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KFORCE Sens® electrogoniometer in the evaluation of wrist range of motion in patients with carpal tunnel syndrome: Validity and reliability

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Abstract

This study aimed to test the validity and reliability of the KFORCE Sens® (electrogoniometer) in carpal tunnel syndrome (CTS) patients. Thirty-one volunteers (aged 32-60 years) diagnosed with unilateral CTS were included in this study. Each of the two raters evaluated the participants' wrist range of motion (ROMs) (flexion, extension, radial deviation, and ulnar deviation) twice, for a total of four times, using an electrogoniometer. In addition, wrist ROMs were evaluated once with a universal goniometer. According to the study findings, both the inter-rater and test-retest reliability of the electrogoniometer device in all ROMs of the wrist were excellent (ICC>0.80). In addition, the ROM values of the electrogoniometer device and the ROM values of the universal goniometer in the same joint were highly correlated ($r>0.80$, $p<0.05$). The electrogoniometer is a valid, reliable, and practical device for evaluating wrist ROMs in patients with CTS.

Keywords: range of motion, carpal tunnel syndrome, electrogoniometers, reliability, wrist

1. Introduction

Carpal tunnel syndrome (CTS) is a common peripheral neuropathic disorder characterized by pain, tingling, and numbness over the dermatomal area of the median nerve (1, 2). Local hyperplasia, fibrosis, and synovial hypertrophy develop in patients with CTS (3, 4). These pathologies cause limitations in the range of motion (ROM) of the wrist. In addition, studies have shown that patients with CTS may experience a decrease in wrist ROM due to pain and immobilization after splinting (5).

Today, the use of electrogoniometers for ROM measurements is becoming more popular as technology advances (6). In many joints, reliability and validity investigations of electrogoniometers have been performed in the assessment of ROMs (7, 8). Studies have often concluded that electrogoniometers are valid and reliable in the wrist, knee, and ankle joints (9-11).

KFORCE Sens® (electrogoniometer) is an electrogoniometer or inertial sensor. It was developed by Kinvent™ (Montpellier, France) engineers to evaluate joint ROM. Electrogoniometers offer real-time biofeedback by measuring the difference between the starting position and the end point of the movement, thanks to their measurement sensors. Data obtained from the device can be transferred to smartphones and computers via Bluetooth® connections (12).

This study aimed to determine the test-retest reliability, inter-rater reliability, and validity of the electrogoniometer in the assessment of wrist ROMs in patients with CTS.

2. Materials and methods

This study was carried out on 31 individuals diagnosed with mild to moderate CTS, aged between 32-60. CTS severity was determined by a neurophysiologic assessment of the median nerve lesion (13). This study was approved by the Kırşehir Ahi Evran University Faculty of Medicine Clinical Research Ethics Committee. Verbal and written informed consent was obtained from all subjects, and the study was conducted in accordance with the Declaration of Helsinki.

2.1. Participants and Methods

The inclusion criteria for the study were as follows: Being older than 18 years of age, volunteering, having a medical diagnosis of unilateral CTS, and having symptoms of CTS for more than one year. Exclusion criteria from the study: the inability to understand instructions was determined to be related to any neuromuscular disorder related to the upper extremity.

2.2. Study design

Wrist ROMs were evaluated with both the universal goniometer and the electrogoniometer. To examine the construct validity of electrogoniometer, its relationship with universal goniometer values was examined. In addition, electrogoniometer evaluations for both inter-rater and test-

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retest reliability were repeated by two physiotherapists (MC, ŞK).

Participants were given an explanation of the protocol and an introduction to the device before the start of the assessment. To avoid distracting the participants, the evaluations were performed in a quiet room on the examination bed. In the study, the wrist ROMs of the participants diagnosed with CTS were evaluated. Two trial assessments were performed first, followed by ten assessments with 30-second rest periods (12). (Since there is no standard time and repetition in the instructions for use of the device or in the literature, these times and repetitions were determined in line with the consensus of the authors.)

2.3. Evaluation of range of motion

Universal goniometer

For wrist flexion and extension measurements, the patient was seated with the forearm pronated and supported on a table edge. The pivot point of the goniometer was the styloid process of the ulna; the fixed arm was parallel to the ulna, and the movable arm followed the fifth metacarpal bone. The ROM value was recorded while the patient was doing active flexion and extension. For wrist ulnar deviation and radial deviation measurements, the patient sat with his forearm pronated and the volar side of his hand supported on the table. The pivot point of the goniometer was proximal to the third metacarpal, the midpoint of the carpometacarpal joint; the fixed arm was parallel to the midpoint of the radius and ulna; and the movable arm followed the third metacarpal bone. The ROM value was recorded while the patient was making active ulnar and radial deviations. After the universal goniometer evaluations, the electrogoniometer evaluations started 5 minutes later (14).

KFORCE Sens® (electrogoniometer)

The positioning of the participants was the same as in the 360° universal goniometer assessments. The device was attached to the lateral aspect of the wrist for wrist flexion-extension and to the dorsal aspect of the wrist for ulnar-radial deviation (Fig. 1). The assessment was started by pressing the "start" button on the mobile device, and then the previous protocol was followed. The device has saved the active ROM values. The gadget features a gyroscopic inertial sensor that allows for joint range of motion measurement, monitoring, and therapy. It calculates the angle with regard to the limb's initial position in a specified anatomic plane. All assessments with the device were performed by two physiotherapists. The physiotherapists then repeated their measurements. There was a 5-minute break between measurements (12).

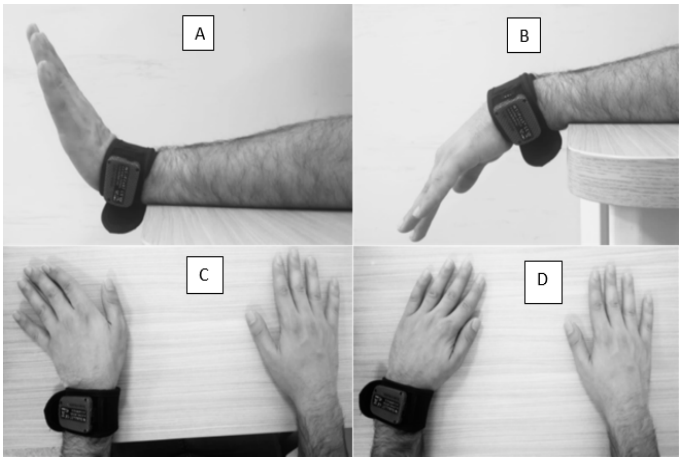

Fig. 1. Evaluation of range of motion with KFORCE Sens® electrogoniometer, A: Wrist extension position, B: Wrist flexion position, C: Wrist ulnar deviation position, D: Wrist radial deviation position

2.4. Statistical analysis

We used the G*Power program (Heinrich-Heine-Universität Düsseldorf, Germany) version 3.1.9.4 to determine the study sample (15). Based on similar articles (12), the power rate of the sample was calculated as $\beta = 80\%$ (type II error rate = 20%), type I error rate $\alpha = 0.05$, and d (effect size) = 0.45, totaling 31 participants.

All statistical analyses were executed utilizing SPSS version 24 software (SPSS Inc, Chicago, Illinois). A combination of visual methods and analytical techniques was employed to evaluate the normal distribution of variables. Assessment of the reliability of the electrogoniometer was conducted using the intraclass correlation coefficient (ICC). The ICC values were categorized as poor (<0.40), fair (0.40-0.59), good (0.60-0.79), and excellent (>0.80) reliability, respectively (16). A Pearson correlation analysis was performed to ascertain the concurrent validity of the electrogoniometer through its relationship with secondary measurements. A correlation coefficient was considered poor (less than 0.30), moderate (between 0.30 and 0.60), and strong (greater than 0.60) (17). Calculation of the standard error of measurement (SEM_{95}) value for the electrogoniometer scores employed the following formula: SEM_{95} = Standard deviation x $\sqrt{(1\text{-ICC})}$. The determination of the minimal detectable change at a 95% confidence interval (MDC_{95}) involved the following formula: $MDC_{95} = 1.96 \times SEM_{95} \times \sqrt{2}$ (18). The established level of statistical significance was set at $p < 0.05$.

3. Results

The demographic information of the patients with CTS included in the study is given in detail in Table 1.

The mean clinical measurement values are given in Table 2.

The first rater's test-retest ICC values for electrogoniometers for wrist flexion, wrist extension, wrist ulnar deviation, and wrist radial deviation were 0.97, 0.96, 0.99, and 0.95, respectively. This result showed us that the patients with CTS included in the study had excellent test-

retest validity in the wrist ROMs evaluation of the electrogoniometer.

Table 1. Participants' demographics features

		(n=31)			
		Mean	SD	Min	Max
Age (years)		46.00	7.95	32.00	60.00
Height (cm)		166.39	6.45	155.00	184.00
Weight (kg)		70.03	13.88	49.00	120.00
BMI (kg/m^2)		25.42	5.49	17.17	41.52
		n		(%)	
Gender	Male	12		38.7	
	Female	19		61.3	
Injured side	Right	17		54.8	
	Left	14		45.2	
Dominant side	Right	18		58.1	
	Left	13		41.9	

SD: Standard Deviation, BMI: Body Mass Index, Min: Minimum, Max: Maximum

When we look at the inter-rater reliability of electrogoniometers between the first and second raters for wrist flexion, wrist extension, wrist ulnar deviation, and wrist radial deviation, the ICC values are 0.98, 0.98, 0.98, and 0.98, respectively. Thus, the inter-rater reliability of the electrogoniometer was also found to be excellent (Table 3).

Table 2. The mean values of the measurements of the wrist ROMs

			(n=31)		Min	Max
			Mean	SD		
Baseline® 360° universal goniometer		Flexion	61.90	9.16	40.00	80.00
		Extension	55.61	6.33	41.00	66.00
		Ulnar deviation	29.03	7.60	16.00	43.00
		Radial deviation	12.77	2.86	8.00	18.00
KFORCE Sens®	Flexion (1)	Test	63.71	9.63	40.00	85.00
		Retest	63.52	9.49	40.00	84.00
	Flexion (2)	Test	63.45	9.63	35.00	81.00
		Retest	63.00	9.07	37.00	79.00
	Extension (1)	Test	56.81	6.53	41.00	70.00
		Retest	56.48	6.24	43.00	67.00
	Extension (2)	Test	56.61	6.20	42.00	69.00
		Retest	56.35	5.90	43.00	68.00
	Ulnar deviation (1)	Test	30.52	7.81	16.00	44.00
		Retest	30.03	7.38	17.00	42.00
	Ulnar deviation (2)	Test	30.71	7.17	17.00	43.00
		Retest	30.55	6.69	18.00	41.00
	Radial deviation (1)	Test	13.58	3.31	8.00	20.00
		Retest	13.48	2.95	7.00	19.00
	Radial deviation (2)	Test	13.58	3.11	8.00	19.00
		Retest	13.74	2.82	9.00	19.00

1: First rater, 2: Second rater, SD: Standard Deviation, Min: Minimum, Max: Maximum

Table 3. Inter-rater (ICC) and test-retest (ICC) reliability of the KFORCE Sens®

n=31	Difference (Mean ± SD)	Inter-rater (ICC $_{1,2}$) (95% CI)	Test-retest (ICC $_{1,1}$) (95% CI)	SEM$_{95}$	MDC$_{95}$
Flexion	-0.19 ± 2.44	0.98 (0.96-0.99)	0.97 (0.93-0.98)	0.37	1.01
Extension	-0.32 ± 1.77	0.98 (0.97-0.99)	0.96 (0.92-0.98)	0.35	0.95
Ulnar deviation	-0.48 ± 1.12	0.98 (0.97-0.99)	0.99 (0.98-0.99)	0.11	0.30
Radial deviation	-0.09 ± 1.01	0.98 (0.96-0.99)	0.95 (0.90-0.98)	0.14	0.38

SD: Standard Deviation, ICC: Intraclass Correlation Coefficient, SEM$_{95}$: standard error of measurement; MDC$_{95}$: minimum detectable change at the 95% confidence interval

The correlation results of the electrogoniometer with the universal goniometric measurements, which are frequently used in the clinic, to determine the concurrent validity of wrist flexion, wrist extension, wrist ulnar deviation, and wrist radial deviation of patients with CTS included in the study are examined in Table 4. According to our results, a high level of statistically significant correlation was found between the wrist ROM values of the electrogoniometer and all the same joint ROM values of the universal goniometer ($p<0.05$).

Table 4. Relationship between KFORCE Sens® and Baseline® 360° universal goniometer ROM evaluations

		Baseline® 360° universal goniometer			
		Flexion	Extension	Ulnar deviation	Radial deviation
KFORCE Sens®	r	0.975	0.976	0.989	0.943
	p	<0.001*	<0.001*	<0.001*	<0.001*

*p<0.001

4. Discussion

Based on the results of the current study, the test-retest reliability of the electrogoniometer in patients with CTS was excellent. Because of the significant relationship between the electrogoniometer and the universal goniometer, we have proven that it is also valid in the evaluation of wrist ROMs in patients with CTS. Also, in this study, we present for the first time the MDC$_{95}$ and SEM$_{95}$ values of the electrogoniometer for the evaluation of wrist ROMs in patients with CTS.

Electrogoniometers are a practical tool to identify functional limitations, guide treatment programs, and provide evidence of treatment efficacy. When the literature is examined, practical and reliable alternative goniometer types have been developed. In this study, we investigated the reliability of the electrogoniometer, which is a portable device that transmits data to smartphones and computers via Bluetooth® connections on wrist ROMs. In a previous study, the reliability of the electrogoniometer in the wrist joint was investigated, and it was concluded that the ICC value was 0.94 for flexion/extension movement and 0.96 for ulnar/radial deviation (12). Pilbeam et al. concluded that the test-retest reliability of the universal goniometer was reliable in evaluating the wrist joint position sense in healthy subjects (19). In another study, Tajali et al. stated that two different electrogoniometers have high reliability except for radial deviation movement in people with limitations in wrist ROM (20). In our study, the test-retest reliability of the electrogoniometer was found to be excellent (ICC > 0.80).

In this study, we used a universal goniometer to test the concurrent validity of the electrogoniometer. When the results

of our study were examined, we found a strong correlation between the electrogoniometer and the universal goniometer in all wrist ROM values ($r > 0.88$, $p < 0.001$). Tekin et al. examined the validity and reliability of the electrogoniometer in healthy subjects and evaluated the construct validity of the electrogoniometer using a universal goniometer. They found a highly strong relationship between both goniometers in flexion-extension movements and a strong relationship for radial-ulnar deviation movements in the dominant extremity. In addition, they found a highly strong correlation for flexion-extension movements and a strong correlation for ulnar-radial deviation movements between both dynamometers in the non-dominant side extremity (12). These results are consistent with the literature, and we think that an electrogoniometer is a valid method for the evaluation of wrist ROMs in patients with CTS.

Camassuti et al. (21) calculated the SEM_{95} values of the MIOTEC® brand electrogoniometer for wrist ROM evaluation as 3.10 for extension, 3.11 for flexion, 1.78 for radial deviation, and 1.63 for ulnar deviation. Tajali et al. (20) found the SEM_{95} values of the J-Tech electrogoniometer to be 3.48 for flexion, 2.82 for extension, 1.94 for radial deviation, and 2.06 for ulnar deviation in patients with hand and wrist motion limitations. Also, Tajali et al. (20) found the MDC_{95} value of the J-Tech electrogoniometer to be 11.86 for flexion, 7.82 for extension, 5.76 for radial deviation, and 5.38 for ulnar deviation. In our study, the MDC_{95} value was 1.01 for flexion, 0.95 for extension, 0.30 for ulnar deviation, and 0.38 for radial deviation. In addition, the SEM_{95} value was 0.37 for flexion, 0.35 for extension, 0.11 for ulnar deviation, and 0.14 for radial deviation.

The most important limitation of the present study is the limited number of studies on the validity and reliability of the electrogoniometer. This makes it difficult to compare the results of our study with the literature. We believe that future studies should investigate electrogoniometry in specific pathologies, age groups, and different extremities.

Test-retest and inter-rater reliability of the electrogoniometer are excellent in assessing wrist ROM in patients with CTS and have strong concurrent validity with the universal goniometer. The electrogoniometer is an easy-to-use and reliable device.

Ethical Statement

This research and the use of data have been approved by Kırşehir Ahi Evran University Faculty of Medicine Clinical Research Ethics Committee Ethics Committee (Number: 2022-22/194, Date: 06.12.2022).

Conflict of interest

No to declare.

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Authors' contributions

Concept: İ.C., Ş.K., Design: İ.C., M.C., Data Collection or Processing: A.Ö., Ş.K., Analysis or Interpretation: İ.C., H.A., Literature Search: İ.C., Ş.K., Writing: M.C., A.Ö., F.T.

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