Dr.Meltem Duraklı Ulukök. (2022). Incidence of Carpal Tunnel Syndrome In Turkish Athletes: Usage of Ultrasonography In Diagnosis and Severity Mapping. Revista Internacional de Medicina y Ciencias de la Actividad Física y el Deporte, 22(88.1), 12-24.
DOI: https://doi.org/10.15366/rimcafd.2022.22.88.1.002

# ORIGINAL

## INCIDENCE OF CARPAL TUNNEL SYNDROME IN TURKISH ATHLETES: USAGE OF ULTRASONOGRAPHY IN DIAGNOSIS AND SEVERITY MAPPING

**Dr.Meltem Duraklı Ulukök**

Neurology Expert
Cankaya Medical Center Neurology Unit, Turkey Orcid No: 0000000209850103
Email: sevimeltem@gmail.com

**Spanish-English translators:**

**UNESCO Code / UNESCO Code:**
**Council of Europe classification / Council of Europe classification:**

**Received** April 30, 2020

**Accepted** June 26, 2020

## ABSTRACT

**Background and Aim:** Carpal Tunnel Syndrome (CTS) is a group of symptoms caused by median nerve compression within the carpal tunnel. It is typically caused by elevated CT pressure and diminished median nerve function. The most common cause of CTS in athletes is the persistent application of greater pressure to their CT during game practice. Ultrasonography (USG) and electro-diagnosis have been applied to determine CTS. This study aims to examine the role of ultrasonography in diagnosing and assessing the severity of CTS in Turkish athletes. **Method:** Between June 2022 and September 2022, 64 athletes without neurological disorders and complaints in the upper extremity were recruited for this investigation. Regarding complaints, the CTS-6 scale was applied to all athletic patients. According to this scale, athletes who scored 12 points or more were deemed CTS-6 positive, while those who scored less than 12 points were deemed CTS-6 negative. **Results:** MNSA (p= 0.000), MMDL (p= 0.000), MSCV (p= 0.000), and BMI (p= 0.002) exhibit statistically significant differences (p0.05) about the severity of CTS. At the cut-off value (MNSA) of 9.5mm2, the sensitivity was 88%, but it was 79% at the cut-off value of 10.5mm2. **Conclusion:** USG has successfully determined the severity of the CTS. USG is largely replacing EDX for physical evaluation since it is more cost effective and quicker. Even in Turkey, most athletes choose to have their CTS diagnosed with USG.

**Keywords:** Ultrasonography; Carpal Tunnel Syndrome; Athletes; Turkey; Severity; Median Nerve

## 1. INTRODUCTION

Carpal tunnel syndrome (CTS) is one of the most prevalent compressive neuropathies of the periphery [1]. Its primary cause is pressure on the median nerve in the wrist's carpal tunnel [2]. On the palm side of the hand, the carpal tunnel is a tiny channel enclosed by ligaments and bones [3]. When the median nerve is compressed during CTS, symptoms may include weakness in the arm and hand or tingling and numbness [4, 5]. Possible contributors to CTS [4] include repetitive hand motions, health concerns, and the structure of the wrist. If CTS could be correctly diagnosed and treated, it may restore hand and wrist function and alleviate tingling and numbness [6]. According to Genova et al. [4], the most prominent symptoms of CTS manifest in the thumb, fingers, palm, and wrist. Carpal tunnel syndrome is prevalent among athletes and sportspeople [7]. One of the primary reasons for this could be that athletes are more susceptible to CTS due to the repeated wrist and hand movements needed in sports [7]. CTS is an inflammatory illness, so any activity or sport that includes repetitive movements that can inflame or irritate the tendons or muscles of the wrists [8] should be avoided. Nine tendons emerge from the carpal tunnel's tiny channel [9]. As the synovial sheaths surrounding these tendons become inflamed or swollen, considerable pressure is initially applied to the tendons, and greater pressure is exerted on the median nerve. According to Vihlborg et al. [10], CTS can be caused by exposure to repetitive wrist movements, intensive manual labor, and vibrations. Carpal tunnel syndrome is frequently diagnosed in athletes [11]. CTS could occur despite a hyperextension injury or distal radius fracture in the wrist. According to Brad [7], most CTS cases associated with sports or athletes involve repetitive wrist flexion extension and are chronic. When there is direct pressure on the wrist, the intra-neural blood flow of the median nerve is severely altered and aberrant [7]. Athletes, particularly wheelchair athletes, weight lifters, archers, and bicyclists, have a high prevalence of carpal tunnel syndrome [7]. Athletes take numerous prudent precautions to prevent CTS. They could include using lighter bows and forearm protectors, rest breaks of five to thirty minutes during training sessions, regular changes in wrist and hand postures, protective padded gloves with extra padding on the palm, and numerous other measures. After a diagnosis of CTS and symptoms are confirmed, the condition must be addressed. The most typical treatments of the modalities are activity modification, splinting of the wrist in the neutral position, and using nonsteroidal anti-inflammatory drugs [7]. In the past, it was quite difficult to diagnose carpal tunnel syndrome, and the procedures were costly and time-consuming [12]. Still, today, ultrasonography makes it simple to detect CTS and gives high-quality images of the body's smallest alterations. In addition to being quick, affordable, and non-invasive [13], this method has proven to be very dependable and authentic and is advantageous for both doctors and patients [14].

### 1.1 Aim of the study

This study aims to investigate the usefulness of ultrasonography in diagnosing and assessing the severity of Carpal Tunnel Syndrome (CTS) in Turkish sportsmen.

## 2. Literature Review

### 2.1 Ultrasonography

According to Wu et al. [15], ultrasonography is an ultrasound-based diagnostic imaging technology. It is utilized to visualize several bodily structures as small as 1.1 mm horizontal and 0.2 mm vertical resolutions [16]. It is increasingly used to visualize internal organs, arteries, joints, muscles, and tendons for potential abnormalities or pathology. According to Izadifar et al. [17], ultrasonography is an excellent imaging tool for soft body tissues. According to the research conducted by Isayama et al. [18], ultrasonography is a method that poses no risk to the patient. It is transmitted via portable devices and is unaffected by ionizing radiation. The development of ultra-high frequency transducers with lower dimensions, the introduction of new high-quality devices, and the growth of technology have all contributed to the acquisition of high-quality images [19]. This led to determining and diagnosing hand and wrist examinations, especially for carpal tunnel syndrome (CTS) [20].

### 2.2 Sonographic examination of the carpal tunnel syndromes

In the past, the lack of a gold standard for diagnosing CTS [21] has been problematic. In the past, this was detected using nerve conduction investigations and their numerous modifications for determining the diagnosis and detecting anomalies in the body [22]. Several publications claim nerve conduction examinations might provide false negative and false positive results [23-25]. In addition, these techniques were unpleasant, costly, and time-consuming [21]. According to Ardakani et al. [26], ultrasonography tests have been performed to diagnose carpal tunnel syndrome for the past twenty years and are regarded as an accurate way of diagnosis. According to Nkrumah et al. [27], neurosurgeons, neurologists, rheumatologists, and orthopedic surgeons routinely utilize ultrasonography for CTS examinations today. Ultrasonography is advantageous for patients and physicians in diagnosing CTS since it can detect structural abnormalities, is well tolerated by patients, requires less time, and is inexpensive [28].

The flexor retinaculum and the wrist bones enclose carpal tunnel syndrome [29]. According to Wee and Simon [30], using ultrasonography as an imaging technique for evaluating CTS is rising quickly. Ultrasonography in patients with electromyography findings of carpal tunnel syndrome has proven advantageous because it reveals nerve swelling and structural changes. It can also visualize other pathologies that other electrophysiological examinations could not determine and detect, such as tumors, tenosynovitis, anatomical variants, muscle hypotrophy, etc. [16]. In addition, Telang et al. [31] demonstrate that ultrasonography can detect CTS by detecting thickening of the flexor retinaculum, palmar migration, nerve compression, median nerve edema, and median nerve alterations. According to Aggarwal et al. [32], the ultrasonographic assessment of CTS has several advantages, including the fact that it is inexpensive, non-invasive, and readily available. It also enables faster and simpler identification of CTS and various median nerve characteristics, including mobility, blood flow, and size. Ultrasonography makes it possible to observe the median nerve in detail. Ultrasonography is a reliable instrument and approach for the diagnosis of CTS, according to Lin et al. [33]. Doppler ultrasound and sonoelastography are supplemental methods [33] for confirming CTS diagnoses. According to Dawood et al. [34], surgical decompression, local corticosteroid injections, and splints have restricted the efficacy of CTS treatment. The patient's wrist could be treated with ultrasonography, which may have an anti-inflammatory impact and relieve CTS symptoms. CTS is a common peripheral nerve entrapment in middle-aged women and athletes. The symptoms may develop complex and increase due to compression of the median nerves in the carpal tunnel, although the underlying cause [38] remains unknown. According to Nasiri et al. [39] .'s investigation, ultrasonography therapy gives moderate CTS patients with short-term relief for at least six months, and the authors state that its favorable benefits endure. According to Ratasvuori et al. [21], ultrasonography is an accurate and rapid diagnostic method for the primary diagnosis of CTS in patients with classic symptoms. Murciano Casas et al. [28] have stated that ultrasonography also enables quantifying changes in the underlying pathological mechanisms in carpal tunnel syndrome, such as the assessment of anatomical alterations, power Doppler uptake, flexor retinaculum bulging, the wrist-forearm index, and the range of nerve thinning.

## 3. METHOD

After meeting the exclusion criteria, 65 athletes who presented to the outpatient neurology clinic of our hospital between June and September 2022 with upper extremity complaints (numbness in the hands or arms, tingling, pain, neck-to-arm pain, etc.) and required electrophysiological examination were included in this study. In addition, the CTS-6 scale (Table 1) was applied to the complaints of all sports patients. According to this scale, athletes who scored 12 points or more were deemed CTS-6 positive, while those who scored less than 12 points were deemed CTS-6 negative.

### 3.1 Inclusion Criteria for Participation

- Athletes above 18 years old and willing to participate were included in this study.
- The athletic patients without neurological issues were included in this study.
- Athletic patients with complaints in the upper extremity were included in this study.

### 3.2 Exclusion Criteria for Participation

- This study did not include athletes with a history of hand or wrist trauma with lacerations or bone fractures.
- Athletic patients with neurological disorders, including "mono neuritis multiplex, proximal median or ulnar neuropathy, cervical radiculopathy, polyneuropathy, and plexopathy," were also not included in this study.
- Athletes with a "carpal tunnel release" history were also excluded.
- The athletic patients with structural or anatomical disjointedness in the above extremity were not included.

- Moreover, the athletes with other lesions within the "carpal tunnel" were also excluded.

USG examination was performed on the same day as ENMG.

### 3.3 Ultra-sonographic Evaluation

The radiologist did ultrasound testing of the median nerve on the same day as the electro-diagnosis but was not given the NCS results. This study utilized Samsung R7 ultrasound equipment with a "4-D linear array transducer." Patients sat in front of the "sonographer" in a good and comfortable location and position, with their palms facing up (supine position) and their fingers in a neutral position at half-extension for all USG examinations. The test was initiated by demonstrating the median nerve in the axial plane during "wrist localization," Any anatomical variations were also found. Moreover, the surrounding tissues of the median nerve were evaluated. Cysts, such as "ganglion cysts," which can compress the nerve or mass space-occupying lesions and cause fluid accumulation in neighboring tendons, such as "tendinitis-tenosynovitis," were also evaluated.

The median nerve was traced from the distal third of the forearm to its most distal level, where it could be viewed in the palm. After viewing the nerve and its surrounding anatomical components, the median nerve's structure, internal echogenicity, and contours were evaluated along the trace.

Then, the cross-sectional area of the median nerve was measured at the "pisiform bone" level, referred to as the proximal level of the carpal tunnel, in the context of the transverse plane (Figure 1, 2). The "manual trace method" included on the USG gadget was also used for area measurements. The drawing was produced over the hyperechoic sheath during the measurements. Throughout the measurement, special care was taken to verify that the nerve entered the examination plane precisely in the axial plane. At the pisiform-scaphoid level, the cross-sectional area of the median nerve in both wrists was measured at the entrance of the carpal tunnel. The border median nerve's hyperechoic epineurium was recognized as the basis for the cross-sectional area. Each measurement was performed three times, and the mean was calculated.

Individuals diagnosed with CTS had a hypoechoic appearance due to edema caused by median nerve compression at the wrist. Moreover, the thin reticular echogenicity loss created by the "epineurium layers" covering the outside of the "neural fascicles" that compose the inner structure of the nerve was notable in these athletes. USG images of the median nerve (MN) in athletes with CTS appear as depicted in the image (Figure 1, 2).

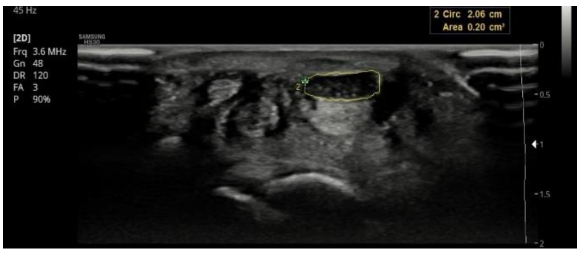


**Figure 1**: MN cross-sectional is a measurement at the level of the carpal tunnel entrance with USG in a patient with severe CTS

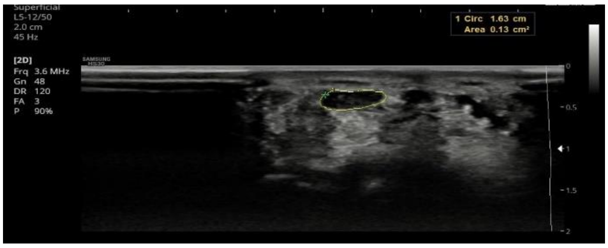

**Figure5**: MN cross-sectional is a measurement at the level of the carpal tunnel entrance with USG in a patient with moderate CTS

**Table 1**. CTS-6 SCALE

**FINDINGS SCORE Symptoms and anamnesis**

*Numbness specific or more in the median nerve area3,5 (sensory complaints inthe thumb, 2nd and 3rd or 4th finger)
*Night time symptoms 4
(symptoms increase at night or wake the patient from sleep)
Physical examination
*The naratrophy or weakness in palmar abduction 5 (Reduction in muscle trunk of the muscle strength in palmar abduction ≤ 4/5)
* Positive Phallen test 5
(Symptoms appear in the median nerve area when the wrist is flexed and held for at least 60 seconds)
*Distortion of 2-point separation (>5mm) 4,5
(Inability to distinguish two points >5mm apart on the median nerve innervated fingertips)
*Positive tinsel test 4
(Numbness and tingling in the MN innervated fingers by gently tapping on the MN at the level of the carpal tunnel)
A score sum of positive findings will be considered positive for ≥12 CTS.

## 4. RESULTS

### 4.1 Descriptive Statistics on Measurement Variables

**Table 2**. Descriptive Statistics on Measurement Variables

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| BMI | 63 | 18.90 | 26.20 | 22.0079 | 1.72255 |
| MNSA | 63 | 6.00 | 30.00 | 12.6508 | 5.35260 |
| CTS 6 Scale | 63 | 4.50 | 22.50 | 13.2063 | 5.05345 |
| MMDL | 63 | 2.60 | 10.10 | 4.2794 | 1.67555 |
| MSCV | 63 | .00 | 54.00 | 34.7857 | 15.64814 |

**BMI: Body Mass Index, MNSA: Median Nerve Section Area, MMDL: Median Motor nerve Distal Latency, MSCV: Median Sensory nerve Conduction Velocity**

The mean BMI of the participants is 22±1.72, and the mean MNSA is 12.65±5.35. The mean of the CTS 6 Scale is 13.20±5.05, the mean of MMDL is 4.27±1.67, and the mean of MSCV is 34.78±15.64.

### 4.2 Descriptive Statistics on Categorical Variables

**Table 3**. Descriptive Statistics on Categorical Variables

| | | N | Percent |
|---|---|---|---|
| **Gender** | **Female** | 33 | 52.4 |
| | **Male** | 20 | 47.6 |
| **Presence of CTS** | **No** | 20 | 31.7 |
| | **Yes** | 43 | 68.3 |
| **Severity of CTS** | **Non-CTS** | 20 | 31.7 |
| | **Mild** | 15 | 23.8 |
| | **Moderate** | 20 | 31.7 |
| | **Severe** | 8 | 12.7 |
| **Dominant Hand** | **Right** | 55 | 87.3 |
| | **Left** | 8 | 12.7 |
| **CTSHand** | **Non-CTS** | 20 | 31.7 |
| | **Right** | 35 | 55.6 |
| | **Left** | 8 | 12.7 |

52.4 percent of participants are female, and 68.3 percent have CTS. 31.7% of participants do not have CTS, 23.8% have mild CTS, 31.7% have moderate CTS, and 12.7% have severe CTS, as determined by the severity of CTS. The right hand is the dominant hand for 87.3% of the participants. 55.6% of individuals have right-hand CTS.

### 4.3 The Relationship between Dominant Hand and the Presence of CTS

**Table 4**. The Relationship between Dominant Hand and the Presence of CTS

| | | Presence of CTS | | $\chi^2$ | df | p |
|---|---|---|---|---|---|---|
| | | No (%) | Yes (%) | | | |
| **DominantHand** | Right | 17 (30.9) | 38 (69.1) | 0.140 | 1 | 0.708 |
| | Left | 3 (37.5) | 5 (62.5) | | | |

There is a "statistically insignificant association" between the dominant hand and the presence of CTS (p>0.05).

### 4.4 The Relationship between Dominant Hand and Severity of CTS

**Table 5.** The Relationship between Dominant Hand and Severity of CTS

| | | Severity of CTS | | | $\chi^2$ | df | p |
|---|---|---|---|---|---|---|---|
| | | Non-CTS(%) | Mild(%) | Moderate (%) | Severe(%) | | |
| **Dominant Hand** | Right | 17 (30.9) | 13 (23.6) | 18 (32.7) | 0.234 7 (12.7) | 3 | 0.973 |
| | Left | 2 (37.5) | 2 (25) | 2 (25) | 1 (12.5) | | |

It is seen that there is a "statistically insignificant association" between the dominant hand and the severity of CTS (p>0.05).

### 4.5 The Relationship between Gender and the Presence of CTS

**Table 6.** The Relationship between Gender and the Presence of CTS

| | Presence of CTS | | $\chi^2$ | df | p |
|---|---|---|---|---|---|
| | No (%) | Yes (%) | | | |
| **Gender** Female | 11 (55) | 9 (45) | 0,081 | 1 | 0.777 |
| Male | 22 (51.2) | 21 (48.8) | | | |

The table above shows no statistically significant relationship between gender and CTS presence (p>0.05).

### 4.6 Difference Analysis of MNSA by Severity of CTS

**Table 7(a).** Difference Analysis of MNSA by Severity of CTS

| | | Severity of CTS | | | | | |
|---|---|---|---|---|---|---|---|
| | | Non-CTS | Mild | Moderate | Severe | $\chi^2$ | P |
| **MNSA** | N | 20 | 15 | 20 | 8 | 55.461 | 0.000 |
| | MR | 11.55 | 26.61 | 45.51 | 59.10 | | |
| **MMDL** | N | 20 | 15 | 20 | 8 | 52.611 | 0.000 |
| | MR | 13.08 | 24.55 | 45.62 | 59.18 | | |
| **MSCV** | N | 20 | 15 | 20 | 8 | 57.205 | 0.000 |
| | MR | 53.50 | 36 | 18.51 | 4.51 | | |
| **BMI** | N | 20 | 15 | 20 | 8 | 14.881 | 0.002 |
| | MR | 33.73 | 20.61 | 31.13 | 51.21 | | |

MR= MeanRank

MNSA, MMDL, MSCV, and BMI differ statistically significantly (p<0.05) according to the severity of CTS. Hence, as CTS severity grows, so does MNSA, and the group with the most severe CTS has the highest MNSA.

Similarly, MMDL increases as CTS severity increases, and the group with the most severe CTS has the greatest MNSA. The opposite is true for MSCV, with the highest MSCV found in the non-CTS group, and the lowest MSCV found in the severe CTS group. The group with the highest BMI is the severe CTS group, while the group with the lowest BMI is the non-CTS group. As CTS severity worsens, BMI increases among CTS-positive individuals.

**Table 7(b)**. Difference Analysis of MNSA by Severity of CTS

| Variables | | Non-CTS | Severity of CTS Mild | Moderate | Severe |
|---|---|---|---|---|---|
| MNSA | N | 20 | 15 | 20 | 8 |
| | Mean ±std. Deviation | 7.70±1.30 | 10.20±1.08 | 15.15±1.08 | 23.37±3.37 |
| | Min-Max | 6-11 | 9-12 | 13-17 | 20-30 |
| MMDL | N | 20 | 15 | 20 | 8 |
| | Mean± std. deviation | 2.92±0.17 | 3.26±0.30 | 5.09±0.57 | 7.53±1.47 |
| | Min-Max | 2.60-3.30 | 2.80-3.90 | 4.10-6.10 | 5.80-10.10 |
| MSCV | N | 20 | 15 | 20 | 8 |
| | Mean± std. deviation | 50.11±1.65 | 38.46±1.26 | 30.61±3.04 | - |
| | Min-Max | 47-54 | 36.70-41 | 24-35.10 | - |
| CTS 6 Scale | N | 20 | 15 | 20 | 8 |
| | Mean± std. deviation | 6.87±2.26 | 14.40±1.93 | 15.97±1.53 | 19.87±2.83 |
| | Min-Max | 4.50-11 | 12.50-20 | 13-18 | 15-22.50 |

When the means are evaluated according to the severity of CTS, the mean MNSA of the non-CTS group is 7.70±1.30, the mean of the mild CTS group is 10.20±1.08, the mean of the moderate CTS group is 15.15±1.08, and the mean of the severe CTS group is 23.37±3.37. The mean of MMDL is 2.92±0.17 in the non-CTS group, 3.26±0.30 in the mild group, 5.09±0.57 in the moderate group, and 7.53±1.47 in the severe group. Regarding MSCV, the mean of the group without CTS is 50.11±1.65, 38.46±1.26 in the mild group, and 30.61±3.04 in the moderate group. When the CTS 6 Scale is examined, the mean of the non-CTS group is 6.87±2.26,14.40±1.93 in the mild group, 15.97±1.53in the moderate group, and 19.87±2.83 in the severe group.

## 4.7 Analysis of the relationships between MNSA, MMDL, and MSCV

**Table 8**. Analysis of the relationships between MNSA, MMDL, and MSCV

| | 1 | 2 | 3 |
|---|---|---|---|
| 1. MNSA | - | | |
| 2. MMDL | 0,867* | - | |
| 3. MSCV | -0,900* | -0,905* | - |

The table shows a significant, positive, and strong association between MNSA and MMDL ($p < 0.01$; r= 0.867). Another finding shows that there is a "statistically significant, negative and strong relationship" between MNSA and MSCV ($p < 0.01$; r= - 0.900). There is also a statistically significant, negative, and strong relationship between MMDL and MSCV (p<0.01; r= -0.905).

## 4.8 ROC Analysis

**Table 9**. ROC Analysis

| Risk Factor | Cut-off | AUC (%95) | *p* | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|
| MNSA | 9.5 | 0.976 (0.944-1.000) | 0.000 | 88.4 | 95 |
| MNSA | 10.5 | 0.976 (0.944-1.000) | 0.000 | 79.1 | 95 |

When the MNSA risk factor was accepted when the cut-off value was

9.5mm$^2$ in the "ROC curve analysis," performed for the presence of CTS, the area under the curve was found to be 0.976, the sensitivity 88%, and the specificity 95% ($p$<0.05).

When the MNSA risk factor was accepted when the cut-off value was 10.5mm$^2$ in the "ROC curve analysis," performed for the presence of CTS, the area under the curve was found to be 0.976, the sensitivity 79%, and the specificity 95% ($p$<0.05).

## 5. DISCUSSION

NCS is considered a standard test for diagnosing carpal tunnel syndrome [40]. Still, USG has emerged as a powerful diagnostic technique for detecting CTS through the visualization of high-quality images of the changes and abnormalities that occur in the median nerve and the space-occupying formulations and their adjacent structures [41]. In addition, USG is a quick, affordable, and painless diagnostic technique [42] that does not cause any harm to the patient. This tool produces dynamic images of the median nerve of superior quality. Sonographic characteristics, including tissue analysis, cross-section ratios, and cross-section area measurements, have been extensively investigated and implemented in USG techniques [43]. The color Doppler analysis has been identified as a promising avenue for further research. On the other hand, empirical evidence from the current literature indicates that there is no consensus about the role of ultrasonography in detecting and diagnosing carpal tunnel syndrome. The ambiguity stems from the occurrence of contradictory findings in the several studies analyzed and examined regarding the sensitivity and specificity of ultrasonography in CTS identification.

Studies have demonstrated that in the general population, the sensitivity of the USG test for the median nerve to detect carpal tunnel syndrome ranges from 57% to 98%. In comparison, its specificity ranges from 63% to 100%. The clinical diagnostic reference standard had a sensitivity of 77.3 percent and a specificity of 92.8 percent. Using the NCS test as the gold standard, the sensitivity was 80.2%, and the specificity was 78.7%. While these numbers are inconsistent, there are numerous possible explanations, such as the criteria for selecting controls and patients, the fourth diagnostic criterion for carpal tunnel syndrome, which is an electrodiagnostic criterion. This includes the inter-rater reliability of MNSA, the sonographer's experience, and the sonography procedures utilized in various circumstances. Using the CTS-6 scale as the gold standard for measurement, they discovered that the sensitivity and specificity of the EDX tool for diagnosing carpal tunnel syndrome are comparable to the MNSA "cut-off value 10 mm2" [44]. As a result, the current study's findings indicate that the severity of CTS increases as MNSA values rise.

Consequently, the group with the most severe CTS also had the highest MNSA. Hence, when the values of MNSA increase, the MMDL value also increases; thus, the group with the most severe CTS also has a larger MMDL. In the case of MSCV, the situation is now inverted, as the greatest MSCV value indicates that the group does not have CTS, while the lowest MSCV value indicates that the group has CTS severity. UGS is becoming an increasingly essential tool for diagnosing CTS due to its several advantages, including its applicability, speed, affordability, and ability to assess the severity of CTS [45].

## 6. RESEARCH IMPLICATIONS

The current investigation is both practical and theoretically sound. This work has contributed to advancing information regarding the USG examination in the context of athletes with CTS. This work has also contributed to underlining the importance of USG in assessing the severity of CTS, which could be used to provide effective treatment. In addition, this study was beneficial in comparing the cost-effectiveness and performance of USG and EDX, encouraging future researchers to work more efficiently to determine the efficacy of combining the two procedures to enhance the treatment and diagnosis of CTS.

The empirical findings of this study may persuade healthcare providers to use USG to determine the severity of CTS in conjunction with MNSA, MMDL, and MSCV. This study can also encourage policymakers to advocate using EDX and USG for assessing and treating CTS in the context of athletic patients to establish a healthy and safe environment for athletes.

## 7. LIMITATIONS AND FUTURE RESEARCH

This study is also limited by some factors that can be addressed in future research. Due to restricted resources, a small sample size of 65 patents was chosen for this investigation. Second, this study was limited to athletic patients with CTS due to research inadequacy. Third, this study was conducted within Turkey, and no data from other countries were used to generate effective empirical conclusions due to the limited availability of such broad data.

Future studies can integrate a bigger sample size to prevent bias in the gathered data to overcome these constraints. In addition, future research should consider the viewpoints of physicians and other healthcare professionals regarding CTS. The topic under debate might also be examined from other nations' perspectives to get effective results.

## 8. CONCLUSION

Even though electrophysiological studies are regarded as useful in the idiopathic diagnosis of CTS, the results of this study indicate that USG findings of MN and carpal tunnel can also be used to diagnose CTS. In addition, USG has been demonstrated to be highly useful for detecting structural anomalies such as a persisting median artery, a bifid MN, and an aberrant Palmarislongus muscle. In this study, both ENMG and USG exams were performed on the same day for 65 Turkish athletes to determine the improvement in the diagnosis and treatment of CTS in the setting of a subset of sporty patients. This study reported CTS severity was associated with MNSA, MMDL, and MSCV. In addition, a ROS analysis was undertaken.

In contrast to EDX, the results of this investigation demonstrated that USG has become an essential component of physical examinations over time. It is reportedly less expensive, more adaptable, and quicker than EDX. In addition, it does not cause any discomfort to the persons being examined. Because of USG's efficacy in detecting the severity of CTS, the EDX is essentially being superseded in most cases involving athletes.

## REFERENCES

Sheibani, S., A. Teimoury, and M. Dehghan, *Carpal tunnel syndrome secondary to the lipoma mass: a case report and review of literature.* 2021.

Li, Z.-M., *Non-surgical Carpal Arch Space Augmentation for Median Nerve Decompression.* Journal of Biomechanical Engineering, 2023: p. 1-22.

Dong, D. and H. Liu, *Prevalence of carpal tunnel syndrome in patients with long-term type 2 diabetes mellitus.* Heliyon, 2022: p. e12615.

Genova, A., et al., *Carpal tunnel syndrome: a review of literature.* Cureus, 2020. **12**(3).

Joshi, A., et al., *Carpal Tunnel Syndrome: Pathophysiology and Comprehensive Guidelines for Clinical Evaluation and Treatment.* Cureus, 2022. **14**(7).

Thakur, M., *Indications, surgical techniques and safety of open versus endoscopic carpal tunnel release.* EC Orthopaedics, 2020. **11**(11): p. 8-14.

Brad, W. *Carpal Tunnel Syndrome (CTS). Includes causes, symptoms, anatomy, plus exercises and stretches to treat and prevent carpal tunnel syndrome.* 2022; Available from: https://stretchcoach.com/articles/carpal-tunnel-syndrome/#:~:text=Carpal%20tunnel%20syndrome%20is%20an,run%20through%20the%20carpal%20tunnel.

O'Brien, C.P., *Leading Wrist Injuries in a Golfing Population. Golf Swing Biomechanics a Significant Cause of Pathology*, in *Recent Advances in Sport Science*. 2021, IntechOpen.

Madani, A.M., et al., *A literature review of carpal tunnel syndrome and its association with body mass index, wrist ratio, wrist to palm ratio, and shape index.* Journal of Hand Therapy, 2022.

Vihlborg, P., et al., *Carpal Tunnel Syndrome and Hand-Arm Vibration: A Swedish National Registry Case–Control Study.* Journal of Occupational and Environmental Medicine, 2022. **64**(3): p. 197.

Mayo, C. *Carpal tunnel syndrome*. 2022; Available from: https://www.mayoclinic.org/diseases-conditions/carpal-tunnel-syndrome/symptoms-causes/syc-20355603.

Gautam, N. and A. Shrivastava, *A Review on Risk Factors and Diagnosis of Carpal Tunnel Syndrome.* ECS Transactions, 2022. **107**(1): p. 6921.

Sharma, N., et al., *Automated Hybrid Deep Learning-Based Paradigm for High-Risk Plaque Detection in B-mode Common Carotid Ultrasound Scans: An Asymptomatic Japanese Cohort Study.* 2022 AIUM Award Winners, 2022. **41**(1): p. 125.

Köroğlu, Ö., et al., *Estimating the most accurate sonographic measurement in the diagnosis of carpal tunnel syndrome: Which is the best?* Turkish journal of physical medicine and rehabilitation, 2019. **65**(2): p. 177.

Wu, J., et al., *Assessment the reliability of ultrasonography in the imaging of the plantar fascia: a comparative study.* BMC medical imaging, 2019. **19**(1): p. 1-7.

Georgiev, GP, et al., *Medical ultrasound in the evaluation of the carpal tunnel: a critical review.* Cureus, 2018. **10**(10).

Izadifar, Z., et al., *An introduction to high intensity focused ultrasound: systematic review on principles, devices, and clinical applications.* Journal of clinical medicine, 2020. **9**(2): p. 460.

Isayama, H., et al., *Clinical practice guidelines for safe performance of endoscopic ultrasound/ultrasonography-guided biliary drainage: 2018.* Journal of Hepato-Biliary-Pancreatic Sciences, 2019. **26**(7): p. 249-269.

Ait ichou, J., S. Gauvin, and R. Faingold, *Ultra-high-frequency ultrasound of superficial and musculoskeletal structures in the pediatric population.* Pediatric Radiology, 2021. **51**: p. 1748-1757.

Erickson, M., M. Lawrence, and A. Lucado, *The role of diagnostic ultrasound in the examination of carpal tunnel syndrome: an update and systematic review.* Journal of Hand Therapy, 2022. **35**(2): p. 215-225.

Ratasvuori, M., et al., *ultrasonography for the diagnosis of carpal tunnel syndrome: correlation of clinical symptoms, cross-sectional areas and electroneuromyography.* Journal of Hand Surgery (European Volume), 2022. **47**(4): p. 369-374.

Yu, Y., *Gold standard for diagnosis of DPN.* Frontiers in Endocrinology, 2021. **12**: p. 719356.

Edwards, C., *Exploring the Potential of a Questionnaire in Predicting Results of Nerve Conduction Studies in Patients with Suspected Carpal Tunnel Syndrome: Exploring a Clinician and Patient Complete Version.* Open Journal of Therapy and Rehabilitation, 2020. **8**(3): p. 110-118.

Demino, C. and J.R. Fowler, *The sensitivity and specificity of nerve conduction studies for diagnosis of carpal tunnel syndrome: a systematic review.* Hand, 2021. **16**(2): p. 174-178.

Fowler, J.R., et al., *False-positive rates for nerve conduction studies and ultrasound in patients without clinical signs and symptoms of carpal tunnel syndrome.* The Journal of hand surgery, 2019. **44**(3): p. 181-185.

Ardakani, A.A., et al., *diagnosis of carpal tunnel syndrome: A comparative study of shear wave elastography, morphometry and artificial intelligence techniques.* Pattern Recognition Letters, 2020. **133**: p. 77-85.

Nkrumah, G., et al., *Ultrasonography findings in severe carpal tunnel syndrome.* Hand, 2020. **15**(1): p. 64-68.

Murciano Casas, M.d.l.P., et al., *evaluation of ultrasound as diagnostic tool in patients with clinical features suggestive of carpal tunnel syndrome in comparison to nerve conduction studies: study protocol for a diagnostic testing study.* medRxiv, 2023: p. 2023.01. 19.23284770.

Güneş, B.E., et al., *Tendon of Flexor Carpi Radialis in carpal tunnel: a radiologic and cadaveric study.* Turkish Journal of Medical Sciences, 2021. **51**(4): p. 1912-1916.

Wee, TC and N.G. Simon, *Ultrasound elastography for the evaluation of* *peripheral nerves: a systematic review.* Muscle & nerve, 2019. **60**(5): p. 501-512.

Telang, M., et al., *Median nerve entrapment by variant anatomical structures.* Eur J Anat, 2022. **26**(2): p. 251-262.

Aggarwal, P., V. Jirankali, and S.K. Garg, *Accuracy of high-resolution ultrasonography in establishing the diagnosis of carpal tunnel syndrome.* ANZ journal of surgery, 2020. **90**(6): p. 1057-1061.

Lin, T.-Y., et al., *ultrasonography for the diagnosis of carpal tunnel syndrome: an umbrella review.* Journal of neurology, 2022. **269**(9): p. 4663-4675.

Dawood, W.F., Z.A.-H. Ahmed, and W.R. Ezzat, *Comparison of Surgical Decompression and Local Steroid Injection in the treatment of Carpal Tunnel Syndrome.* Research Journal of Pharmacy and Technology, 2019. **12**(5): p. 2490-2492.

Dąbrowska-Thing, A., et al., *Ultrasound elastography as a potential method to evaluate entrapment neuropathies in elite athletes: a mini-review.* Polish Journal of Radiology, 2019. **84**: p. 625-629.

Martorana, A., et al., *The E-Sports Athlete Ergonomics: Carpal Tunnel and Common Injuries Related to Prolonged Gaming.* J Comm Med and Pub Health Rep, 2022. **3**(08).

Cazares-Manríquez, M.A., et al., *A review of carpal tunnel syndrome and its association with age, body mass index, cardiovascular risk factors, hand dominance, and sex.* Applied Sciences, 2020. **10**(10): p. 3488.

Gadkari, PD, G.D. Dahikar, and R.O. Ganjiwale, *A review on carpal tunnel syndrome.* Research Journal of Pharmacy and Technology, 2020. **13**(10): p. 4961-4965.

Nasiri, A., F. Rezaei Motlagh, and M.A. Vafaei, *Efficacy comparison between ultrasound-guided injections of 5% dextrose with corticosteroids in carpal tunnel syndrome patients.* Neurological research, 2023: p. 1-10.

Sartorio, F., et al., *Relationship between nerve conduction studies and the Functional Dexterity Test in workers with carpal tunnel syndrome.* BMC Musculoskeletal Disorders, 2020. **21**: p. 1-10.

Finance, J., et al., *Low dose chest CT and lung ultrasound for the diagnosis and management of COVID-19.* Journal of Clinical Medicine, 2021. **10**(10): p. 2196.

Umay-Altaş, E., et al., *Mid-term effects of two different Kinesio tape treatments in female patients with subacromial impingement syndrome: Randomized controlled ultrasonographic study.* Journal of Hand Therapy, 2023.

Sieroń, D., et al., *Knee Diameter and Cross-Section Area Measurements in MRI as New Promising Methods of Chondromalacia Diagnosis-Pilot Study.* Medicina, 2022. **58**(9): p. 1142.

Sarraf, P., et al., *The best cut-off point for median nerve cross sectional area at the level of carpal tunnel inlet.* Acta Medica Iranica, 2014: p. 613-618.

Kele, H., et al., *The potential value of ultrasonography in the evaluation of carpal tunnel syndrome.* Neurology, 2003. **61**(3): p. 389-391.