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Evaluation of Joint Position Sense with Two Different Electrogoniometers in Carpal Tunnel Syndrome

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ABSTRACT

Carpal tunnel syndrome causes changes hand proprioception but there are a limited number of studies on joint position sense in patients with CTS. The aim of the study was to investigate the validity and reliability of the KForce Sens® for the evaluation of wrist joint position sense in individuals with CTS. Wrist joint position sense was assessed with KForce Sens® and Baseline® electrogoniometer. The validity and reliability of the KForce Sens® for wrist position sense evaluation were investigated by comparing the two data sets. The study was conducted in 35 patients (29 females, 6 males) with CTS and 35 healthy individuals (29 females, 6 males). In test-retest measurements of the KForce Sens®, a significant correlation was found in 60° flexion (ICC=0.730), 30° extension (ICC=0.904), 60° extension (ICC=0.849), 15° ulnar deviation (ICC=0.834) and 10° radial deviation (ICC=0.952). A significant correlation was found between KForce Sens® and Baseline® electrogoniometer in 30° flexion, 60° flexion, 30° extension, 60° extension, 15° ulnar deviation and 10° radial deviation ($p<0.05$). The difference in joint position sense was significant in 30° flexion ($p<0.001$), 60° flexion ($p=0.023$), 30° extension ($p=0.003$), 60° extension ($p=0.037$) compared to the healthy controls. There was no significant difference in ulnar deviation and 10° radial deviation movements ($p>0.05$). The KForce Sens® device is a valid and reliable tool for the assessment of wrist joint position sense in patients with CTS. Even if the severity of CTS was mild, joint position sense was lower than that of healthy controls.

Keywords: Carpal tunnel, joint position sense, electrogoniometer.

INTRODUCTION

Carpal tunnel syndrome (CTS), the most common compression neuropathy affecting the upper extremity, is caused by the entrapment of the median nerve in the carpal tunnel[1]. This compression may lead to neural ischemia leading to the demyelination of the nerve and loss of axons, altered nerve conduction, and nerve damage[2]. In the diagnosis, the patient's complaints are important when wake up at night or in the morning[3,4]. Patients complain of pain, numbness, and tingling in the hand and wrist, especially on the radial side of the 4th finger and palmar surface of the first 3 fingers and spreading from the wrist to the forearm and upper arm[3,4]. Diagnosis can be made with provocative tests, electrodiagnostic tests, electromyography (EMG), ultrasonography (USG), and magnetic resonance imaging (MRI)[5,6]. According to the result of EMG, disease severity can be classified as mild, moderate, and severe CTS[3].

Compression of the median nerve can causes cortical changes because it affects the tendons, muscles, and skin receptors that provide hand proprioception[7]. In addition the initial signs of CTS encompass pain, numbness, and paresthesias within the median nerve distribution. As a consequence of complex neurological pathways, pain could interfere with proprioception at various neurophysiological levels of processing. For example, the receptor function could be directly affected, propagation of the afferent proprioceptive signals could be interrupted by competing sensory inputs, or the conscious appreciation of proprioceptive input in the somatosensory cortex could be suppressed by strong nociceptive signals. There could also be interference with a descending proprioceptive command, which

has been systemically overwritten by nociceptive feedback. In summary, the underlying influence of pain remains unclear as it pertains to proprioception senses[8].

Decreased proprioception results in incorrect positioning of the wrist during activities, affecting functional skills[7]. This can be an important parameter that affects the hand in work life. It may also cause impaired muscle tone, hand coordination, and decreased proprioception and position sense[9]. Proprioception includes joint position sense, kinesthesia, and neuromuscular control[10]. Joint position sense is defined as the ability to accurately reproduce a joint angle[10]. Evaluation of joint position sense is important because hand is a joint that leads to numerous movements and skills in daily life[11]. In the literature, there is no gold standard assessment method for the evaluation of wrist joint position sense. Goniometric measurement is the most preferred method for the evaluation of joint position sense[10]. Recently, electrogoniometers have been introduced instead of traditional plastic goniometers[12] and the validity and reliability of electrogoniometers in measuring joint position sense in different joints have been done[13,14]. Also, the validity and reliability study of the measurement of joint range of motion by an electrogoniometer was conducted in individuals with joint limitation[15].

Beyond the commonly recognized symptoms of CTS, proprioception—despite its critical role in fine motor control and overall hand function—remains insufficiently investigated and frequently overlooked in both clinical assessment and research. Early diagnosis and rehabilitation of proprioceptive deficits may enhance treatment outcomes by improving hand function and reducing long-term disability[16]. In the current literature, there is no study examining the validity and reliability of the use of electrogoniometers in the measurement of wrist joint position sense in patients with CTS. KForce Sens® (Kinvent, France) is an electrogoniometer developed to measure range of motion and compare the affected limb with the unaffected limb. It offers real-time biofeedback based on the range of motion with its inertial measurement sensors[17].

In line with all this information, the primary aim of our study was to investigate the validity and reliability of the KForce Sens® device for the evaluation of wrist joint position sense in individuals with CTS. Another aim was to investigate how joint position sense changes in individuals with CTS compared to healthy controls.

MATERIALS AND METHOD

The study was conducted in 35 patients with CTS and 35 healthy individuals aged 22-65 years. Approval for the study was granted by the Non-Interventional Research Ethics Committee (decision no: 136447, dated: 03.12.2021). Participants were informed about the study and asked to sign the Informed Consent Form if they voluntarily agree to participate in the study. All study procedures were performed by the principles stated in the Declaration of Helsinki.

Study Design

Function and symptom severity were evaluated with the Boston Carpal Tunnel Questionnaire (BCTQ). Joint position sense was evaluated with the KForce Sens® and Baseline electrogoniometer as parallel material for validity analysis. KForce Sens evaluation was repeated after one week for reliability analysis. At the same time, joint position sense was assessed in the healthy control group. Affected extremities of the participants with CTS and both extremity results of healthy controls were included in the analysis.

Participants

The study included participants with mild to moderate CTS confirmed with EMG. Mild CTS, if, there are prolonged sensory latencies, and normal motor studies. Prolonged median sensory latencies and relative or absolute prolongation of the median motor distal latency were classified as moderate CTS[18].

Also, they included having symptoms for at least 3 months and not receiving medical treatment and physiotherapy until 3 months before the study at the latest, having no trauma in the affected extremity in the last 6 months, no cervical radiculopathy, no brachial plexopathy, no cognitive problems, and no neurological problems, and those who were not pregnant.

Outcome Measures and Assessments

Boston Carpal Tunnel Questionnaire: This questionnaire includes symptom severity scale (BCTQ-S) and functional status scale (BCTQ-F). The BCTQ-S included 11 items indicating the severity, frequency, and duration of symptoms, and the BCTQ-F includes 8 items indicating difficulty in performing daily tasks. Each item has five possible answers in Likert scale scored from 1 (never) to 5 (most severe). Mean values were calculated for all items in the BCTQ. The validity and reliability of this questionnaire in Turkish were established[19].

Assessment of joint position sense: The evaluation of participants' wrist position sense was performed separately with a Baseline® electrogoniometer and KForce Sens®. All assessments were performed by a single physiotherapist for standardization. The participant's eyes were closed during the assessment. For validity analysis, In the measurement with the Baseline® electrogoniometer, the extremity was placed on the table with the shoulder and elbow joint in 90° flexion and the forearm in pronation. The pivot point of the goniometer was placed next to the ulnar styloid for 30° and 60° wrist flexion and extension, and also it was placed in the middle carpometacarpal joint for 10° radial deviation and 15° ulnar deviation[20,21]. A passive movement was made to the extremity in a predetermined amount and direction. The participant was asked to hold the extremity position for 5 seconds at the end of the movement and to remember this position[19,20]. Then, the participant was asked to return the extremity to this position when their eyes were closed (Figure 1). Assessment was repeated 3 times[21], a 10-second rest interval was given between each evaluation, and the average error was calculated by averaging the amount of inconsistency in each repetition. This procedure was repeated with the KForce Sens® device (Figure 2). The device was attached to the middle of the wrist joint with the help of Velcro for all movements. Starting position of the extremity was determined and this position was introduced to the device as the reference position. Then, the participant was asked to perform the movement[17]. KForce Sens® measurements were repeated 7 days later for test-retest reliability.

Statistical Analysis

The effect size obtained in the reference study[15] was strong. In the power analysis, which was made considering that a lower level of effect size (r=0.40) could be obtained, it was calculated that 95% confidence level and 80% power could be obtained when at least 34 participants are included in the study. In addition, post hoc power analysis was performed when the study was completed.

Data were analyzed using the SPSS (SPSS Inc., Chicago, IL, USA) program. Conformity to normal distribution was assessed with the Shapiro Wilk Test. Demographic, disease, and questionnaire data were

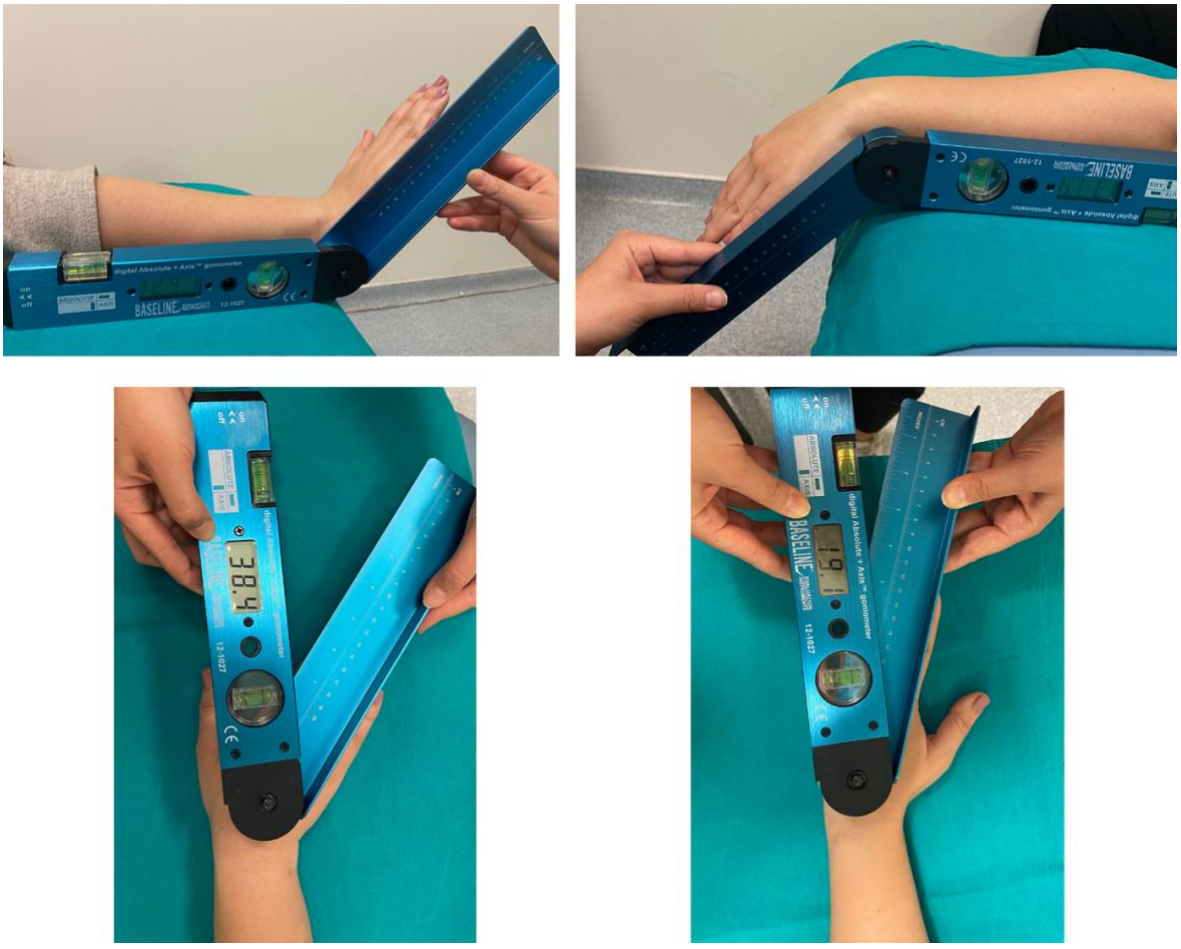

Fig. 1 — Assessment of joint position sense with Baseline electrogoniometer.

Fig. 2 — Assessment of joint position sense with KForce Sens.

assessed with descriptive analysis and are given as mean (mean), standard deviation (SD), median, interquartile range (IQR), and percentage. In the comparison between groups, t test was used in independent groups if parametric conditions were met, and if parametric conditions were not met, the Mann-Whitney U test was used. In the scale validity and reliability analysis, for the reliability of the scale, intraclass correlation coefficient (ICC) was used in test-retest examinations. Two-way mixed model was used as the ICC model. The ICC is a value between 0 and 1, where values below 0.5 indicate poor reliability, between 0.5 and 0.75 moderate reliability, between 0.75 and 0.9 good reliability, and any value above 0.9 indicates excellent reliability[22]. In parallel form studies, Pearson's correlation coefficient (if the data has a normal distribution) or Spearman's correlation coefficient (if the data does not fit the normal distribution) were used as a reference.

RESULTS

The study included 35 patients (52 hands) with CTS (29 females, 6 males) with a mean age of 46.17±10.17 years and 35 (70 hands) healthy controls (29 females, 6 males) with a mean age of 41.11±11.17 years. Forty-one extremities of the patients with CTS had a mild involvement (78.8%) and 11 extremities had a moderate involvement (21.2%). Demographic and disease data and the results of the BCTQ are given in Table I. A significant correlation was found between the KForce Sens® and Baseline® electrogoniometer in each movement including 30° flexion (r = 0.828), 60° flexion (r=0.679), 30° extension (r=808), 60° extension (r=0.656), 15° ulnar deviation (r=0.822), and 10° radial deviation (r=0.810) (Table II). In test-retest measurements of the KForce Sens® joint position sense measurements, a significant correlation was found in all angles of motion including 30° flexion (ICC=0.930), 60° flexion (ICC=0.730), 30° extension (ICC=0.904), 60° extension (ICC=0.849),15° ulnar deviation (ICC=0.834), and 10° radial deviation (ICC=0.952); therefore, it was reliable (Table III). In the post hoc power analysis performed with r correlation coefficients and ICC values, the power

Table I. — Demographic and disease-related data of the participants.

	CTS (n=35, n_{hand}=52)	Healthy (n=35, n_{hand} =70)	p
Age (years)	46.17±10.17	41.11±11.17	0.070
Dominant Side [n, (%)] Right Left	 34 (97.1) 1 (2.9)	 33 (94.3) 2 (5.7)	1.000
Gender [n, (%)] Female Male	 29 (82.9) 6 (17.1)	 29 (82.9) 6 (17.1)	1.000
Affected Side [n_{hand}, (%)] Dominant Nondominant	 28 (53.8) 24 (46.2)		
Severity [n_{hand}, (%)] Mild Moderate	 41 (78.8) 11 (21.2)		
BCTQ (Symptom severity)	2.35±0.70		
BCTQ (Functional status)	2.31±0.85		
CTS = Carpal Tunnel Syndrome, BCTQ = Boston Carpal Tunnel Questionnaire.			

Table II. — Correlation analysis of electrogoniometer and KForce Sens® joint position sense measurements.

	Instruments	X±SD	Median (IQR)	r	p
30° Flexion	Baseline Electrogoniometer	6.01±3.74	5.44 (4.84)	0.828	0.000
	KForce Sens	5.73±3.24	5.90 (4.19)		
60° Flexion	Baseline Electrogoniometer	5.24±3.01	4.76 (2.96)	0.679	0.000
	KForce Sens	5.13±2.98	4.46 (3.47)		
30° Extension	Baseline Electrogoniometer	6.23±4.16	5.64 (4.37)	0.808	0.000
	KForce Sens	5.44±4.07	4.75 (4.59)		
60° Extension	Baseline Electrogoniometer	6.22±4.89	4.75 (6.05)	0.656	0.000
	KForce Sens	5.27±4.11	4.15 (4.80)		
Ulnar Deviation	Baseline Electrogoniometer	2.33±1.43	2.10 (1.33)	0.822	0.000
	KForce Sens	2.53±1.33	2.48 (1.71)		
Radial Deviation	Baseline Electrogoniometer	2.73±1.74	2.36 (2.14)	0.810	0.000
	KForce Sens	2.89±1.79	2.63 (2.17)		
X: mean, SD: standard deviation, IQR:interquartile range, ICC: intraclass correlation coefficient, CI: confidence interval.					

was found to be 99%. The difference in joint position sense was significant in 30° flexion (p<0.001), 60° flexion (p=0.023), 30° extension (p=0.003), 60° extension (p=0.037), and 15° movements in patients with CTS compared to healthy controls. There was no significant difference in ulnar deviation (p=0.441) and 10° radial deviation (p=0.062) movements (Table IV).

DISCUSSION

According to the results of the study, the KForce Sens® device was found to be valid and reliable tool in the assessment of wrist joint position sense in patients with CTS. The ICC for joint position sense was high in all wrist movements. In addition, although most of the patients had mild CTS, their joint position senses in the flexion and extension directions were lower than the healthy control group.

Consistent with the study, Tajali et al. investigated the reliability of two different electrogoniometers in participants with range of motion limitation and reported that both devices had high reliability (ICC: 0.64-0.97) except for only radial deviation[15]. In a study investigating the reliability of electrogoniometer in the assessment of wrist movements, ICCs were found to be 0.91 for flexion, 0.92 for extension, 0.93 for radial deviation, and 0.95 for ulnar deviation. In conclusion, they reported that the electrogoniometer

Table III. — Test-retest evaluation of joint position measurement with KForce Sens.

	Test		Retest		ICC (%95 CI)	Cronbach
	X±SD	Median (IQR)	X±SD	Median (IQR)		
30° Flexion	5.73±3.24	5.90 (4.19)	5.90±3.39	5.36 (3.74)	0.930 (0.881-0.959)	0.964
60° Flexion	5.13±2.98	4.46 (3.47)	5.36±3.09	4.93 (2.98)	0.730 (0.572-0.836)	0.844
30° Extension	5.44±4.07	4.75 (4.59)	5.14±3.81	4.33 (3.13)	0.904 (0.839-0.944)	0.950
60° Extension	5.27±4.11	4.15 (4.80)	4.69±3.26	3.98 (3.29)	0.849 (0.751-0.911)	0.918
Ulnar Deviation	2.53±1.33	2.48 (1.71)	2.42±1.47	2.09 (1.55)	0.834 (0.728-0.901)	0.910
Radial Deviation	2.89±1.79	2.63 (2.17)	2.81±1.74	2.35 (2.10)	0.952 (0.918-0.972)	0.975
X: mean, SD: standard deviation, IQR:interquartile range, ICC: intraclass correlation coefficient, CI: confidence interval.						

Table IV. — Comparison of joint position sense in CTS and healthy individuals.

	Healthy		CTS		p
	X±SD	Median (IQR)	X±SD	Median (IQR)	
30° Flexion	3.71±1.64	3.96 (2.57)	5.73±3.24	5.90 (4.19)	0.000
60° Flexion	4.21±2.09	3.63 (2.73)	5.13±2.98	4.46 (3.47)	0.023
30° Extension	4.67±1.70	3.76 (2.43)	5.44±4.07	4.75 (4.59)	0.003
60° Extension	3.23±1.64	3.20 (2.17)	5.27±4.11	4.15 (4.80)	0.037
Ulnar Deviation	2.33±1.03	2.16 (1.64)	2.53±1.33	2.48 (1.71)	0.441
Radial Deviation	2.36±1.44	1.83 (2.16)	2.89±1.79	2.63 (2.17)	0.062
X: Mean, SS: standard deviation, IQR: interquartile range.					

is a reliable tool and can be used as an option for clinical applications for wrist motion assessment[23]. In our study, ICCs were found to be between 0.730 and 0.952. Between the KForce Sens® and the Baseline® electrogoniometer in the correlation coefficients for 60° flexion and extension angles were 0.679 and 0.656, respectively. The high power in the findings related to validity and reliability supports our findings in terms of methodological and selected methods.

The participant may have estimated the angle more easily with the KForce Sens® measurement than with the Baseline® electrogoniometer due to the stretching of the Velcro where the device was attached at these angles of the wrist. This may have particularly affected the correlation with the Baseline® electrogoniometer. The KForce Sens® device, which was found to be valid and reliable, is smaller than the electrogoniometer and it is portable, which increases the accuracy of measurement as it can be used easily. Moreover, it can be connected to all devices via Bluetooth and measurement results can be recorded and stored with a smartphone application. However, as far as we observed in the study, it is more difficult to fixate it around small joints and displacement problem may occur after fixation[24].

Factors that may prevent accurate measurement in the assessment of joint position sense are tactile and visual stimulus[11]. Therefore, we assessed the joint position sense with the participants' eyes closed. Because the Baseline® electrogoniometer does not come into contact with the skin, it eliminates the skin input; however, we could not eliminate this input in the KForce Sens®, because we attached it to the wrist with Velcro. In addition, we limited the number of measurements to 3 trials for each movement, since learning effect of the wrist occurs more quickly and joint position sense may change when fatigue occurs[25]. The assessments were performed by a single physiotherapist to increase the reliability of test-retest results and measurements between devices.

According to the results regarding the other aim of the study, joint position sense in flexion and extension was significantly lower in patients with CTS compared to the healthy controls. Only one study evaluated joint position sense in patients with CTS. In this study, the joint position sense of patients with CTS impaired significantly compared to the healthy control group[7]. However, there was no significant difference in ulnar and radial deviation in our study. Tekin et al. used KForce Sens® to evaluate wrist joint position sense in healthy participants, and they found ulnar and radial deviation results similar to the results of our study[24]. According these results, the ulnar and radial deviation joint position sense of the patients with CTS included in the study was not affected. Furthermore, compression of the median nerve in

flexion and extension positions may have affected the joint receptors in these movements. This problem may have led to a decrease in the sense of joint position.

We believe that assessing position sense and kinesthetic sensation in the diagnosis and follow-up of CTS patients may contribute to early diagnosis. Furthermore, it may be an effective outcome measure in the long term for return to daily living activities and work. More evidence may be needed regarding the use of the KForce Sens® device for monitoring in different neuropathy conditions. We also consider this device plays an important role in monitoring recovery before and after decompression, conservative treatment, or rehabilitation processes.

Limitations of our study, the use of Velcro to fasten the KForce Sens® to the wrist limited ability to eliminate skin input in measuring joint position sense. Another limitation is we only included mild to moderate CTS in the study. Our findings on wrist joint position sense in CTS patients may not be generalizable to patients with severe symptoms. Future studies may compare joint position sense as well as other senses with healthy controls to obtained normal values for the joint position sense of the KForce Sens® for the evaluation of inter-test validity. Studies on proprioception evaluation can be performed in cases of severe CTS or postsurgical patients. The effects of proprioceptive training specific to joint position sense can be investigated in CTS patients.

CONCLUSION

The KForce Sens® device is a valid and reliable tool for the assessment of wrist joint position sense in patients with CTS. It is a fast, accurate, and reliable new approach that can be used in the current practice. The fact that the data is stored and the application can be used free of charge may make the device advantageous. Even if the severity of CTS was mild, joint position sense was lower than that of healthy controls. Regardless of the severity of CTS, joint position is a sense that should be considered in both surgical and conservative treatment steps.

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