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ARE JOINT POSITION SENSE, TWO-POINT DISCRIMINATION, FINE MOTOR CONTROL, GRIP STRENGTH, LIGHT TOUCH SENSATION, PAIN, AND FUNCTIONALITY AFFECTED BILATERALLY IN UNILATERAL CARPAL TUNNEL SYNDROME?

TEK TARAFLI KARPAL TÜNEL SENDROMUNDA EKLEM POZİSYON HİSSİ, İKİ NOKTA AYRIMI, İNCE MOTOR KONTROL, KAVRAMA KUVVETİ, HAFİF DOKUNMA DUYUSU, AĞRI VE İŞLEVSELLİK BİLATERAL OLARAK ETKİLENİR Mİ?

Gülfem Ezgi ÖZALTIN[1], Havva ADLI[2], Burcu TALU[1]

[1]Inonu University, Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, Malatya, Turkiye
[2]Inonu University, Vocational School of Health Services, Department of Therapy and Rehabilitation, Malatya, Turkiye

ORCID IDs of the authors: G.E.Ö. 0000-0003-1591-4844; H.A. 0000-0002-4802-9131; B.T. 0000-0002-5623-8291

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ABSTRACT

Objective: This study aimed to evaluate joint position sense, two-point discrimination, fine motor control, grip strength, light touch sensation, pain, and functionality in patients with unilateral carpal tunnel syndrome and to determine whether these variables change in the unaffected hands of patients with unilateral carpal tunnel syndrome.

Materials and Methods: The study was planned as a single-blind, cross-sectional case-control study. Individuals between the ages of 20-65 who were diagnosed with carpal tunnel syndrome (n=22) and healthy (n=22) were included. The device was designed for the study of measurements; discriminator; 9-hole peg test, dynamometer, and pinch meter, Semmens Weinstein monofilament test; The visual analog scale was evaluated bilaterally with the Boston questionnaire.

Results: There was a significant difference between all measurements in the affected and unaffected hands between the CTS group and the control group ($p<0.05$). There was no significant difference between the joint position sense, two-point discrimination, fine motor control, grip strength, light touch sense, and functionality between the affected and unaffected hand in the CTS group ($p>0.05$).

Conclusion: This is the first study evaluating joint position sense in the wrist, metacarpophalangeal joints, and interphalangeal joints in unilateral CTS syndrome. It was noteworthy that patients

ÖZET

Amaç: Bu çalışmanın amacı, tek taraflı karpal tünel sendromlu hastalarda eklem pozisyon hissi, iki nokta ayırt etme, ince motor kontrol, kavrama kuvveti, hafif dokunma hissi, ağrı ve fonksiyonelliği değerlendirmek ve hastaların etkilenmeyen ellerinde de bu değişkenlerin değişip değişmediğini belirlemektir.

Gereç ve Yöntem: Çalışma tek kör, kesitsel vaka-kontrol çalışması olarak planlandı. 20-65 yaş aralığında karpal tünel sendromu tanısı alan (n=22) ve sağlıklı (n=22) bireyler dahil edildi. Ölçümler çalışma için tasarlanan cihaz; diskriminatör; 9 delikli peg test, dinamometre ve pinchmetre, semmens weinstein monoflament test; visuel analog scale, Boston anketi ile bilateral değerlendirildi.

Bulgular: Karpal tünel sendromu grubu ile kontrol grubu arasında etkilenen ve etkilenmeyen ellerinde tüm ölçümler arasında anlamlı farklılık vardı ($p<0.05$). KTS grubunda etkilenen el ve etkilenmeyen el arasında eklem pozisyon hissi, iki nokta diskriminasyonu, ince motor kontrol, kavrama kuvveti, hafif dokunma duyusu, fonksiyonellik arasında anlamlı fark bulunmadı ($p>0.05$).

Sonuç: Bu çalışma tek taraflı KTS sendromunda el bileği, metakarpofalangeal eklemler ve interfalangeal eklemlerde eklem pozisyon hissini değerlendiren bildiğimiz kadarıyla ilk çalışmadır. Tek taraflı karpal tünel sendromlu hastaların eklem pozisyon hissi, ince motor kontrol, iki nokta diskriminasyonu, hafif dokunma duyusu ve kavrama kuvveti sağlıklı kontrol grubuna göre eksik

Corresponding author/İletişim kurulacak yazar: Gülfem Ezgi ÖZALTIN – gulfemezgi@gmail.com

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with unilateral carpal tunnel syndrome had deficiencies in joint position sense, fine motor control, two-point discrimination, light touch sense, and grip strength compared to the healthy control group, as well as deficiencies in the unaffected sides.

Keywords: Carpal tunnel syndrome, proprioception, motor skills, grip strength

bulunmasının yanı sıra etkilenmeyen taraflarında da eksiklikler olması dikkat çekici bulundu.

Anahtar Kelimeler: Karpal tünel sendromu, propriosepsion, motor beceri, kavrama kuvveti

INTRODUCTION

Carpal tunnel syndrome (CTS) is one of the most common peripheral neuropathies caused by compression of the median nerve within the carpal tunnel. Its prevalence is about 2.7% to 8%. It is more common in women than men, between the ages of 40-46 and 70-85, in the general population (1). The median nerve affects the tendons, muscles, and skin receptors that provide hand proprioception. In this syndrome, which is seen due to frequent use, patients misposition the wrist, afferent impulses are carried to the upper centers and cause cortical changes. It is thought that these neuroplastic changes in the somatosensory cortex may affect the proprioceptive mechanism and functional skills (2). Localized sensory, motor and autonomic disorders occur because of the compression of the median nerve in the tunnel. In the clinic, patients mostly complain of pain, numbness, and gripping difficulties in the palm and first three fingers (3). Symptoms usually increase at night and may even wake the patient from sleep. There is also a tactile sensory weakness, two-point discrimination, and a loss of functional motor skills such as grasping small objects. Studies evaluating grip strength, fine motor control, and pain in patients with CTS have also been found before (4-6). However, the cause of the symptoms and the cause of bilateral deficiencies are not fully known.

Since there are many factors affecting proprioception, which has a multisensory structure, it is difficult to evaluate specifically, but two easy-to-apply methods have been determined, namely joint position sense and passive joint movement detection threshold, to provide ease of application in the clinic and to give an idea about the proprioceptive effect. Proprioception is considered a subcomponent of the sensorimotor system. It contains afferent information originating from receptors that contribute to postural control, joint stability, and motor control (7). The body diagram is created by the information coming from the afferent path. An increasing number of studies show that proprioceptive knowledge and thus body schema are impaired in chronic painful conditions (8,9). One of the ways to evaluate the body chart is with the two-point discrimination test. Two-point discrimination has been reported as a clinical measure of body schema in the primary somatosensory cortex. (10). In individuals with hand-wrist pathology, it was observed that the sense of two-point discrimination carried by the same spinal route as proprioception was decreased, but no study investigating whether there was a pathological change in the sense of joint position sense was found in the literature (11). Studies examining joint position sense changes in the unaffected hand in patients with unilateral CTS are one of the missing points in the literature. Since spinal motor neurons receive afferent information from both the ipsilateral and contralateral extremities, we think that the joint position sense should also be evaluated in the contralateral extremity in patients with CTS (12). Therefore, we aimed to evaluate the joint position sense, two-point discrimination, fine motor control, grip strength, light touch sensation, pain, and functionality in patients with unilateral CTS and to determine whether these variables change in the unaffected hands of unilateral CTS patients.

MATERIALS AND METHODS

This study was conducted with a cross-sectional case-control research model. The study was reviewed and approved by the local Clinical Research Ethics Committee (Date:13.03.2018, No: 2018/6-27), and the study was conducted by the principles of the Declaration of Helsinki. The individuals participating in the study were informed about the purpose, duration, and scope of the study, and informed consent was obtained from the individuals. Data were collected between March 2018 and June 2018.

The population of the study consisted of individuals between the ages of 25-65. Individuals diagnosed with unilateral carpal tunnel syndrome who were willing to participate in the study were included in the carpal tunnel syndrome group (CTSG), and healthy individuals were included in the control group (CG). Individuals with a history of any surgical operation, including CTS surgery on the wrist, with any condition that may affect the wrist, and individuals who refused to participate in the study were excluded from both groups. Patients who participated in the study and met the inclusion criteria were selected from the relevant population using the improbable random sampling method. Demographic variables of all participants were recorded, including age, gender, weight, height, and dominant hand.

Assuming that the contralateral healthy hand is affected by 10% in the power analysis performed before the start of the study, with α=0.05 and 1-β (power)=0.80, it was calculated that 22 subjects should be included in each group in the study (13, 14). Power analysis was performed using the publicly available statistical software OpenEpi, version 3 (http://www.openepi.com) to calculate the sample size. A total of 44 individuals were evaluated within the scope of the study.

Measurement

The joint position sense was measured with the device designed for the study (Figure 1) by asking participants to actively move their wrists to recreate the predetermined target positions (wrist flexion and extension (WF-WE) 30°, radial deviation (RD) 10°, ulnar deviation (UD) 15°, metacarpophalangeal joint flexion (MCPF) 45°, metacarpophalangeal joint extension (MCPE) 10°, and proximal interphalangeal joint flexion (PİPF) 50°) (15) (Figure 2). Three replications were made for the target angles in all motion axes, and the arithmetic average was recorded. Throughout the measurement, no feedback on their performance was given to eliminate the possibility of participants rearranging their responses.

A two point discrimination evaluation was measured with a 1-millimeter precision discriminator. While the eyes are open, the individual's finger is warned about two points far from each other, "these are the two points in question", then a single point warning is given, and preliminary information is given as "this is the only point" (11). All the 1st, 2nd, and 3rd fingertips are touched from the widest to the narrowest distance for 1-1.5 seconds, and the individual is asked "single or even?" questions. For CTSG, the application was repeated for the affected and intact hand. The narrowest double point distance that the individual could feel was recorded.

Fine motor control, the assessment was measured with the Nine Hole Peg Test. It consists of a wooden surface with 9 holes on it and 9 cylinders attached to these holes. Individuals were asked to insert the rods into the holes as quickly as possible and then collect them back. This time was measured with a stopwatch (16). Measurements were repeated 3 times and averaged.

Evaluation of grip strength, hand grip strength according to the standard position recommended by the American Association of Hand Therapists; The patient was measured in an upright position, knees in 90° flexion, shoulder in adduction and a neutral position, elbow in 90° flexion, forearm in mid-rotation, and wrist in neutral, using a Baseline brand dynamometer, and 3 measurements were made with a one-minute break between each measurement, and the average was recorded (17). A baseline brand pinch meter was used for finger grip strength. Subjects were asked to sit with support, shoulder in adduction and neutral position, elbow in 90˚ flexion, forearm in a neutral position, wrist in 0-30˚ extension, and 0-15˚ ulnar deviation. For lateral grip (key grip) strength, the grip strength between the thumb and the radial side of the index finger was evaluated. While assessing the grip, the patient was told to press the pinch meter from the top with the middle of the distal phalanx of the thumb and support the second phalanx of the index finger from the lower part of the pinch meter. During the measurements, the patients were asked to squeeze at maximum force. Each measurement was made three times and the averages were recorded (18).

Semmes-Weinstein monofilaments were used for light touch assessment. The filaments (from thick to thin) were

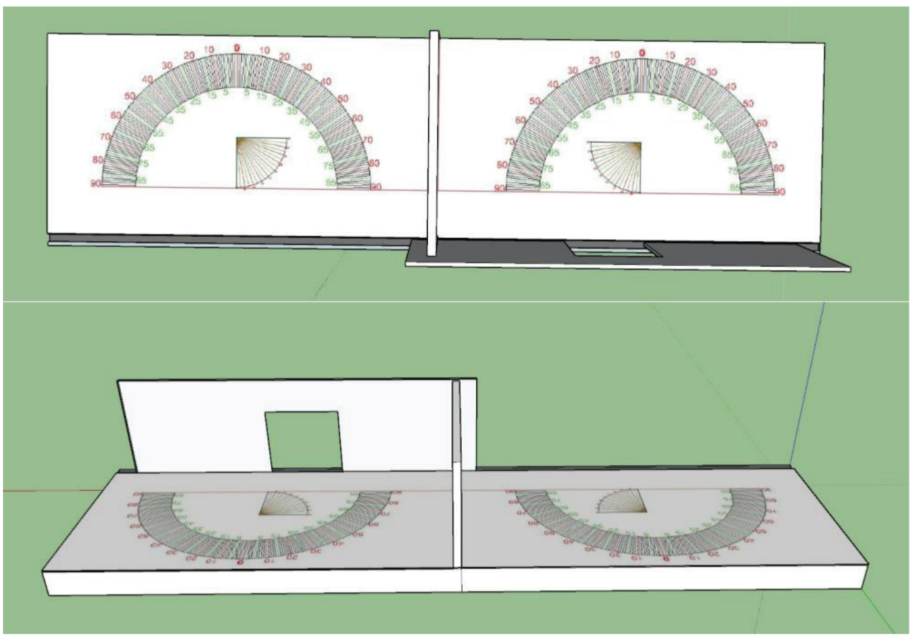

Figure 1: Device designed for the study

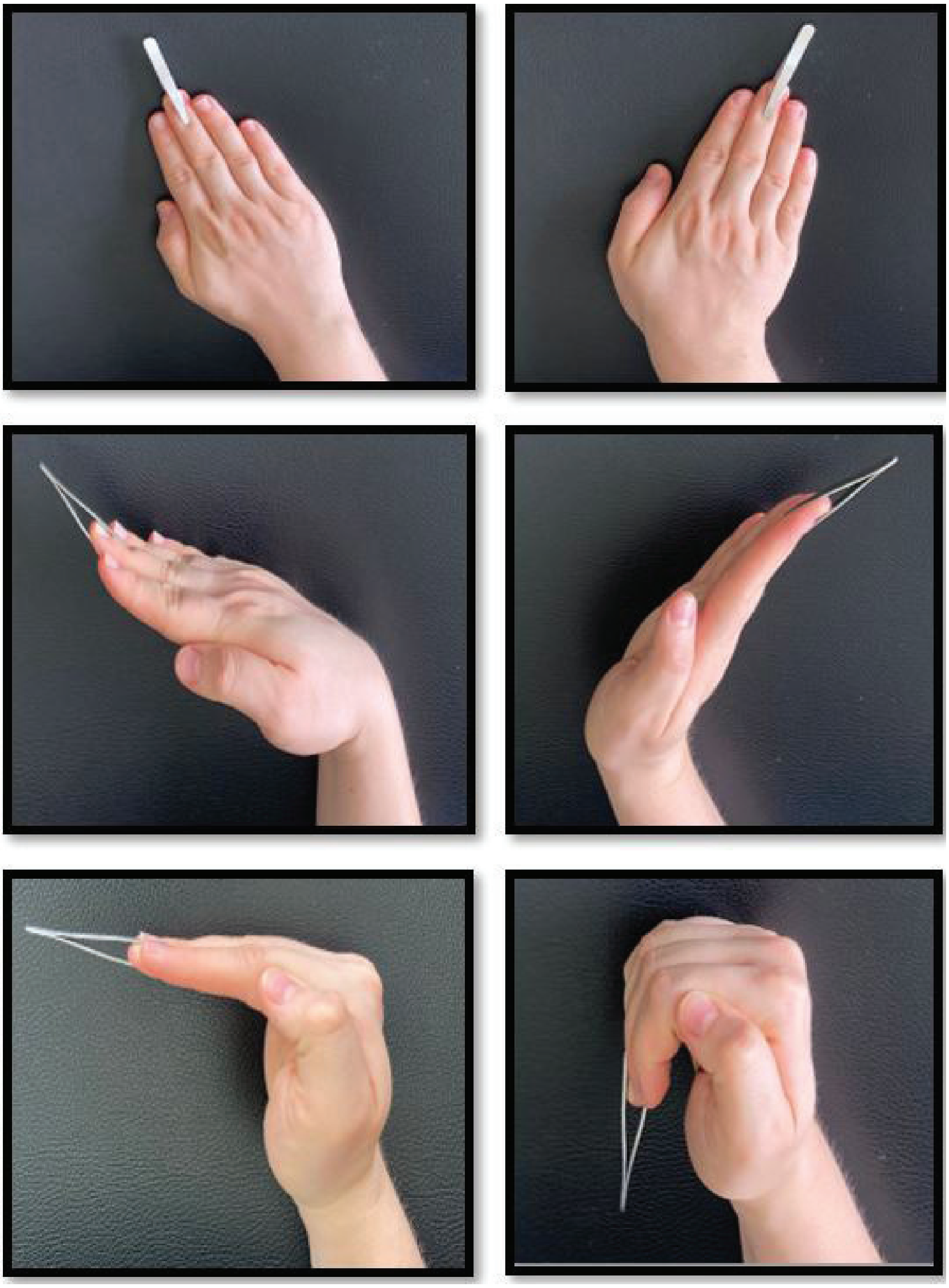

Figure 2: Assessment of joint position sense

touched for 1-1.5 seconds with the eyes closed so that a slight elastic deformation would occur, and the individual was asked if he felt the touch. The thinnest filament coefficient felt during the application was recorded (19).

Pain assessment, Visual Analogue Scale (VAS) was used. On a 10 cm horizontal line, the beginning was marked as 0 (no pain) and the ending (extreme pain), and the subjects were asked to mark on this horizontal line according to the degree of pain they felt. The point marked on the line was then measured with the help of a ruler and recorded as the VAS value in cm. In addition, the degree of pain they felt at rest, during activity, and at night was questioned and recorded in three different ways (20).

The Boston Carpal Tunnel Syndrome Questionnaire (BCTSQ), which consists of two subsections, the Boston Symptom Severity Scale (BSSS) and the Boston Functional Capacity Scale (BFCS), was used in the disease-specific assessment scale. There are 11 questions about the patient's symptoms in the BSSS and eight questions about the functional capacity in the BSSS. Questions are scored between 1 and 5. A high score indicates severe symptoms and reduced functional capacity (21). Results for BSSS and BFCS were recorded separately.

Statistical analysis

The data of the study were uploaded to the computer with the program "SPSS (Statistical Package for Social Sciences) for Windows 20.0 (SPSS Inc, Chicago, IL)" and evaluated. Descriptive statistics were presented as mean±standard deviation, percentage, and median (25%-75%). In the power analysis, it was calculated that 22 individuals should be included in each group, assuming that α=0.05 and 1-β (strength)=0.80, and the rate of involvement of the contralateral healthy hand is 10% (13). The Public OpenEpi program was used to calculate the sample size. The Pearson chi Square test was used to evaluate categorical variables. The conformity of numerical variables to the normal distribution was calculated using the Shapiro Wilk test. Statistically significant data were analyzed with the One Way ANOVA test for data with normal distribution. The Tukey test was used in case of significant difference and homogeneity of variances; the Tamhane test was used when homogeneity of variances was not achieved. The Kruskal Wallis Test was used for data that did not fit the normal distribution. The Mann-Whitney U test was used in the dual evaluation of the groups that differed in the Kruskal Wallis test.

RESULTS

A total of 44 individuals were evaluated within the scope of the study (Figure 3). All participants were female and right-handed dominant. According to the affected hand evaluation of individuals with CTS, the tinel test was negative in five individuals and positive in 17 individuals; The Phalen test was found to be negative in four individuals

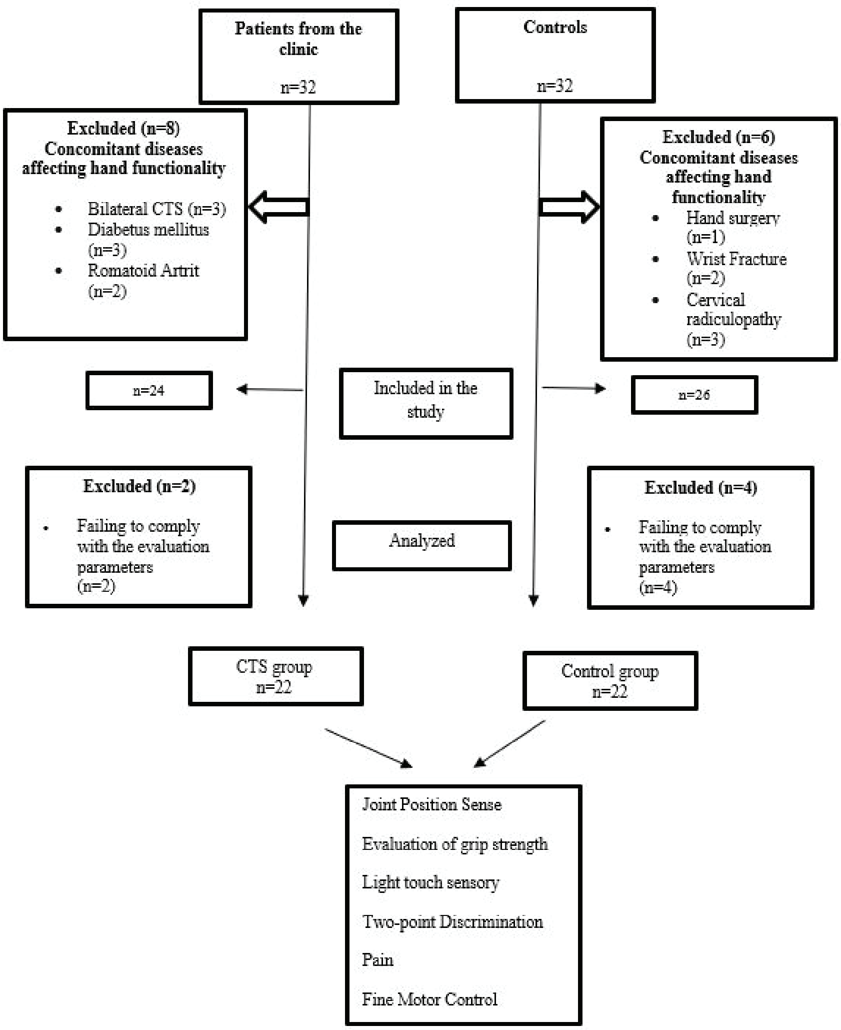

Figure 3: Flow diagram of the study population
CTS: Carpal tunnel syndrome

Table 1: Demographic data

	CTS (n=22) Mean±SD	Kontrol (n=22) Mean±SD	p[a]
Age (years)	50.4545±9.02	49.0±11.57	0.577
Height (m)	1.59±0.68	1.61±0.06	0.140
Weight (kg)	74.77±9.78	71.50±9.21	0.190
BMI (kg/m²)	29.58±4.33	27.23±2.92	0.012

a: Independent Sample t Test, BMI: Body musk index

and positive in 18 individuals. Both tests were negative in the entire control group. The demographic characteristics of the individuals included in the study are shown in Table 1 (Table 1).

While there was a significant difference between CTS (affected side) and the control group in joint position sense, two-point discrimination, hand and finger grip strength, light touch sense, and functional skill tests ($p>0.05$); There was no significant difference between the affected and unaffected side in individuals with CTS ($p>0.05$) (Table 2).

Table 2. Intergroup joint position sense, hand and finger grip strength, light touch sense, two-point discrimination, functional skill results

	Patients (n=22)		Control (n=22)	P	Affected-non-affected	Affected-control	Unaffected-control
	Affected side	Unaffected side			p	p	p
JPS-RD	8.54±7.32	6.81±3.74	1.77±1.60	0.000[a]	0.467[b]	0.000[b]	0.003[b]
JPS-UD	10.63±6.82	7.36±6.31	2.31±2.12	0.000[a]	0.128[b]	0.000[b]	0.010[b]
JPS-WF	19.81±8.40	15.54±8.93	2.13±2.73	0.000[a]	0.133[b]	0.000[b]	0.000[b]
JPS- WE	12.45±8.41	10.22±6.95	2.72±2.76	0.000[a]	0.495[b]	0.000[b]	0.001[b]
JPS- MCPF	10.13±7.80	7.09±4.27	2.5±2.11	0.000[a]	0.143[b]	0.000[b]	0.015[b]
JPS-MCPE	8.09±4.86	5.0±4.01	2.18±2.46	0.000[a]	0.029[b]	0.000[b]	0.051[b]
JPS-PİPF	10.00±5.34	6.54±5.22	1.09±1.60	0.000[a]	0.031[b]	0.000[b]	0.000[b]
Two-point discrimination 1st Finger	3.82±2.13	2.86±1.98	1.68±0.71	0.001[a]	0.345[f]	0.000[f]	0.042[f]
Two-point discrimination 2nd Finger	3.18±2.28	2.5±1.84	1.45±0.59	0.006[a]	0.630[f]	0.006[f]	0.053[f]
Two-point discrimination 3rd finger	3.45±2.22	2.73±1.88	1.59±0.59	0.002[a]	0.575[f]	0.003[f]	0.036[f]
Hand grip strength[c]	12.50(3-21)	13.36(8-21)	18.00(14-31)	0.000[d]	0.364[e]	0.000[e]	0.000[e]
Finger grip strength[c]	3.64(1-7)	4.00(1-6)	5.00(3-8)	0.001[d]	0.836[e]	0.002[e]	0.001[e]
Light touch sensation 1st finger[c]	3.84(2.36-4.93)	3.84(2.83-5.07)	2.83(0.22-3.61)	0.000[d]	0.850[e]	0.000[e]	0.000[e]
Light touch sensation 2nd finger[c]	3.72(2.36-5.07)	3.61(2.83-5.07)	2.83(2.36-3.61)	0.000[d]	0.739[e]	0.000[e]	0.000[e]
Light touch sensation 3rd finger[c]	3.96(2.83-5.07)	3.61(2.83-4.93)	2.83(2.36-3.61)	0.000[d]	0.259[e]	0.000[e]	0.000[e]
Nini hole peg test[c]	26.50(16-47)[c]	23.50(17-44)	18.50(15-27)	0.000[d]	0.204[e]	0.000[e]	0.001[e]
Boston carpal tunnel severity scale	30.14±5.41	30.14±5.41	11±00	0.000	1.00[b]	0.000[b]	0.000[b]
Boston carpal tunnel status scale	25.82±5.78	25.82±5.78	8±00	0.000	1.00[b]	0.000[b]	0.000[b]

a: One Way ANOVA, b: Tukey, c: Median(min-max), d: Kruskall Wallis, e: Mann Whitney U, f: Tamhane
JPS: joint position sense, RD: radial deviation, UD: ulnar deviation, WF: wrist flexion, WE: wrist extension, MCPF: metacarpophalangeal flexion, MCPE: metacarpophalangeal extension, PİPF: proximal interphalangeal flexion

No significant relationship was found between pain level and motor functions in individuals with CTS.

While there was a significant difference in functional capacity between individuals with CTS and the healthy control group ($p<0.05$), there was no significant difference between the affected and unaffected sides of the patients ($p>0.05$) (Table 2).

DISCUSSION

In this study, it was observed that the joint position sense, two-point discrimination, fine motor control, grip strength, light touch sensation, pain, and functional level of patients with CTS were significantly changed when compared with the healthy control group. In addition, the most striking result is the loss of joint position sense, two-point discrimination, fine motor control, grip strength, light touch sense, and functional level in the unaffected hands, although the patients present with unilateral CTS.

So far, many studies have shown that joint position sense is impaired in different musculoskeletal problems (22-24). There has been no previous study that we found in the literature on joint position sense in patients with CTS. In our study, a significant difference was found in the sense of joint position between individuals with CTS and the healthy control group; There was no significant difference in any joints of the individuals with CTS on the affected and unaffected sides. Our study is the first to evaluate joint position sense in different joints in the affected and unaffected hand. In studies examining the loss of proprioception on the affected and unaffected side in different extremities such as the knee and shoulder, it was revealed that while the results of the affected and unaffected extremities were similar, there was a difference between the results of the healthy group (12-25). Robert et al. concluded that patients with anterior cruciate ligament injury also have a proprioceptive loss in the unaffected knee. They explained this situation by arguing that faulty afferent information from the periarticular receptors in the injured knee alters the functioning of muscle spindles on the contralateral side. This deficiency on the unaffected side is the result of processing feedback from the subcortical level. Spinal motor neurons receive afferent information from both the ipsilateral and contralateral limbs. Cross connections between contralateral limbs contribute to simultaneous learned responses in the cerebral cortex (12). While acquiring skills with one extremity by repeating a task, skill acquisition takes place in the other extremity in the same way. Similarly, functional loss in one-sided extremity may cause disorders on the other side. Two theories have been proposed to explain this situation. First, task-oriented training leaves a mark on the motor cortex of the extremity; task performance in the untrained extremity, in which the motor effects developed in the dominant hemisphere of the brain are accessible to the opposite hemisphere through the corpus callosum (callosum access hypothesis); the second is based on the observation that the execution of many unilateral tasks produces cortical activity (i.e., cross-activation) on both the opposite and the same side of the trained limb. According to the ‘cross-activation’ hypothesis, bilateral cortical activity produced by unilateral training leads to adaptations in both hemispheres (26). Thus, unilateral training causes changes in motor organization associated with task-specific activation of the same muscles on the contralateral side. Afferent nerves responsible for proprioception receive information from muscles, tendons, and cutaneous receptors at the wrist level and are involved in the perception of joint movement, the fluent maintenance of grip, and other functional movements (27). While contralateral activation is gained with unilateral training, the same functions can be lost on the contralateral side with unilateral involvement.

In a study conducted with individuals with CTS, a significant difference was observed in the sense of two-point discrimination and kinesthesia compared to the healthy control group (28). Caseiro et al. examined the integrity of the body chart in individuals with chronic non-traumatic unilateral shoulder pain using two-point discrimination and right/left discrimination test. In conclusion, there was no difference between the symptomatic and asymptomatic shoulders (9). A recent systematic review also found no difference in right-left discrimination between painful and healthy limbs in individuals with unilateral shoulder pain (29). Hearkens et al. evaluated tactile acuity in patients with chronic arm, neck, and shoulder pain with a two-point discrimination test, and no difference was observed in the symptomatic and asymptomatic regions (30). In a study evaluating grip strength and fine motor control in individuals with unilateral CTS, it was suggested that there was bilateral involvement in individuals with CTS compared to the healthy control group and that this was due to central sensitization (31). In our study, there was no difference in the two-point discrimination test between symptomatic and asymptomatic hands in individuals with CTS, but there was a significant difference between them and the healthy group. In a study conducted on women with CTS, two-point discrimination, grip strength, and kinesthetic differentiation (joint range of motion) of the radiocarpal joint were evaluated. A significant difference was found according to the group (32, 33). It has been observed that patients with unilateral CTS develop symptoms on the asymptomatic side as well as decreased fine motor control and grip strength in the affected hand (34). Similar to the literature, in our study, when individuals with CTS were compared with healthy controls, significant differences were observed in terms of fine motor control, two-point discrimination, light touch, and grip strength. There was no significant difference between the affected and unaffected sides. The underlying cause of the reduction in grip strength has not been fully determined. It may cause loss of flexion in the metacarpophalangeal joint due to muscle tension in the forearm; Another reason is that there is tension in the lumbrical muscles in patients with CTS, which causes drag towards increased resistance/extension, preventing the DIP joints and PIP joints from achieving strong flexion. An additional cause of strength reduction may include sensory impairment common in CTS, which can reduce the ability to properly regulate force production (33).

Out of the scope of our work; previous studies investigating the relationship between motor functions and pain in CTS have reported conflicting results. In the Wiebusch et al. study, it was observed that patients with unilateral lateral elbow tendinopathy had a bilateral lack of fine motor control and joint position sense, and unilateral pain syndrome was found to cause bilateral deficits (35). Another study suggested that bilateral deficits in fine motor control and grip strength were negatively correlated with pain intensity in individuals with CTS (31). It has been suggested that central sensitization plays a role in the formation of CTS. However, since the device (Purdue pegboard) used in the study could not evaluate median nerve damage only, it was insufficient to explain contralateral deficits. Rincon et al. found that unilateral and bilateral deficits of fine motor control and grip strength were not associated with pain in individuals with CTS. In our study, the presence of bilateral symptoms was not found to be associated with pain. Another hypothesis explaining the bilateral findings of unilateral musculoskeletal problems is supraspinal mechanisms. The second somatosensory cortex and posterior parietal areas are responsible for areas of sensory and proprioceptive integration (37). Regions representing the hand in the primate motor cortex have callosal connections. Motor cortex activation is transferred to both hemispheres during ipsilateral hand use (15).

Study limitations

Our study has some limitations in that it used a small sample size. In addition, the fact that all the participants in the study were women is one of the limitations of the study. Future studies with larger samples will be needed.

CONCLUSION

This is the first study to evaluate joint position sense in the wrist, metacarpophalangeal joints, and interphalangeal joints in unilateral CTS syndrome. Patients who have bilateral deficits in joint position sense, fine motor control, two-point discrimination, light touch sense, grip strength, and the affected and unaffected sides were missing from the healthy control group. In addition, the detected bilateral deficiencies were not associated with pain.

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Ethics Committee Approval: This study was approved by the Inonu University Health Sciences Non-Invasive Clinical Research Ethics Committee (Date: 13.03.2018, No: 2018/6-27)

Peer Review: Externally peer-reviewed.

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REFERENCES

1. Luckhaupt SE, Dahlhamer JM, Ward BW, Sweeney MH, Sestito JP, Calvert GM. Prevalence and work-relatedness of carpal tunnel syndrome in the working population, United States, 2010 national health interview survey. Am J Ind Med 2013;56(6):615-24. [CrossRef]
2. Rothwell JC, Traub MM, Day BL, Obeso JA, Thomas PK, Marsden CD. Manual motor performance in a deafferented man. Brain 1982;105(3):515-42. [CrossRef]
3. Talu B, Bazancir Z. The Effects of Sensory Therapy on Pain, Upper Extremity Functions and Sleep Quality in Patients with Carpal Tunnel Syndrome. Ann Yoga Phys Ther 2016;1(2):1007.
4. Lowe BD, Freivalds A. Effect of carpal tunnel syndrome on grip force coordination on hand tools. Ergonomics 1999;42(4):550-64. [CrossRef]
5. Thonnard J, Saels P, Van den Bergh P, Lejeune T. Effects of chronic median nerve compression at the wrist on sensation and manual skills. Exp Brain Res 1999;128(1-2):61-4. [CrossRef]
6. Tamburin S, Cacciatori C, Marani S, Zanette G. Pain and motor function in carpal tunnel syndrome: a clinical, neurophysiological and psychophysical study. J Neurol 2008;255(11):1636-43. [CrossRef]
7. Hillier S, Immink M, Thewlis D. Assessing proprioception: a systematic review of possibilities. Neurorehabil neural repair 2015;29(10):933-49. [CrossRef]
8. Moseley GL, Gallace A, Spence C. Bodily illusions in health and disease: physiological and clinical perspectives and the concept of a cortical 'body matrix.' Neurosci Biobehav Rev 2012;36(1):34-46. [CrossRef]
9. Caseiro M, Dos Reis FJJ, Barbosa AM, Barbero M, Falla D, de Oliveira AS. Two-point discrimination and judgment of laterality in individuals with chronic unilateral non-traumatic shoulder pain. Musculoskelet Sci Pract 2021;56:102447. [CrossRef]

10. Ngomo S, Mercier C, Bouyer LJ, Savoie A, Roy J-S. Alterations in central motor representation increase over time in individuals with rotator cuff tendinopathy. Clin Neurophysiol 2015;126(2):365-71. [CrossRef]
11. Wolny T, Saulicz E, Linek P, Myśliwiec A. Two-point discrimination and kinesthetic sense disorders in productive age individuals with carpal tunnel syndrome. J Occup Health 2016;58(3):289-96. [CrossRef]
12. Arockiaraj J, Korula RJ, Oommen AT, Devasahayam S, Wankhar S, Velkumar S, et al. Proprioceptive changes in the contralateral knee joint following anterior cruciate injury. Bone Joint J 2013;95-b(2):188-91. [CrossRef]
13. Provinciali L, Giattini A, Splendiani G, Logullo F. Usefulness of hand rehabilitation after carpal tunnel surgery. Muscle Nerve 2000;23(2):211-6. [CrossRef]
14. De Krom M, Knipschild P, Kester A, Thijs C, Boekkooi P, Spaans F. Carpal tunnel syndrome: prevalence in the general population. J Clin Epidemiol 1992;45(4):373-6. [CrossRef]
15. Cramer SC, Finklestein SP, Schaechter JD, Bush G, Rosen BR. Activation of distinct motor cortex regions during ipsilateral and contralateral finger movements. J Neurophysiol 1999;81(1):383-7. [CrossRef]
16. Poole JL, Burtner PA, Torres TA, McMullen CK, Markham A, Marcum ML, et al. Measuring dexterity in children using the Nine-hole Peg Test. J Hand Ther 2005;18(3):348-51. [CrossRef]
17. Geere J, Chester R, Kale S, Jerosch-Herold C. Power grip, pinch grip, manual muscle testing or thenar atrophy-which should be assessed as a motor outcome after carpal tunnel decompression? A systematic review. BMC Musculoskelet Disord 2007;8(1):1-9. [CrossRef]
18. Shiratori AP, Iop Rda R, Borges Júnior NG, Domenech SC, Gevaerd Mda S. Evaluation protocols of hand grip strength in individuals with rheumatoid arthritis: a systematic review. Rev Bras Reumatol 2014;54(2):140-7. [CrossRef]
19. Borchers S, Hauser T-K, Himmelbach M. Bilateral hand representations in human primary proprioceptive areas. Neuropsychologia 2011;49(12):3383-91. [CrossRef]
20. Rasmussen PV, Sindrup SH, Jensen TS, Bach FW. Symptoms and signs in patients with suspected neuropathic pain. Pain 2004;110(1-2):461-9. [CrossRef]
21. Sezgin M, İncel NA, Sevim S, Çamdeviren H, As İ, Erdogan C. Assessment of symptom severity and functional status in patients with carpal tunnel syndrome: reliability and validity of the turkish version of the boston questionnaire. Disabil Rehabil 2006;28(20):1281-6. [CrossRef]
22. Tong MH, Mousavi SJ, Kiers H, Ferreira P, Refshauge K, van Dieën J. Is there a relationship between lumbar proprioception and low back pain? A systematic review with meta-analysis. Arch Phys Med Rehabil 2017;98(1):120-36. [CrossRef]
23. Stanton TR, Leake HB, Chalmers KJ, Moseley GL. Evidence of impaired proprioception in chronic, idiopathic neck pain: systematic review and meta-analysis. Phys Ther 2016;96(6):876-87. [CrossRef]
24. Relph N, Herrington L. Knee joint position sense ability in elite athletes who have returned to international level play following ACL reconstruction: A cross-sectional study. The Knee 2016;23(6):1029-34. [CrossRef]
25. Sahin E, Dilek B, Baydar M, Gundogdu M, Ergin B, Manisali M, et al. Shoulder proprioception in patients with subacromial impingement syndrome. J Back Musculoskelet Rehabil 2017;30(4):857-62. [CrossRef]
26. Lee M, Hinder MR, Gandevia SC, Carroll TJ. The ipsilateral motor cortex contributes to the cross-limb transfer of performance gains after ballistic motor practice. J Physiol 2010;588(1):201-12. [CrossRef]
27. Wright TW, Glowczewskie Jr F, Wheeler D, Miller G, Cowin D. Excursion and strain of the median nerve. JBJS 1996;78(12):1897-903. [CrossRef]
28. Wolny T, Saulicz E, Linek P, Myśliwiec A. Two-point discrimination and kinesthetic sense disorders in productive age individuals with carpal tunnel syndrome. J Occup Health 2016;58(3):289-96. [CrossRef]
29. Breckenridge JD, Ginn KA, Wallwork SB, McAuley JH. Do people with chronic musculoskeletal pain have impaired motor imagery? A meta-analytical systematic review of the left/right judgment task. J Pain 2019;20(2):119-32. [CrossRef]
30. Heerkens RJ, Köke AJA, Lötters FJB, Smeets RJEM. Motor imagery performance and tactile acuity in patients with complaints of arms, neck, and shoulder. Pain manag 2018;8(4):277-86. [CrossRef]
31. Fernández-De-Las-Peñas C, Pérez-de-Heredia-Torres M, Martínez-Piédrola R, de la Llave-Rincón AI, Cleland JAJEbr. Bilateral deficits in fine motor control and pinch grip force in patients with unilateral carpal tunnel syndrome Exp. Brain Res 2009;194(1):29-37. [CrossRef]
32. Wolny T, Linek P, Saulicz E. Assessment of manual dysfunction in occupationally active women with carpal tunnel syndrome. Int J Occup Med Environ Health 2019;32(2):185-96. [CrossRef]
33. Baker NA, Moehling KK, Desai AR, Gustafson NP. Effect of carpal tunnel syndrome on grip and pinch strength compared with sex-and age-matched normative data. Arthritis Care Res 2013;65(12):2041-5. [CrossRef]
34. Padua L, Padua R, Nazzaro M, Tonali P. Incidence of bilateral symptoms in carpal tunnel syndrome. J Hand Surg Eur 1998;23(5):603-6. [CrossRef]
35. Wiebusch M, Coombes BK, Silva MF. Joint position sense, motor imagery, and tactile acuity in lateral elbow tendinopathy: A cross-sectional study. Musculoskelet Sci Pract 2021;55:102422. [CrossRef]
36. Pelletier R, Paquette É, Bourbonnais D, Higgins J, Harris PG, Danino MA. Bilateral sensory and motor as well as cognitive differences between persons with and without musculoskeletal disorders of the wrist and hand. Musculoskelet Sci Pract 2019;44:102058. [CrossRef]