monofilament value between non-CTS and mild CTS hands. Similarly, it is sometimes difficult to diagnose CTS using only an electrophysiological study in cases of early and mild CTS.

The internal comparison method was used as part of the SWM testing when aiming to determine whether a patient had CTS in previous studies[5–13]. The basis of the internal comparison can be explained by the non-pathologic causes of a diminished sensation within an individual, such as an individual with skin changes due to any reason. However, the results of the previous studies show that the sensitivity of this method is markedly lower in comparison with CM. According to our data, an evaluation of the fifth finger by internal comparison did not add any benefit, including the method of using the threshold value of 3.22 in diagnosing mild-to-severe CTS. Silver et al. reported that a significant percentage of patients with CTS also have ulnar nerve abnormality[20]. Therefore, measurement of the fifth finger may not be considered an alternative method to distinguish CTS patients from asymptomatic controls.

The present study showed that SWM testing might be a beneficial part of clinical examination for detecting moderate-to-severe CTS when the criterion of 3.22-CM is applied. It could be an option for diagnosing carpal tunnel syndrome, especially for patients in whom other diagnostic methods are non-preferred or are confusing.

The current study has some limitations. First, there were more women than men in the sample. Although gender was not considered an independent variable in this study, future research at the individual level, predominantly in men, might allow comparisons between men and women that are more direct. Second, reliability was not assessed within the current study due to the retrospective nature of the study. However, the methods performed in the study were precisely described to prevent misinterpretations.

In light of our results, it can be concluded that a threshold abnormality of 3.22 using CM may detect moderate-to-severe CTS in patients. SWM testing may be of value as a diagnostic adjunct in cases of suspected CTS, particularly if electrophysiological tests are not available for any reason. Future studies with a larger sample size (and perhaps more men), as well as further analyses of different threshold abnormalities of moderate-to-severe CTS hands, are needed. Ultimately, SWM testing is a useful complementary tool for the clinical examination of CTS patients.

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