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Diagnostic and clinical value of mixed–sensory nerve conduction velocity differences between wrist–elbow and second finger–wrist segments in carpal tunnel syndrome

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Abstract

Background & Objective: This study aimed to evaluate the diagnostic utility of the nerve conduction velocity difference between the mixed (wrist–elbow) and sensory (second finger–wrist) segments of the median nerve (WE–FW). *Methods:* This prospective study included 40 CTS patients (61 extremities) and 40 healthy controls (40 extremities). Diagnosis was based on clinical findings. The Visual Analog Scale (VAS) and Disabilities of the Arm, Shoulder and Hand (DASH) questionnaire were administered to the CTS group. The WE–FW was derived from orthodromic (WE–FW/O) and antidromic (WE–FW/A) sensory conduction studies in the second finger–wrist segment of the median nerve, using both onset and peak latencies. *Results:* There were no significant differences in age or sex between groups ($p>0.05$). WE–FW/O and WE–FW/A values were significantly higher in CTS patients than controls ($p<0.001$ for all). Sensitivities of WE–FW/O (onset and peak latency) were 84.1% and 77.3%, with specificities of 85.0% and 77.5%. WE–FW/A sensitivities were 83.3% (onset) and 81.5% (peak), with 82.5% specificity for both. WE–FW/O (peak latency; $p=0.044$, $r=0.306$) and WE–FW/A (onset latency; $p=0.005$, $r=0.376$) positively correlated with clinical CTS severity. Both parameters also significantly correlated with VAS and DASH scores.
Conclusions: WE–FW shows strong diagnostic potential in CTS. This novel method correlates with clinical and neurophysiological severity, and may serve as valuable adjuncts in diagnosis and follow-up.

Keywords: carpal tunnel syndrome, mixed nerve, nerve conduction study, sensory nerve

INTRODUCTION

Carpal tunnel syndrome (CTS) is the most common entrapment mononeuropathy, characterized by compression of the median nerve at the wrist.[1-3] Clinically, CTS manifests with sensory deficits in the first three digits and may progress to weakness or atrophy in the hand muscles innervated by the median nerve.[1-3] While clinical findings remain central to the diagnosis, electrodiagnostic studies offer essential information for diagnosis, differential diagnosis, and assessment of disease severity.[1,2] However, in certain cases, standard electrodiagnostic tests may fail to detect CTS.[2-4]

Although median sensory nerve conduction studies (NCSs) performed in the second and third finger to wrist segments are commonly used for diagnosis, additional techniques such as comparing median and ulnar compound nerve action potential (CNAP) latencies can improve diagnostic sensitivity.[5-7] Electrodiagnostic studies are also employed to evaluate the severity of CTS, although previous research has reported inconsistent correlations between clinical severity and electrophysiological findings.[2,8,9]

Mixed NCSs performed in the forearm are typically used to evaluate neuropathies localized to the forearm or more proximal segments.[10-13] We hypothesize that median mixed NCSs in the forearm remain unaffected unless CTS reaches advanced stages. Therefore, in this study, we investigated the diagnostic utility of the nerve conduction velocity (NCV) difference between the mixed (wrist-elbow) and sensory (second finger-wrist) segments of the median nerve (WE–FW),

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as well as its association with clinical parameters in CTS.

METHODS

Study design and subjects

This prospective study was conducted between June 2022 and June 2023 in the Clinical Neurophysiology Laboratory of Adana City Training and Research Hospital, University of Health Sciences. Participants included individuals over 18 years of age, comprising both healthy controls and patients with clinical findings consistent with carpal tunnel syndrome (CTS). Ethical approval was obtained from the hospital's local ethics committee (No. 106/1956, 2022), and written informed consent was obtained from all participants. CTS was diagnosed based on the presence of nocturnal or diurnal paresthesia in the first three digits, or sensory abnormalities in the same distribution identified during neurological examination.[1-3] These findings could be accompanied by weakness or atrophy in median-innervated hand muscles. Exclusion criteria for the CTS group included history of CTS surgery or major upper extremity trauma, diabetes mellitus or other conditions causing neuropathy, polyneuropathy or neurodegenerative disease, electrodiagnostic findings consistent with Martin-Gruber anastomosis, treatment for neuropathic pain, clinical or electrodiagnostic evidence of ulnar or radial neuropathy, or damage to other upper extremity nerves. Controls were healthy individuals without any clinical signs of CTS and were subject to the same exclusion criteria.

The clinical classification of CTS patients was defined as follows:[14,15] 1) Nocturnal paresthesia only; 2) Both nocturnal and diurnal paresthesia; 3) Sensory loss; 4) Atrophy or weakness of the thenar muscles innervated by the median nerve; 5) Paralysis of the thenar muscles innervated by the median nerve. CTS patients completed the Visual Analog Scale (VAS) and the Disabilities of the Arm, Shoulder and Hand (DASH) questionnaires.[16-19] In cases of bilateral CTS, the VAS, and DASH assessments were performed for both sides. For each patient, VAS scores were determined based on the most severe pain experienced and the average pain level during the past four weeks. In addition to the DASH questionnaire, the DASH work module was also administered.

Electrodiagnostic tests

Nerve conduction studies (NCSs) were performed using a Cadwell Sierra EMG device (Cadwell Laboratories, Kennewick, WA, USA). All recordings were obtained when the skin temperature of the extremities was above 32°C; the extremities of patients with cold skin were warmed prior to testing. Surface electrodes were used for both stimulation and recording. NCSs were conducted in accordance with standard recommended protocols.[20,21] For sensory and motor NCSs, the band-pass filter settings were 20 Hz–2 kHz and 20 Hz–10 kHz, respectively. Sensitivity and sweep speed were set at 10 μV/division and 1 ms/division for sensory NCSs, and 2 mV/division and 5 ms/division for motor NCSs. Bilateral median and ulnar sensory-motor NCSs were performed in all patients with CTS, whereas in the control group, NCSs were performed unilaterally and randomly on either the right or left upper limb. For median and ulnar motor NCSs, recording electrodes were placed over the abductor pollicis brevis and abductor digiti quinti muscles, respectively, in accordance with the muscle belly–tendon principle. The distance between the wrist stimulation site and the active recording electrode was standardized to 5 cm in motor NCSs.

Ulnar sensory NCS was performed antidromically over the fifth digit-to-wrist segment. Median sensory NCS was performed over the second digit-to-wrist segment and the palm-to-wrist segment of the mixed nerve. In addition, median mixed nerve conduction studies were conducted over the wrist-to-elbow segment.[9,10] Compound muscle action potential (CMAP) and compound nerve action potential (CNAP) amplitudes of the median and ulnar nerves were measured peak-to-peak. Sensory and mixed nerve conduction velocities (NCVs) were calculated using both onset and peak latencies. WE–FW was calculated by subtracting the median sensory NCV obtained from the second digit-to-wrist segment from the median mixed NCV measured over the forearm segment. WE–FW obtained using orthodromic median sensory NCS in the 2nd finger–wrist segment was defined as WE–FW/O; the antidromic counterpart was defined as WE–FW/A. For example, if the forearm mixed NCV was 62 m/s and sensory NCV from the 2nd finger-wrist segment was 52 m/s, then WE-FW would be 10 m/s. Figure 1 illustrates the WE–FW value along with the sensory and mixed NCSs of the median nerve in a control subject.

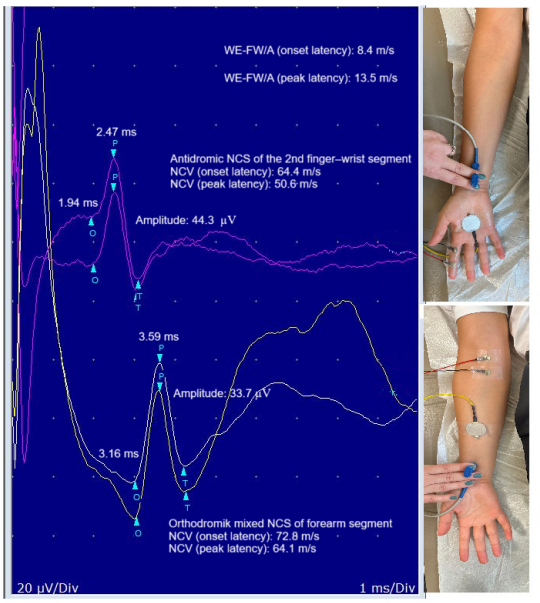

Figure 1. Median sensory and mixed nerve conduction studies, and WE–FW in a control subject
Notes: NCV: nerve conduction velocity; WE-FW: NCV difference between the mixed (wrist-elbow) and sensory (second finger-wrist) segments of the median nerve; WE-FW/A: WE–FW obtained by performing antidromic median sensory NCS in the 2nd finger–wrist segment. Example of WE-FW calculation using onset latency-derived NCVs (72.8 - 64.4 = 8.4 m/s) and peak latency-derived NCVs (64.1 – 50.6 = 13.5 m/s).

Statistical analysis

Categorical variables were expressed as counts and percentages (%), while numerical variables were presented as mean ± standard deviation (SD) and minimum–maximum (min–max) values. The Shapiro–Wilk test was used to assess the normality of the data distribution. The Pearson Chi-square test was employed to compare categorical variables between groups. For comparisons of independent numerical variables between groups, the Student's *t*-test was used for normally distributed variables, whereas the Mann–Whitney *U* test was applied for non-normally distributed variables. Receiver Operating Characteristic (ROC) analysis was performed to determine the cut-off values, sensitivity, and specificity for WE–FW/O and WE–FW/A. ROC analysis was performed using the presence or absence of CTS as determined by clinical findings (symptoms and neurological examination) as the reference standard. The cut-off values were chosen at the points on the ROC curves that maximized the Youden index; for each, the area under the curve, sensitivity, and specificity were also reported. Spearman correlation analysis was used to assess the correlations between variables. A P value < 0.05 was considered statistically significant. All statistical analyses were conducted using SPSS version 22.0 (Statistical Package for the Social Sciences, IBM Corp., Armonk, NY, USA).

RESULTS

Forty patients with CTS (9 males) and 40 control subjects (9 males) were included in the study. The demographic characteristics of all participants, along with the clinical findings of the affected extremities in CTS patients, are presented in Table 1. Body mass index (BMI) was higher in CTS patients than in controls (p=0.004). NCSs were performed on the right upper extremity in 19 and on the left in 21 control subjects. CTS was bilateral in 21 patients, unilateral on the right in 16, and unilateral on the left in 3 patients. The clinical findings of the affected extremities in CTS patients are presented in Table 1. Of the 40 patients with CTS, 24 were housewives, 4 were manual laborers, and the remaining patients had various occupations, including teachers, healthcare workers, and secretaries. CTS clinical grades 1 to 5 included 11, 25, 21, 4, and 0 extremities, respectively.

Table 2 presents the comparison of WE–FW values and median NCSs between the groups. As shown in Table 2, WE-FW/O and WE-FW/A values were significantly higher in CTS extremities than in controls for both onset- and peak-latency- derived NCVs (all $p < 0.001$). In some CTS patients, median nerve CNAPs could not be obtained in the 2nd finger-wrist segment, particularly with the orthodromic technique. Orthodromic and antidromic median nerve CNAPs in the second digit–wrist segment could not be obtained in 17 and 7 extremities of CTS patients, respectively, out of a total 61 CTS-affected extremities. The number of extremities in which orthodromic median nerve CNAPs could not be recorded were 2, 5, 6, and 4 in CTS clinical grades 1, 2, 3, and 4, respectively. For the antidromic median nerve CNAPs, the corresponding numbers were 0, 2, 4, and 1, respectively. Accordingly, WE-FW/O could be calculated in 44 extremities, and WE-FW/A in 54 extremities. The ROC analysis results, including cut-off values, sensitivity, and specificity for WE–FWs, are shown in Table 3. The cut-off values for WE-FW/O were 18.85 m/s (onset latency) and 15.30 m/s (peak latency),

Table 1: Clinical and electrodiagnostic findings of the extremities with CTS

Demographic data	CTS patients	Controls	P value
Age years- mean±SD	46.1±11.5	44.5±10.7	0.515
Height cm- mean±SD	163.3±6.6	166.1±9.6	0.127
Weight kg- mean±SD	77.7±14.1	72.2±13.7	0.080
BMI kg/m^2- mean±SD	29.1±4.7	26.1±4.2	**0.004**
Clinical findings	**Extremities with CTS**		
Symptoms			
Nocturnal paresthesias -number (%)	55 (90.1)		
Diurnal paresthesias -number (%)	53 (86.9)		
Subjective weakness -number (%)	22 (36.1)		
Neurological examination			
Sensory abnormality -number (%)	32 (52.5)		
Motor weakness -number (%)	6 (9.8)		
Positive Phalen's sign -number (%)	26 (42.6)		
Positive Tinel's sign -number (%)	15 (24.6)		
VAS and DASH			
Mean VAS score -mean±SD	5.0±2.1		
Maximum VAS score -mean±SD	7.4±2.6		
DASH score -mean±SD	32.6±17.8		
DASH-WM score -mean±SD	48.6±23.3		
Clinical grading of CTS -number (%)			
1 / 2 / 3 / 4	11 (18) /25 (41) / 21 (34) / 4(7)		

Notes: CTS: carpal tunnel syndrome; DASH: the Disabilities of the Arm, Shoulder and Hand; DASH-WM: the Disabilities of the Arm, Shoulder and Hand- work module; VAS: the Visual Analog Scale.

while those for WE-FW/A were 19.55 m/s (onset latency) and 18.35 m/s (peak latency). The sensitivities and specificities of WE-FW/O ranged from 77.3% to 84.1% and from 77.5% to 85.0%, respectively; for WE-FW/A, these values ranged from 81.5% to 83.3% and were both 82.5%. ROC curves for WE–FW/A and WE–FW/O are displayed in Figure 2. Based on the WE–FW cut-off values, abnormal WE–FW was detected in 37 of the 44 and in 45 of the 54 extremities of CTS patients for which WE-FW/O and WE–FW/A could be calculated, respectively. Because median sensory CNAPs could not be obtained in all extremities using both orthodromic and antidromic techniques, WE-FW/O and WE-FW/A were calculated in 29 and 34 of 36 extremities classified as Grade 1 or Grade 2, which had normal neurological examination and no motor weakness, but sensory symptoms. According to the corresponding WE-FW cut-off values, abnormal WE-FW/O was found in 25 extremities (86%) when using onset latency and in 22 extremities (76%) when using peak latency. For WE-FW/A, abnormal values were observed in 27 extremities (79%) and 26 extremities (77%) when onset and peak latencies were used, respectively. Correlation findings between clinical parameters and WE–FW values are presented in Table 4. According to Table 4, significant positive correlations were observed between WE-FW values and both DASH scores and clinical severity grades, particularly for WE-FW/O (peak latency). The correlations of WE–FW/O with the DASH score and mean VAS score are illustrated in Figure 3.

DISCUSSION

This study investigated the utility of WE–FW, a novel electrodiagnostic parameter, in the diagnosis of CTS. The results demonstrated that WE–FW may serve as a valuable tool for diagnosing CTS. In addition, clinical measures such as VAS and DASH scores demonstrated significant correlations with WE–FW values.

Although the diagnosis of CTS is primarily based on clinical findings, electrodiagnostic studies provide valuable physiological information regarding median nerve function. These tests not only support the diagnosis but also help determine the severity of CTS.[1-3]

Table 2: Comparison of NCS findings and WE-FW values between the groups

WE-FW/O	Controls Mean±SD (min-max) (number)	CTS patients Mean±SD (min-max) (number)	p Value
NCV m/s (onset latency)	13.96±5.26 (-2.60-21.90) (n=40)	25.02±8.37 (7.70-44.60) (n=44)	**<0.001**
NCV m/s (peak latency)	11.81±4.52 (0.60-24.00) (n=40)	20.83±7.92 (4.40-39.70) (n=44)	**<0.001**
WE-FW/A			
NCV m/s (onset latency)	14.86±5.49 (2.10-29.10) (n=40)	28.25±8.26 (10.50-43.10) (n=54)	**<0.001**
NCV m/s (peak latency)	14.25±4.02 (7.10-23.80) (n=40)	24.55±7.51 (12.0-43.80) (n=54)	**<0.001**
Median sensory NCS in the 2nd finger-wrist segment (Antidromic)			
CNAP amplitude	38.55±15.81 (18.8-86.8) (n=40)	23.62±11.78 (6.2-53.4) (n=54)	**<0.001**
NCV m/s (onset latency)	55.49±4.77 (45.9-65.5) (n=40)	40.30±5.32 (28.1-50.4) (n=54)	**<0.001**
NCV m/s (peak latency)	44.65±2.78 (40.0-51.6) (n=40)	32.88±4.31 (23.0-38.9) (n=54)	**<0.001**
Median sensory NCS in the 2nd finger-wrist segment (Orthodromic)			
CNAP amplitude	16.87± 6.78 (6.9-36.8) (n=40)	9.39± 8.15 (0.0-34.1) (n=61)	**<0.001**
NCV m/s (onset latency)	56.39±4.29 (46.8-66.5) (n=40)	43.10±6.43 (22.0-59.3) (n=44)	**<0.001**
NCV m/s (peak latency)	47.09± 3.53 (41.0-54.0) (n=40)	36.58±5.33 (18.0-49.0) (n=44)	**<0.001**
Median sensory NCS in the palm-wrist segment (Orthodromic)			
CNAP amplitude	40.07±15.41 (14.6-66.3) (n=40)	22.95±16.59 (0.0-58.9) (n=61)	**<0.001**
NCV m/s (onset latency)	62.08±7.40 (45.7-81.6) (n=40)	42.24±11.89 (16.0-52.4) (n=53)	**<0.001**
NCV m/s (peak latency)	47.31±4.57 (38.5-58.0) (n=40)	33.31±8.00 (13.0-52.4) (n=53)	**<0.001**
Median mixed NCS in wrist-elbow segment (Orthodromic)			
CNAP amplitude	23.39±8.96 (10.0 – 48.7) (n=40)	18.85±9.37 (5.6-47.3) (n=61)	**0.017**
NCV m/s (onset latency)	70.35±4.57 (59.0 – 75.0) (n=40)	68.92±5.20 (55.0-75.0) (n=61)	0.159
NCV m/s (peak latency)	58.91±4.13 (49.6-66.7) (n=40)	57.92±5.52 (47.0-72.7) (n=61)	0.337

Notes: CNAP: compound nerve action potential; CTS: carpal tunnel syndrome; NCS: nerve conduction study; NCV: nerve conduction velocity; WE-FW: the nerve conduction velocity (NCV) difference between the mixed (wrist-elbow) and sensory (second finger-wrist) segments of the median nerve; WE-FW/A: WE–FW obtained by performing antidromic median sensory NCS in the 2nd finger–wrist segment; WE-FW/O: WE–FW obtained by performing orthodromic median sensory NCS in the 2nd finger–wrist segment.

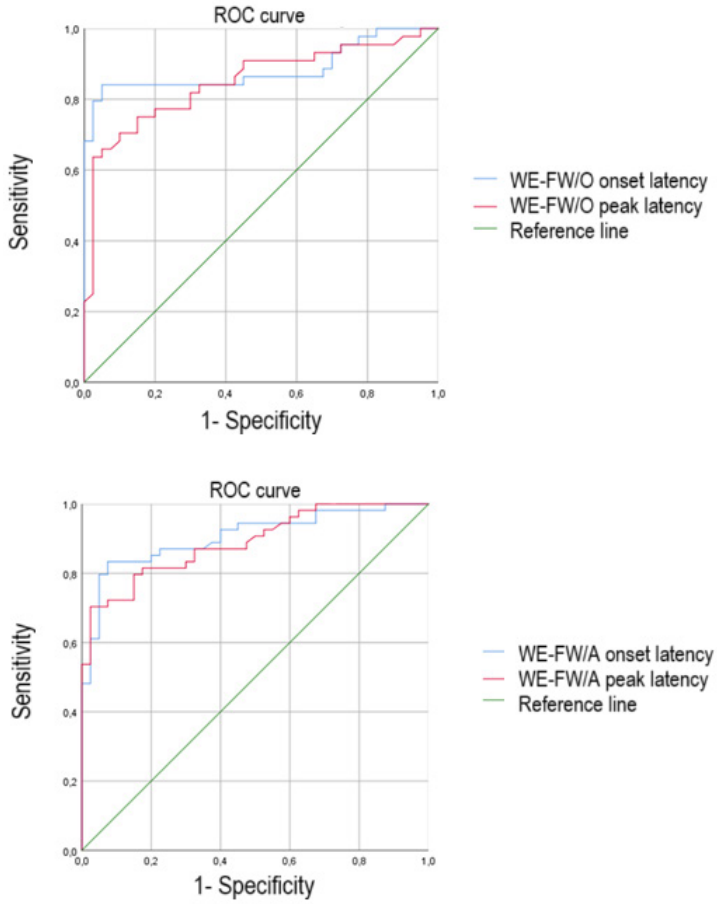

Figure 2. ROC curve of WE-FW in CTS

Notes: NCV: nerve conduction velocity; ROC: Receiver Operating Characteristic; WE-FW: NCV difference between the mixed (wrist-elbow) and sensory (second finger-wrist) segments of the median nerve; WE-FW/A: WE–FW obtained by performing antidromic median sensory NCS in the 2nd finger–wrist segment; WE-FW/O: WE–FW obtained by performing orthodromic median sensory NCS in the 2nd finger–wrist segment.

Table 3: ROC-derived cutoff values, sensitivity, and specificity of WE–FW parameters

WE-FW/O ROC analysis	**Cutoff (m/s)**	**Area Under the Curve (AUC) (95% Confidence Interval) (Upper–Lower limit)**	**Sensitivity (%)**	**Specificity (%)**	**p value**
NCV (onset latency)	18.85	0.885 (0.806 – 0.964)	84.1	85.0	**<0.001**
NCV (peak latency)	15.30	0.849 (0.765 – 0.934)	77.3	77.5	**<0.001**
WE-FW/A ROC analysis					
NCV (onset latency)	19.55	0.906 (0.845 – 0.967)	83.3	82.5	**<0.001**
NCV (peak latency)	18.35	0.889 (0.826 – 0.952)	81.5	82.5	**<0.001**

Notes: NCV: nerve conduction velocity; ROC: Receiver Operating Characteristic; WE-FW: NCV difference between the mixed (wrist-elbow) and sensory (second finger-wrist) segments of the median nerve; WE-FW/A: WE–FW obtained by performing antidromic median sensory NCS in the 2nd finger–wrist segment; WE-FW/O: WE–FW obtained by performing orthodromic median sensory NCS in the 2nd finger–wrist segment.

Table 4: Correlations between WE-FW and clinical findings

Clinical findings	WE-FW/O (onset latency)	WE-FW/O (peak latency)	WE-FW/A (onset latency)	WE-FW/A (peak latency)
Clinical grading	P=0.055, r=0.291	**P=0.044, r=0.306**	**P=0.005, r=0.376**	P=0.063, r=0.255
Mean VAS score	P=0.057, r=0.290	**P=0.013, r=0.372**	P=0.063, r=0.255	**P=0.026, r=0.303**
Maximum VAS score	P=0.108, r=0.246	**P=0.019, r=0.353**	P=0.065, r=0.253	**P=0.041, r=0.279**
DASH score	**P=0.036, r=0.318**	P=0.117, r=0.240	P=0.520, r=0.089	P=0.663, r=-0.061
DASH-WM score	P=0.050, r=0.298	**P=0.028, r=0.331**	P=0.080, r=0.240	P=0.344, r=0.131

Notes: DASH: the Disabilities of the Arm, Shoulder and Hand; DASH-WM: the Disabilities of the Arm, Shoulder and Hand- work module; WE-FW: the nerve conduction velocity difference between the mixed (wrist-elbow) and sensory (second finger-wrist) segments of the median nerve; WE-FW/A: WE–FW obtained by performing antidromic median sensory NCS in the 2nd finger–wrist segment; WE-FW/O: WE–FW obtained by performing orthodromic median sensory NCS in the 2nd finger–wrist segment; VAS: the Visual Analog Scale.

Electrodiagnostic studies in CTS commonly involve median sensory and motor NCSs, ulnar NCSs, and needle electromyography, which are essential not only for diagnosis but also for differential diagnosis. Previous studies have reported that the sensitivity of median NCSs ranges from approximately 50% to 85%, while specificity varies between 90% and 99%.[1,7,9,22,23] Commonly used electrodiagnostic techniques include assessments of median sensory conduction in the first three digits and median–ulnar latency comparison.[5,6]

In the present study, we hypothesized that unless CTS is severe, median NCV in the forearm segment would be preserved. Based on this hypothesis, we investigated the diagnostic

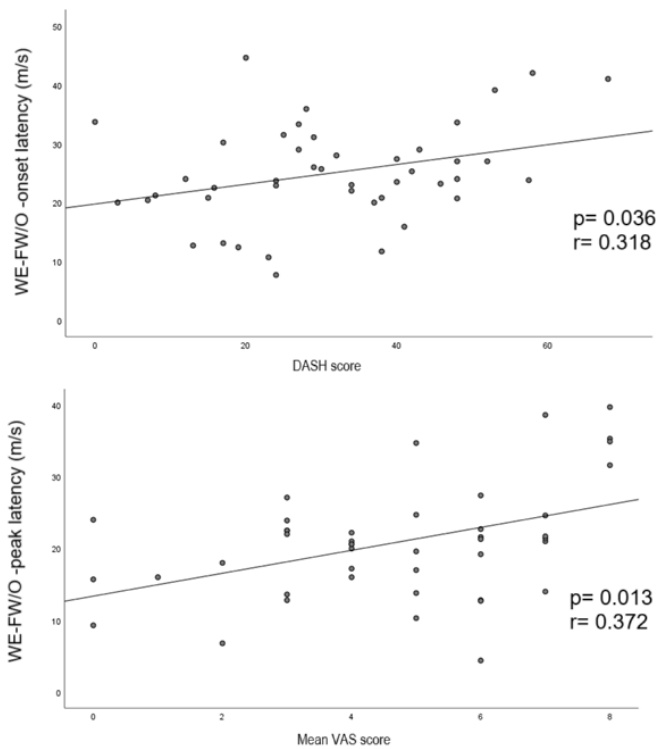

Figure 3. Correlations of WE–FW/O with DASH and Mean VAS Scores
Notes: DASH: the Disabilities of the Arm, Shoulder and Hand; WE-FW: NCV difference between the mixed (wrist-elbow) and sensory (second finger-wrist) segments of the median nerve; WE-FW/O: WE–FW obtained by performing orthodromic median sensory NCS in the 2nd finger–wrist segment; VAS: visual analog scale

utility of the WE–FW parameter in CTS. A similar segmental comparison approach is used in other entrapment neuropathies, such as ulnar neuropathy at the elbow, where differences in motor NCV between the forearm and elbow segments support the diagnosis.[21,24] Other examples include sural and superficial radial nerve comparisons in polyneuropathy, or comparing an affected nerve with one that is typically spared.[25] Similar to comparisons between the NCS findings of those different nerves, the observation that both the sensitivity and specificity of WE–FW ranged between 77.3%-84.1% and 77.5%-85.0%, respectively, suggests that suggests that this novel electrodiagnostic approach may be a reliable and valuable tool in both the diagnosis and differential diagnosis of CTS. Additionally, the study examined CTS extremities with abnormal WE-FW values, as defined by cut-off points, in patients who had normal neurological examination findings and only sensory symptoms, corresponding to Grade 1 and Grade 2 in the clinical classification. In these mild CTS patients, abnormal WE-FW/O and WE-FW/A values were found in 86% and 79% of the extremities, respectively, when onset latency was used, and in 76% and %77, respectively, when peak latency was used. These results suggest that the WE-FW method may be useful for identifying clinically mild CTS, especially in patients who cannot be diagnosed using conventional electrodiagnostic techniques.

Previous studies have reported the sensitivity of median-ulnar sensory latency difference in the palm-wrist segment to be approximately 70-75%, and in the fourth finger-wrist segment to range from 55% to 85%.[7,9,26] In line with these findings, the comparable sensitivity of WE-FW found in the present study underscores the clinical relevance of this method. In conditions such as ulnar neuropathy or polyneuropathy, where methods such as the median-ulnar latency difference may have limited applicability, this method could provide advantages for the diagnosis of CTS.

There are conflicting reports regarding the relationship between clinical and electrodiagnostic findings in CTS.[1,8-10] In the present study, significant correlations were observed between WE–FW and both the DASH scores and clinical grading, which reflect clinical status. These significant positive correlations were of modest strength, which may be attributed to the subjective nature of patient complaints in contrast to the objective character of electrophysiological findings. Moreover, pain perception is primarily mediated by small nerve fibers, whereas routine NCSs predominantly assess large myelinated fibers. Nevertheless, WE–FW showed significant correlations with VAS scores, which are indicative of neuropathic pain intensity. Taken together, these findings suggest that WE–FW may serve as a valuable tool not only for diagnosis but also for the clinical monitoring of CTS.

All NCS findings, including all WE-FW values but excluding the median mixed NCV, differed significantly between CTS patients and controls. This may indicate that, unlike the median mixed CNAP amplitude, the median mixed NCV is either unaffected or only minimally affected in CTS, supporting our hypothesis. In other words, while proximal (i.e., retrograde) axonal degeneration in CTS clearly impacts CNAP amplitudes, its effect on NCV may be limited. Likewise, a previous study found no difference in conduction velocities but reported significantly altered amplitudes in CTS, supporting the present findings.[10] Taken together, this and the other findings support that WE-FW is a reliable method for use in CTS.

In the present study, the majority of CTS patients were housewives; however, individuals with occupations such as manual labor and teaching were also represented. Housewives frequently engage in repetitive hand and wrist movements, while some manual laborers perform tasks that place additional strain on the hand, wrist, forearm, and elbow.[27,28] Mixed forearm NCSs may be influenced in individuals who perform repetitive movements involving the forearm or elbow. Therefore, studies examining WE-FW in relation to occupational groups may offer valuable insights into the pathophysiology of CTS and other entrapment neuropathies. Similarly, but without a mechanical cause, mixed nerves in the forearm segment may be affected in chronic conditions such as diabetes mellitus or thyroid disorders, as these diseases can involve generalized neuropathy, potentially altering the WE-FW cut-off values.[11,13] In addition, the electrodiagnostic diagnosis of CTS can be challenging in such conditions due to the presence of widespread nerve involvement.[13,29] Studies examining WE-FW in patients with endocrine disorders may help clarify the diagnosis of CTS and provide insight into the pathophysiology of neuropathies associated with these conditions.

This study has several limitations. The BMI values of the CTS patients and controls differed, which was expected given that obesity is a known risk factor for CTS.[1,30] However, the higher BMI observed in CTS patients compared to controls

may have influenced mixed NCS findings in the forearm.[30,31] Therefore, further studies are needed to explore the relationship between BMI and WE-FW or mixed forearm NCSs in CTS. Additionally, WE-FW was not compared with other electrodiagnostic methods commonly used for CTS, which may also be considered a limitation. Future research in this area may help clarify the diagnostic value of WE-FW in CTS. Another limitation of the study is that CNAPs could not be obtained in a subset of CTS patients, especially orthodromically. This may reflect a technical limitation of the WE-FW method in severe CTS cases, as CNAPs cannot be recorded in such instances. Nonetheless, this study also had notable strengths. In addition to its prospective design, detailed assessments using the VAS and DASH questionnaires were performed in CTS patients. Furthermore, sensory NCSs were conducted using both orthodromic and antidromic techniques, and NCVs were calculated based on both onset and peak latencies.

This study demonstrated that the WE–FW parameter, derived from mixed–sensory nerve conduction velocity differences between the forearm and wrist segments, offers strong diagnostic potential in CTS. WE–FW values were significantly increased in CTS patients and showed meaningful correlations with both clinical severity and patient-reported outcomes, including VAS and DASH scores. These findings suggest that WE–FW not only reflects neurophysiological impairment but may also serve as a surrogate marker of symptom burden. The diagnostic sensitivity and specificity of WE–FW were comparable to conventional electrodiagnostic methods, highlighting its utility as a complementary tool in the diagnostic process. WE–FW appears to be a reliable, clinically relevant, and practical addition to the electrophysiological evaluation of CTS, with potential applications in both diagnosis and follow-up.

DISCLOSURE

Ethics: Ethical approval was obtained from the hospital's local ethics committee (No. 106/1956, 2022). Written informed consent was obtained from all participants.

Data availability: Data are available on reasonable request.

Financial support: None

Conflict of interest: None

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