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# Two-point discrimination and kinesthetic sense disorders in productive age individuals with carpal tunnel syndrome

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**Abstract: Objectives:** The aim of this study was to evaluate two-point discrimination (2PD) sense and kinesthetic sense dysfunctions in carpal tunnel syndrome (CTS) patients compared with a healthy group. **Methods:** The 2PD sense, muscle force, and kinesthetic differentiation (KD) of strength; the range of motion in radiocarpal articulation; and KD of motion were assessed. **Results:** The 2PD sense assessment showed significantly higher values in all the examined fingers in the CTS group than in those in the healthy group (p<0.01). There was a significant difference in the percentage value of error in KD of pincer and cylindrical grip (p<0.01) as well as in KD of flexion and extension movement in the radiocarpal articulation (p<0.01) between the studied groups. **Conclusions:** There are significant differences in the 2PD sense and KD of strength and movement between CTS patients compared with healthy individuals.

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**Key words:** Carpal tunnel syndrome, Discrimination sense, Kinesthetic sense

## Introduction

Carpal tunnel syndrome (CTS) is the most common compression mononeuropathy and is also one of the most common condition of working age population, resulting in absence from work or worsened productivity. The incidence of CTS provided by different authors ranges from 1.5% to 3.8%[1-3].

Among the causes of CTS, both professional and non-professional factors are listed. Some authors are of the opinion that the relationship between occupational exposure and the risk of CTS is based on strong scientific evidence[4,5]. Many authors indicate an increase in the incidence of CTS over the last few years[6]. Mondelli et al. reported an increased incidence in women by 8% and in men by 74% between 1991 and 1998[7]. In turn, Latinovic et al. reported an increase in incidence in women by 13% and in men by 35% in a British population between 1992 and 2000[8]. Recent studies by Bongers et al. reported an increase in the prevalence of CTS from 190/100,000 women and 60/100,000 men in 1987 to 280/100,000 women and 90/100,000 men in 2001[9]. These data clearly show a significant socioeconomic issue, which is possibly related to professional work[4,5].

There are a number of subjective and objective symptoms in CTS[10,11]. Initially, there are night paresthesia and pain. Then, these disorders also occur during the day. Over time, sensory disturbances develop in the area of the median nerve innervation, followed by muscular atrophy and movement disorders. Abnormal sensation and movement are the predominant symptoms of CTS[10,11]. The hand is an important organ of sensation but also the most precise motion organ. There is no doubt that such symptoms may affect both professional life and daily living activities, leading to increased disability and reduced productivity.

The quality of two-point discrimination (2PD) sense indicates the density of innervation of the skin (touch receptors) and somatosensory cortical representation. This kind of sense is conducted via the posterior column-medial lemniscus pathway to the central nervous system. 2PD sense may be impaired by both damage to the medial lemniscus pathway and peripheral nerve damage[12]. The 2PD test is a functional test used to assess the quality of tactile sensibility[13]. It is also regarded as an integrative test because it requires a high degree of sensory processing. A number of perceptive resources are needed to identify the type of stimulus being presented during the 2PD

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test[13]. For example, the subject may be instructed to identify an object by handling it while blindfolded[13,14].

The ability of kinesthetic differentiation (KD) of strength and movement has not been assessed in CTS patients. This ability can be an important parameter influencing the efficiency of the hand in occupational life. Large muscle strength will be particularly important in occupations associated with hard physical work, whereas the ability of KD of strength can be associated with professions requiring precision operations. The same is true of the ability to make KD of movement. It can play a significant role in planning and conducting movement. It can also affect muscle tone and coordination of hand muscle operation, and this will be important in occupations that require high-precision movements.

To date, no one has assessed 2PD sense and KD of strength and movement in productive-age CTS patients compared with healthy individuals. Disorders in these types of senses may have a considerable influence on professional work and efficiency. The aim of this study was to assess 2PD sense and KD of strength and movement in individuals with mild to moderate CTS compared with healthy individuals at a productive age.

## Material and Methods

The study was authorized by the Bioethics Committee for Scientific Studies at the Jerzy Kukuczka Academy of Physical Education in Katowice on 31 May 2007 (Decision No. 16/2007). All study procedures were performed according to the Helsinki Declaration of Human Rights of 1975, modified in 1983. All participants gave their signed informed consent to participate in the research.

*Research participants*

A total of 272 individuals participated in the study: 140 healthy individuals and 132 individuals with diagnosed CTS. The study included only healthy individuals with a dominant right hand and individuals with CTS of the dominant right hand. All participants included in the study were from the working population and were divided into three worker categories: white-collar workers, pink-collar workers, and blue-collar worker. The characteristics of the respondents and the results of testing the homogeneity of the groups are presented in Table 1.

*CTS diagnostic criteria*

Diagnosis of CTS was made in each case by a specialist. The main criteria for the clinical diagnosis were data collected in the interview and the presence of two or more positive symptoms from the following list:

1. Numbness and tingling first in the area of the median nerve innervation
2. Night paresthesia
3. A positive Phalen symptom
4. A positive Tinel symptom
5. Pain around the wrist radiating to the shoulder[15].

The criteria for exclusion from the study included the following: previous surgery or the use of orthotics; pharmacological steroid and nonsteroidal treatment; the presence of cervical radiculopathy, cervical myelopathy, polyneuropathy, thoracic outlet syndrome, inflammation of the tendon sheath, rheumatoid diseases (rheumatoid arthritis), diabetes, thyroid diseases, pregnancy; history of wrist injuries (fractures); thenar eminence muscle atrophy; fibromyalgia; and mental illness.

Patients who qualified for the study were diagnosed with mild to moderate CTS, meeting the diagnostic criteria. A mild degree of severity of CTS symptoms was evaluated using the Historical-Objective (Hi-Ob) scale[10]. For mild and moderate forms of CTS, the qualifying individuals obtained results equal to 1-3 on the Hi-Ob scale. The different degrees of the scale indicate successive stages of CTS severity:

- 0-no symptoms suggestive of CTS (no paresthesia or other symptoms),
- 1-only night paresthesia or immediately after waking up in the area supplied by the median nerve,
- 2-night and day paresthesia (even if they occur during repeated activities or long holding of a position),
- 3-abnormal sensation in the area supplied by the median nerve (objectively checked by the investigator using a piece of material on the middle and little fingers),
- 4-hypotrophy of the thenar eminence (compared with the other hand), and (or) reduced force of thenar eminence muscles (assessed by thumb moving) innervated by the median nerve,
- 5-atrophy and paralysis of the thenar eminence muscles[10].

Electrophysiological examination was not used as a diagnostic criterion for qualification to participate in the experiment because, as Nora et al.[16] states, most authors believe that the clinical signs are much more useful for making an accurate diagnosis, even if no evidence of nerve conduction disorders is found[17-20].

Nerve conduction examinations were performed in all CTS patients. Symptom severity and physical capacity were evaluated using the Boston Carpal Tunnel Questionnaire (BCTQ)[21]. The Numerical Pain Rating Scale (NPRS; 0: no pain, 10: maximum pain) was used to assess current hand pain (see Results section)[22].

*Study methodology*

Testing of the 2PD sense was performed in its static variety by judging the innervation density of the slowly adapting touch receptors. The study used a standardized Dellon discriminator. This device comprises a set of two plastic discs, each of which contains a series of metal spikes spaced at different distances from 1 to 25 mm. The discriminator spikes were applied perpendicularly to the

**Table 1.** Participants characteristics - mean value and standard deviation (SD), minima and maxima or the number of participants (%) as well as mean of differences (95% CI) between groups along with the t-test result for independent samples.

| Characteristics | Group | | | |
|---|---|---|---|---|
| | CTS (n=132) | Control (n=140) | CTS minus control | Significance level |
| Age (*years*) | 52.37 (9.1)<br>26-65 | 50.9 (7.76)<br>35-65 | 1.47<br>(–3.52-0.52) | 0.1441[1] |
| Weight (*kg*) | 70.87 (11.33)<br>43-105 | 72.98 (13.17)<br>42-105 | 2.11<br>(–0.82-5.06) | 0.1576[1] |
| Height (*cm*) | 164.7 (6.85)<br>144-188 | 166.7 (8.09)<br>153-196 | 2.00<br>(0.19-3.78) | 0.0297*[1] |
| BMI | 26.29 (4.48)<br>17.28-38.69 | 26.32 (4.45)<br>17.28-38.33 | 0.03<br>(–1.03-1.11) | 0.9482[1] |
| Women. number (%) | 115 (87.12) | 121 (86.43) | 6 | 0.8662[2] |
| Men. number (%) | 17 (12.88) | 19 (13.57) | 2 | 0.9563[2] |
| White-collar worker (%) | 39 (29.55) | 40 (28.57) | –1 | |
| Pink-collar worker (%) | 47 (35.61) | 51 (36.43) | –4 | 0.9824[2] |
| Blue-collar worker (%) | 46 (34.85) | 49 (35.00) | –3 | |
| Work experience (years) | 28.94 (7.69)<br>8-40 | 27.52 (6.28)<br>12-40 | 1.42<br>(–3.09-0.24) | 0.0946[1] |
| Working week (hours) | 38.42 (1.63)<br>36.75-40 | 38.35 (1.63)<br>36.75-40 | 0.07<br>(–0.46-0.31) | 0.7144[1] |

CTS - carpal tunnel syndrome; *statistically significant difference; [1] t-test for equal variances; [2] Chi/Chi
White-collar workers - professional, managerial, or administrative work; Blue-collar workers - manual labour; Pink-collar workers - jobs in the service industry

long axis of the distal phalanges of fingers I, II, and III. If the values exceeded the width of a finger, the spikes were applied parallel to the long axis of the finger. The discriminator was placed on the skin with a little pressure, sufficient for the subject to feel stimulation, but no pain. The sense value was determined several times, with short breaks between tests to determine the 2PD sense. In the case of one-sided CTS, first the healthy limb was studied, and then the affected limb. The test was considered completed if two of the same answers were achieved from three consecutive trials[23].

To assess the amount of error in KD of strength, the maximum strength was measured as well as 50% of the maximum strength. Cylindrical hand grip strength and pinch grip strength were measured using a Jamar hydraulic dynamometer[24]. The test was performed in a sitting position. For the assessment of grip strength, a dynamometer cylinder was placed between the metacarpus and fingers II-V, whereas in the test of pinch strength it was placed between the thumb and the side surface of the bent index finger. The task of the patient in both studies was to create pressure with the maximum possible power. Readings were expressed in kilograms of force (KG). In each test the measurement was performed three times and the average value was taken for further analysis.

In examining the cylindrical grip strength and pinch strength, the ability to KD of strength was also assessed. The measurement methods were the same as in the measurement of strength, except that after creating pressure with the maximum possible strength, the task of the subject was to perform a test pressure of 50% of the maximum strength. The measurement was also performed three times in this test, and for further analysis the average value was taken.

The examination of strength and the ability of its KD allowed the calculation of the error made by the subject. For this purpose the following formula was used:

$$\frac{50\%SM - RPSM}{50\%SM} \times 100 = \%$$

50%SM: 50% of maximum strength value.
RPSM: the actual value obtained during the measurement of 50% of the maximum strength.

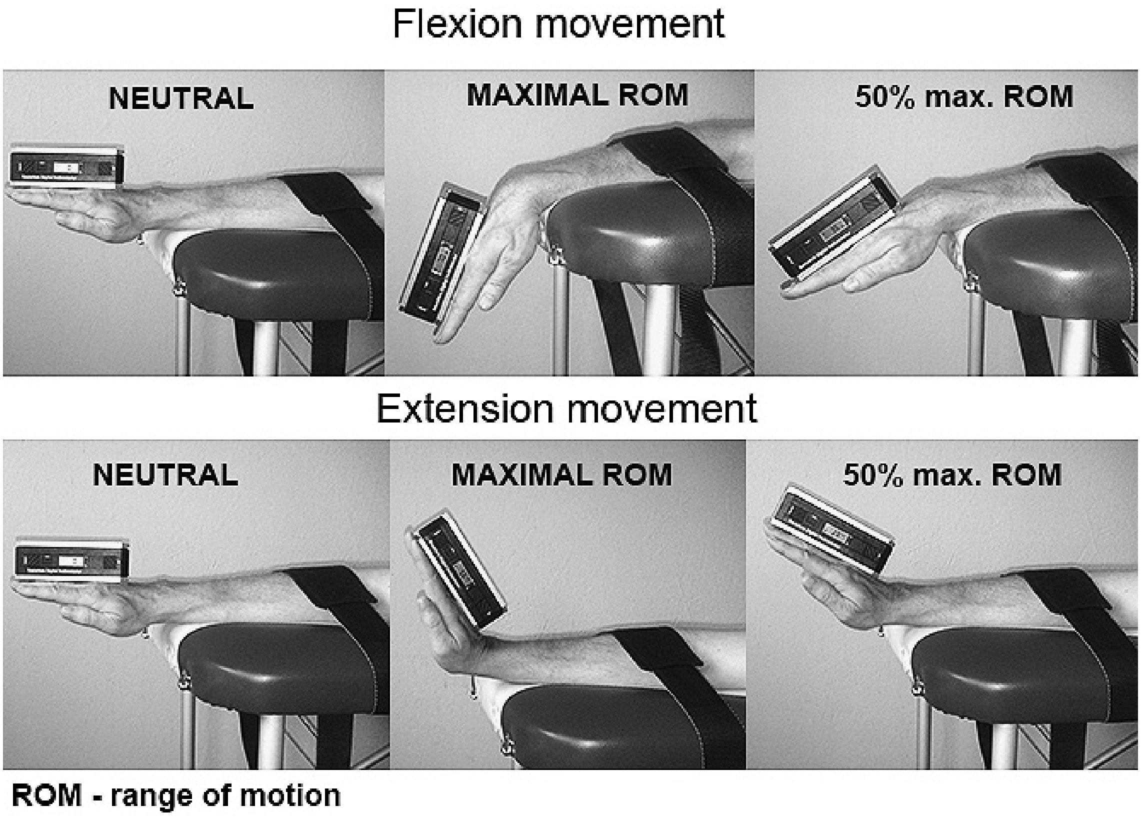


**Fig. 1.** Examination of range of motion and kinesthetic differentiation of motion.

To assess the amount of error in KD of motion, the maximum range of motion and the actual value of range of motion obtained while trying to get 50% range of motion were measured. The range of motion of flexion and extension in the radiocarpal joint was measured. For this purpose, a digital Saunders inclinometer was used. The measurements were carried out in accordance with the guidelines set by the manufacturer based on American Medical Association guidelines[25]. The tests were performed in a sitting position; the patient's upper limb was positioned neutrally in the shoulder and bent to an angle of 90° in the elbow with the forearm in pronation. The forearm rested on the therapeutic table and the radiocarpal joint was set in neutral (parallel to the table) position. The hand was positioned outside the table with the palmar side facing towards the ground. This position enables the full range of flexion and extension movements to be obtained freely. In both tests (flexion and extension movements) the inclinometer was applied on the dorsal side of the hand parallel to the third metacarpal bone and middle finger. At the beginning of the examination, the display of the inclinometer showed a value of 0 degrees and then the subject actively performed maximal extension in the radiocarpal joint. After reading the gained degree of the extension movement (in the final position), the inclinometer was returned to the initial position, and the measurement of active flexion of the radiocarpal joint was executed. Measurements of the maximum of the active range of motion of the extension and flexion were carried out three times, and for further analysis the average value was taken (Fig. 1).

In examining the range of motion in the radiocarpal joint, the ability of KD of movement was also assessed. The measurement methods were the same as in the measurement of motion range, except that after performing the active movement in full range, the task of the subject was to perform active movement in 50% of the maximum range of motion for flexion and extension separately (Fig. 1). When attempting to copy the movement at half of its range, the subjects were prevented from watching the tested hand by a 50×50-cm piece of cardboard placed against their faces. This was to eliminate the possibility of visually inspecting the tests performed. The measurement was also carried out three times in this study, and for further analysis the average values were taken. Examination of the range of motion and the ability of KD of movement allowed for the calculation of the error by the test. For this purpose the following formula was used:

$$\frac{50\%ZR - RPZR}{50\%ZR} \times 100 = \%$$

50%ZR: 50% of the maximum range of motion value.
RPZR: the actual value obtained during the measurement

**Table 2.** Two-point discrimination - mean value and standard deviation (SD), minima and maxima as well as two point discrimination mean of differences (95% CI) between groups along with the t-test result for independent samples.

| 2PD | Group | | CTS minus Control | Significance level |
|---|---|---|---|---|
| | CTS | Control | | |
| Finger I [mm] | 5.29 (1.79)<br>2-10 | 2.32 (0.66)<br>2-6 | 2.97<br>(2.65-3.28) | ***W |
| Finger II [mm] | 4.75 (1.33)<br>2-8 | 2.34 (0.62)<br>2-5 | 2.41<br>(2.16-2.65) | ***W |
| Finger III [mm] | 3.83 (0.85)<br>2-7 | 2.27 (0.55)<br>2-4 | 1.56<br>(1.38-1.72) | ***W |

CTS - carpal tunnel syndrome; ***p<0.001; [W]Welch's t-test for unequal variances

**Table 3.** Kinesthetic sense of strength - mean value and standard deviation (SD), minima and maxima as well as kinesthetic sense of strength mean of differences (95% CI) between groups along with the t-test result for independent samples.

| Grip | Group | | | |
|---|---|---|---|---|
| | CTS | Control | CTS minus Control | Significance level |
| Pincer grip<br>[% error] | 36.42 (19.39)<br>0-86.66 | 16.27 (13.24)<br>0-66.66 | 20.15<br>(16.2-24.1) | *** |
| Cylindrical grip<br>[% error] | 32.68 (17.85)<br>0-93.75 | 23.8 (19.39)<br>0-80.95 | 8.88<br>(4.42-13.3) | ***W |

CTS - carpal tunnel syndrome; ***p<0.001; [W]Welch's t-test for unequal variances

of 50% of the maximum strength.

In both measurements (muscle strength and range of motion), the percentage values obtained from the calculations allow the size of the error to be estimated. Lower percentages indicate less error committed by the subject.

*Statistical analysis of results*

All the obtained results were statistically analyzed. The homogeneity of the variance for each variable was checked using Levene's test. Next, the variables were analyzed using the t-test for independent samples (equal variances) or Welch's t-test for independent samples (unequal variances). The paper presents mean values (mean values of differences), standard deviations (SD), and 95% confidence intervals (95% CI). The critical level of the p-value was set at 0.05.

## Results

For the CTS patients, the mean conduction velocity in the sensory fibers was $\bar{x}$ = 32.31 m/s, SD = 10.43, and this was reduced from the normal values (normal values ≥ 50 m/s). The mean conduction velocity in the motor fibers was $\bar{x}$ = 54.01 m/s, SD = 6.8, and this was not reduced from the normal values (normal values ≥50 m/s). The mean terminal latency of the median nerve was $\bar{x}$ = 5.53 m/s, SD = 1.1 (normal values ≤4.0). The mean symptom severity was $\bar{x}$ = 2.96, SD = 0.68 (maximum 5.0), and the physical capacity was $\bar{x}$ = 2.78, SD = 0.82 (maximum 5.0). The mean pain score was 5.48 m/s, SD = 1.64 (maximum 10).

In the 2PD sense evaluation, the results presented in Table 2 show significantly higher values of discrimination sense in all fingers tested in the CTS group than those in the control group (Table 2).

According to the data in Table 3, there was a significant difference between the two groups in the percentage error of KD of both the pinch and cylinder grip (Table 3). In the case of the kinesthetic sense of the strength in pinch grip, the error in the CTS group was significantly higher than that of the control subjects (mean difference > 20%). With regard to the kinesthetic sense of strength in cylindrical grip, the mean error was also significantly higher in the CTS group than in the control group (mean difference ~9%).

According to KD of movement, in assessing both the flexion and extension there were significant differences between the CTS and control groups (Table 4). In both cases the CTS group had a higher mean value of the error during KD of the flexion and extension movement.

## Discussion

Our results indicate that in mild and moderate forms of

**Table 4.** Kinesthetic sense of movement - mean value and standard deviation (SD), minima and maxima as well as kinesthetic sense of movement mean of differences (95% CI) between groups along with the T-test result for independent samples.

| ROM | Group | | | |
|---|---|---|---|---|
| | CTS | Control | CTS minus Control | Significance level |
| Extension [% error] | 20.25 (15.48) 0-66.66 | 14.06 (13.59) 0-68.11 | 6.19 (2.72-9.67) | *** |
| Flexion [% error] | 18.19 (14.26) 0-55.88 | 14.16 (11.6) 0-61.11 | 4.03 (0.93-7.12) | **W |

CTS - carpal tunnel syndrome; **p=0.01; ***p<0.001; WWelch's t-test for unequal variances

CTS significant disturbances occur in both the 2PD sense and KD of the strength and motion, relative to those in healthy subjects. In the case of the sense of discriminatory finger I, the difference from that in the healthy subjects was up to 128%. In the assessment of fingers II and III, this was 103 and 69%, respectively. The size of the error committed by individuals with CTS in the evaluation of KD of pinch grip strength was 124% higher than in healthy subjects. A slightly smaller error occurred in the assessment of the cylindrical grip; this amounted to 37%. The error in KD of movement in patients with CTS was 44% in the case of extension and 28% in the case of flexion.

Evaluation of discrimination sensation is widely used in clinical practice and research[13,26,27]. According to Shooter, 2PD sense is a widely used technique for determining tactile agnosia. It is also an accurate and reproducible tool for assessing the peripheral nerve repair process[28]. Eryilmaz et al. showed that the 2PD test is a practical, cost-effective, and more easily applicable method that was completed in less time than nerve conduction studies[29]. Novak et al. showed a high correlation between the 2PD sense and hand function in patients after median nerve injury[30]. In turn, Nowak and Noszczyk showed a high correlation between the 2PD sense and sensory nerve conduction in CTS (larger than that with Phalen's test, Durkan, or the Katz hand diagram)[31]. Hansson examined the effects of the loss of the 2PD sense after median nerve injury on the activation of neurons in the somatosensory cortex[32]. He showed greater activation of the somatosensory cortex on the injured side. The author stresses that this enlarged area of activation may be the result of reorganization and may indicate that large areas of the cortex are involved in the 2PD sense after peripheral nerve injury. It seems that a similar mechanism could also be true for CTS.

Tactile sensory examination is important because diminished sensation may increase the risk of skin injury and trauma. This is important both at work and in daily activities[13]. It is very likely that irregularities in the 2PD sense can indicate damage to both exteroceptive and proprioceptive function, which probably affects proper hand function.

Muscle strength is evaluated relatively often in CTS. Normally, the pinch and cylindrical grip are tested. However, in the literature there are no reports of the evaluation of the kinesthetic sense of strength. McDermid stated that in the mild to moderate form of CTS, muscle strength is often correct. Only in cases in which the disease progresses are the subjective symptoms reduced while there is muscle atrophy and weakness[33]. The experiment conducted shows that before the muscle atrophy and weakness appear, the kinesthetic sense of strength is disrupted in the evaluation of both the pinch and cylindrical grip. This can lead to impaired hand function, especially in activities and occupations that require high-precision movement. This may of course be a reason for declining productivity. Since one of the symptoms of CTS is pain, it can also affect muscle strength and KD of strength. Tamburin et al. showed that pain can be one of the factors that contribute to strength weakening. They also write that chronic pain can impair motor control and efficiency in the implementation of various tasks using the hand[34]. Various models have been proposed to explain the relationship between pain and motor skills but so far no single position has been developed. Some researchers suggest the hypothesis of a reflex defense mechanism from the core levels, others suggest that the interaction between pain and movement occurs at a cortical level[35,36].

As in the case of KD of strength, for KD of movement there are no reports on the comparison of the behavior of patients with CTS to that of healthy volunteers and its potential impact on their professional life. In the experiment, a decrease in KD of movement was demonstrated, which can lead to a reduction of movement precision, and this can reduce productivity. Up to a point, proprioceptive information can be compensated for by sight. However, those with impaired deep sensation very often provide the additional information by enhancing muscle tone or the performance of motor tasks in a different, often incorrect manner. Such compensation may cause the formation of pathological motor programs that can result in improper charging of many tissues, and this may also adversely affect the already pressed median nerve in the CTS, exacerbating its pathology. Such pathological patterns used for compensation may affect the other areas of the musculoskeletal system and continue to exacerbate the pathology (e.g. arthrosis), reducing work efficiency. Of course, we should keep in mind that even in the case of KD of movement, pain may be the agent modifying control of movement[34]. And in this case, the pain can cause a change in movement strategy by reducing the agonist muscle activity. In addition, impaired nerve function in the circuit with time may result in neuroplastic changes in the central nervous system and thus interfere with the proper KD of motion[37].

The relationship between 2PD sense disorder and agnosia disorders, and even reorganization changes in the cerebral cortex, described by various authors, suggests that even in the early stages of CTS, worse movement control may occur, which in turn may adversely affect professional life and everyday activities, especially in those professions and activities that require high-precision movement.

Given the paucity of studies on this subject, future work should be carried out to evaluate the impact of the loss of the 2PD sense and KD of strength and movement of the hand and the effect of different kinds of interventions to improve tactile sensibility.

## Conclusions

1. In mild and moderate forms of CTS, there are significant differences in the 2PD sense and KD of strength and motion compared with a healthy indywiduals

2. The occurrence of disorders of various kinds of sense of CTS, even in their mild and moderate forms, may affect the efficiency of work of individuals affected by this disease.

*Conflict of Interest:* The authors declare that they have no conflicts of interest.

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