Relation of anthropometric hand measurements to idiopathic carpal tunnel syndrome

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Context
Certain individuals are more prone to developing idiopathic carpal tunnel syndrome (ICTS) than others, suggesting that certain personal factors can be implicated in its occurrence.
Aim
The aim of this work was to study anthropometric hand and wrist measurements in ICTS patients, and to correlate them with median nerve electrophysiologic study.
Patients and methods
The study included 50 patients with clinically diagnosed and electrophysiologically confirmed ICTS and 50 age-matched and sex-matched healthy volunteers as the control group. Both groups performed sensory and motor conduction studies of the median nerve. External hand and wrist anthropometric measurements were taken for both groups including wrist depth and width, wrist ratio (WR), palm length and width, third digit length, and hand ratio (HR).
Results
Patients had significantly higher wrist depth (P=0.000), higher WR (P=0.000), shorter palm length (P=0.002), shorter hand length (P=0.001), and lower HR (P=0.000). Patients had more square wrists and shorter hands. Some of these measurements correlated well with median nerve conduction study parameters. Wrist depth and WR were positively correlated with median motor and sensory latencies (P=0.000) and negatively correlated with median motor and sensory amplitudes (P=0.000), and sensory conduction velocity (P=0.000). HR was negatively correlated to median motor and sensory latencies (P=0.01) and positively correlated to median motor (P=0.001) and sensory amplitudes (P=0.039), and sensory conduction velocity (P=0.001). Palm width was negatively correlated with median motor amplitude (P=0.043).
Conclusion
Certain hand anthropometric characteristics predispose to ICTS. Short hand and square wrist configurations could predict the development of ICTS.

Keywords:
anthropometric measurements, hand ratio, idiopathic carpal tunnel syndrome, wrist ratio

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Introduction

Carpal tunnel syndrome (CTS) is the most common entrapment mononeuropathy [1,2]. It describes median nerve entrapment within the osteofibrous carpal tunnel. From the pathophysiological point of view, nerve compression and traction may sequentially create problems relating to intraneural blood microcirculation, lesions at the level of the myelin sheath and at the axonal level, and changes to the supporting connective tissue [3].

The incidence of CTS is 1–3 cases per 1000 patients per year; prevalence is ~50 cases per 1000 patients in the general population. Incidence may rise as high as 150 cases per 1000 patients per year, with prevalence rates greater than 500 cases per 1000 patients in certain high-risk groups [4]. It can affect hand function leading to the loss of working hours, and the occasionally permanent compromise of thumb movements has substantial socioeconomic and healthcare consequences [5].

CTS can be predisposed by certain disease such as diabetes mellitus and rheumatoid arthritis, wrist and hand injuries, as well as certain occupational-related factors (repetitive and forceful exertion of the hand and wrist) [5–9]. However, most cases are idiopathic. Several studies have attempted to find an explanation for idiopathic carpal tunnel syndrome (ICTS) [8–11]. Evidence from epidemiologic studies support an association of ICTS with female sex, age, and high BMI [6,7]. However, certain individuals are more liable to the occurrence of CTS than others, even under the same conditions or occupational settings. This indicates that there might be certain individual-related factors that predispose to median nerve entrapment at the wrist. Several studies confirmed that persons with high BMI are a high-risk category for developing ICTS [12,13]. However, not every obese individual, under the same circumstances, develops CTS.

Several studies have implicated hand anthropometric measurements in the development of CTS [14,15]. Square wrist indicated the presence of narrow carpal tunnel and less space for the tendons, blood vessels, and median nerve, leading to more predisposition to CTS [14]. Other hand anthropometric measurements were also suggested to be associated with CTS [15]. Boz *et al.* [16] revealed hand shape as a determinant factor in the development of CTS. Accordingly, it was suggested that square wrist and short hand could predispose to CTS.

Aim

The aim of this work was to study anthropometric hand and wrist measurements in patients with ICTS, and to correlate them with electrophysiologic study of median nerve.

Patients and methods

The study included 50 female patients with clinically diagnosed and electrophysiologically confirmed ICTS (patients group), and 50 healthy individuals served as controls (age-matched and sex-matched healthy volunteers who had no symptoms of CTS). Patients were included if they had typical CTS symptoms (i.e. paresthesia and nocturnal pain in the distribution of the median nerve) and definite electrophysiologic abnormalities in the nerve conduction studies. Criteria for the diagnosis of CTS were set at 4.2 ms or higher for motor distal latency (DL) of the median nerve and 49 m/s or lower for median sensory nerve conduction velocity (SNCV) [15]. All the patients are subjected to the following:

(1) Full history was taken, and women with a history of trauma or fracture of the wrist, or having rheumatoid arthritis, diabetes, hypothyroidism, or other diseases and conditions predisposing to CTS were excluded.
(2) Clinical examination was performed to exclude those with history, clinical, or electrophysiological data from their upper extremities suggesting other peripheral neuropathy, such as ulnar nerve entrapment neuropathy, mononeuropathy multiplex, polyneuropathy, or cervical radiculopathy.
(3) Laboratory study was conducted to exclude diabetes mellitus, rheumatoid arthritis, and connective tissue disease.
(4) Plain radiograph of the cervical spine was taken to exclude cervical spondylosis.
(5) Electrophysiological study was performed using Neuropack 2 electromyography apparatus from Nihon Kohden (Japan). Temperature of the room was adjusted for standardized results. Nerve conduction studies were performed for all the studied patients according to the AAEM criteria [17]. In the patient group, the symptomatic side or the more severely affected side was studied. In the healthy controls, measurements were performed on the dominant hand. In both patients and controls, motor and sensory conduction studies of the median nerve were performed. Criteria for the diagnosis of CTS were prolonged DL and slowing of SNCV as mentioned before [15].
(6) Anthropometric measurements were performed in both groups with a metallic caliper. Measurements were repeated three times and the average of the three measurements was taken. The following measurements were obtained with the hand on the palm side and fingers fully extended on a flat hard surface. Wrist dimensions were taken including wrist depth (palmodorsal dimension) and wrist width (mediolateral dimension) at the level of the distal flexor crease. Wrist ratio (WR) was calculated by dividing the depth by the width [18]. Palm length (distance of the volar surface between the distal flexor crease of the wrist to the proximal crease of the third digit); third digit length (distance of the proximal flexor crease of the third digit to the tip of the same digit); hand length (distance from the distal flexor crease of the wrist on the volar surface to the distal end of the third digit); and palm width (maximal distance of the palm at the level of the heads of the index and fifth finger metacarpal) were taken. Hand ratio (HR) was calculated by dividing the hand length by the palm width [15]. A higher WR indicated a more squared wrist and lower HR indicated shorter hand.

Care was also taken so that occupational and household activities were not different between the two groups.

Ethical considerations

The nature of the present study was explained to all patients. Verbal and written consents were obtained from all patients and controls. Research protocol was approved by the Ethical Committee of Faculty of Medicine, Alexandria University.

Statistical analysis

Statistical analyses were performed using SPSS statistics (version 20; SPSS Inc., Chicago, Illinois, USA). Latencies and conduction velocities of the unobtainable responses were considered as missing values (were excluded from the number of cases), whereas amplitudes of the unobtainable responses were considered zero. The statistical significance level was set as P value of less than 0.05. Descriptive statistics, including mean, SD, and median, were calculated for each nerve conduction parameter. Comparisons between patients and controls were computed using Student's t-test or Mann–Whitney U-test (depending on the normality of the distribution of the variables). The correlation between electrophysiologic parameters of median nerve and the wrist and hand anthropometric characteristics of both patients and control groups was examined by Pearson's correlation (r=–1 to 1).

Results

This case–control study included 50 clinically and electrophysiologically proven CTS female patients [mean (SD) age: 50.1 (9.28) years, range: 33–74 years], as well as 50 healthy controls [mean (SD) age: 47.8 (8.789) years, range: 32–74 years]. There was no statistically significant difference between patients and the control group regarding age (t=1.029, P=0.307). Comparisons of median nerve parameters between CTS patients and healthy controls showed that patients had significantly prolonged DL (P=0.000), lower compound muscle action potential (CMAP) amplitude (P=0.000), prolonged peak latency (PL) (P=0.000), lower sensory nerve action potential (SNAP) amplitude (P=0.000), and slower SNCV (P=0.000) compared with the control group (Table 1).

With regard to anthropometric wrist and hand measurements, patients had significantly higher wrist depth (P=0.000), higher WR (P=0.000), shorter palm length (P=0.002), shorter hand length (P=0.001), and lower HR (P=0.000) (Table 2).

Table 3 showed correlation of wrist and hand measurements with median nerve electrophysiologic parameters of both patients and control groups. Wrist depth was positively correlated with median motor DL (r=0.504, P=0.000) and sensory PL (r=0.651, P=0.000), and negatively correlated with CMAP amplitude (r=–0.414, P=0.000), SNAP amplitude (r=–0.422, P=0.000), and SNCV (r=–0.642, P=0.000). Similarly, WR was positively correlated with median motor DL (r=0.558, P=0.000) and sensory PL (r=0.651, P=0.000), and negatively correlated with CMAP amplitude (r=–0.389, P=0.000), SNAP amplitude (r=–0.402, P=0.000), and SNCV (r=–0.698, P=0.000) (Fig. 1).

Table 1 Comparisons of median nerve electrophysiological parameters between carpal tunnel syndrome patients and healthy controls

Variables	Patients (n=50)	Controls (n=50)	Test statistics	P value
Median motor DL (ms)				
Mean (SD)	5.62 (2.13)	3.62 (0.39)	0.389 (t-test)	0.000*
Median	5.00	3.600		
Median CMAP amplitude (mV)				
Mean (SD)	8.92 (5.93)	14.80 (3.96)	4.478 (t-test)	0.000*
Median	10.05	13.30		
Median FMCV (m/s)				
Mean (SD)	51.70 (5.02)	52.78 (4.58)	0.868 (t-test)	0.389
Median	51.600	54.30		
Median PL (ms)				
Mean (SD)	4.68 (0.55)	3.55 (0.40)	36 (Mann–Whitney U-test)	0.000*
Median	4.500	3.50		
Median SNAP amplitude (μV)				
Mean (SD)	13.14 (15.38)	29.36 (21.6)	972 (Mann–Whitney U-test)	0.000*
Median	10.00	24.25		
Median SNCV (m/s)				
Mean (SD)	35.75 (6.19)	54.60 (4.88)	825 (Mann–Whitney U-test)	0.000*
Median	38.00	53.80		

CMAP, compound muscle action potential; DL, distal latency; FMCV, forearm median motor conduction; PL, peak latency; SNAP, sensory nerve action potential; SNCV, sensory nerve conduction velocity. *$P \leq 0.05$, significant.

Table 2 Comparisons of anthropometric wrist and hand measurements between carpal tunnel syndrome patients and healthy controls

Variables	Patients (*n*=50)	Controls (*n*=50)	*t*-Test (*P* value)	Cutoff values
Wrist width (cm)				
Mean (SD)	5.92 (0.55)	6.12 (0.44)	1.587 (0.117)	5.24
Median	6.00	6.50		
Wrist depth (cm)				
Mean (SD)	3.24 (0.38)	2.44 (0.36)	8.703 (0.000)*	3.16
Median	3.00	2.50		
Wrist ratio				
Mean (SD)	0.55 (0.06)	0.40 (0.04)	11.726 (0.000)*	0.48
Median	0.54	0.38		
Palm length (cm)				
Mean (SD)	9.91 (0.60)	10.36 (0.49)	3.265 (0.002)*	9.38
Median	10.00	10.00		
Palm width (cm)				
Mean (SD)	8.030 (0.79)	7.74 (0.39)	1.741 (0.086)	8.52
Median	8.00	7.50		
Third digit length (cm)				
Mean (SD)	8.330 (0.64)	8.60 (0.50)	1.836 (0.07)	7.68
Median	8.25	9.00		
Hand length (cm)				
Mean (SD)	18.24 (0.88)	18.96 (0.89)	3.324 (0.001)*	17.18
Median	18.50	19.00		
Hand ratio				
Mean (SD)	2.28 (0.16)	2.45 (0.08)	4.686 (0.000)*	2.29
Median	2.3100	2.40		

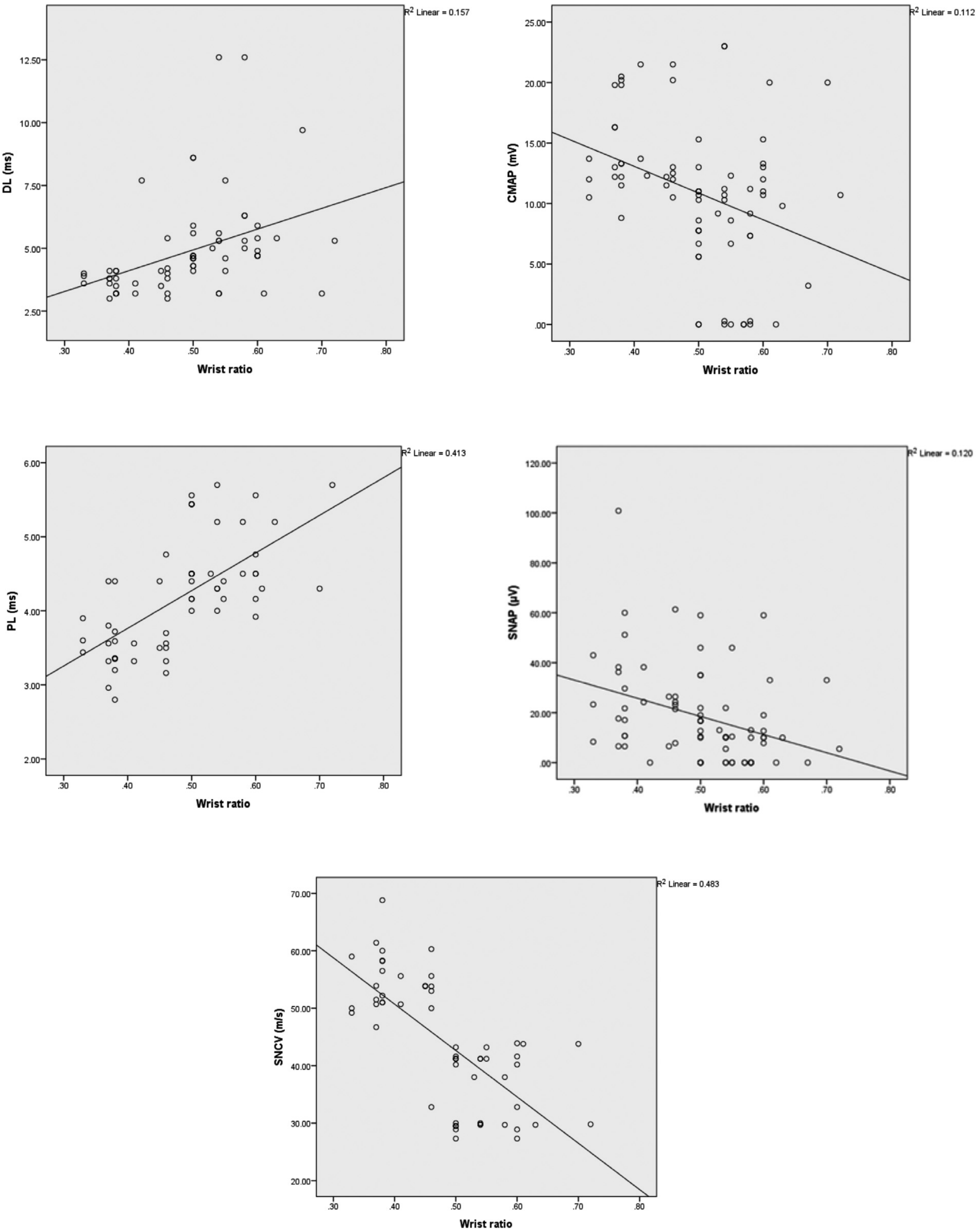
*$P\leq0.05$, significant.

Table 3 Correlation between wrist and hand measurements, and median nerve electrophysiologic parameters

Variables	DL (ms) (*n*=92)	CMAP (mV) (*n*=100)	FMCV (m/s) (*n*=92)	PL (ms) (*n*=83)	SNAP (μV) (*n*=100)	SNCV (m/s) (*n*=83)
Wrist width (cm)						
r	–0.199	0.025	–0.081	–0.250	–0.006	0.243
P	0.106	0.834	0.521	0.058	0.957	0.066
Wrist depth (cm)						
r	0.504	–0.414	–0.134	0.651	–0.422	–0.642
P	0.000*	0.000*	0.286	0.000*	0.000*	0.000*
Wrist ratio						
r	0.558	–0.389	–0.072	0.651	–0.402	–0.698
P	0.000*	0.001*	0.566	0.000*	0.000*	0.000*
Palm length (cm)						
r	–0.057	0.158	–0.120	–0.045	0.129	0.071
P	0.646	0.175	0.341	0.737	0.269	0.597
Palm width (cm)						
r	0.129	–0.234	–0.097	0.171	–0.189	–0.205
P	0.299	0.043*	0.443	0.199	0.104	0.123
Hand length (cm)						
r	–0.145	0.162	0.064	–0.051	0.115	0.093
P	0.242	0.166	0.614	0.706	0.328	0.487
Hand ratio						
r	–0.315	0.372	0.177	–0.332	0.239	0.431
P	0.010*	0.001*	0.159	0.011*	0.039*	0.001*
Third digit length (cm)						
r	–0.195	0.113	0.139	–0.059	0.079	0.068
P	0.114	0.333	0.269	0.659	0.501	0.612

CMAP, compound muscle action potential; DL, distal latency; FMCV, forearm median motor conduction; PL, peak latency; SNAP, sensory nerve action potential; SNCV, sensory nerve conduction velocity; *r*, Pearson's correlation coefficient. *$P\leq0.05$, significant.

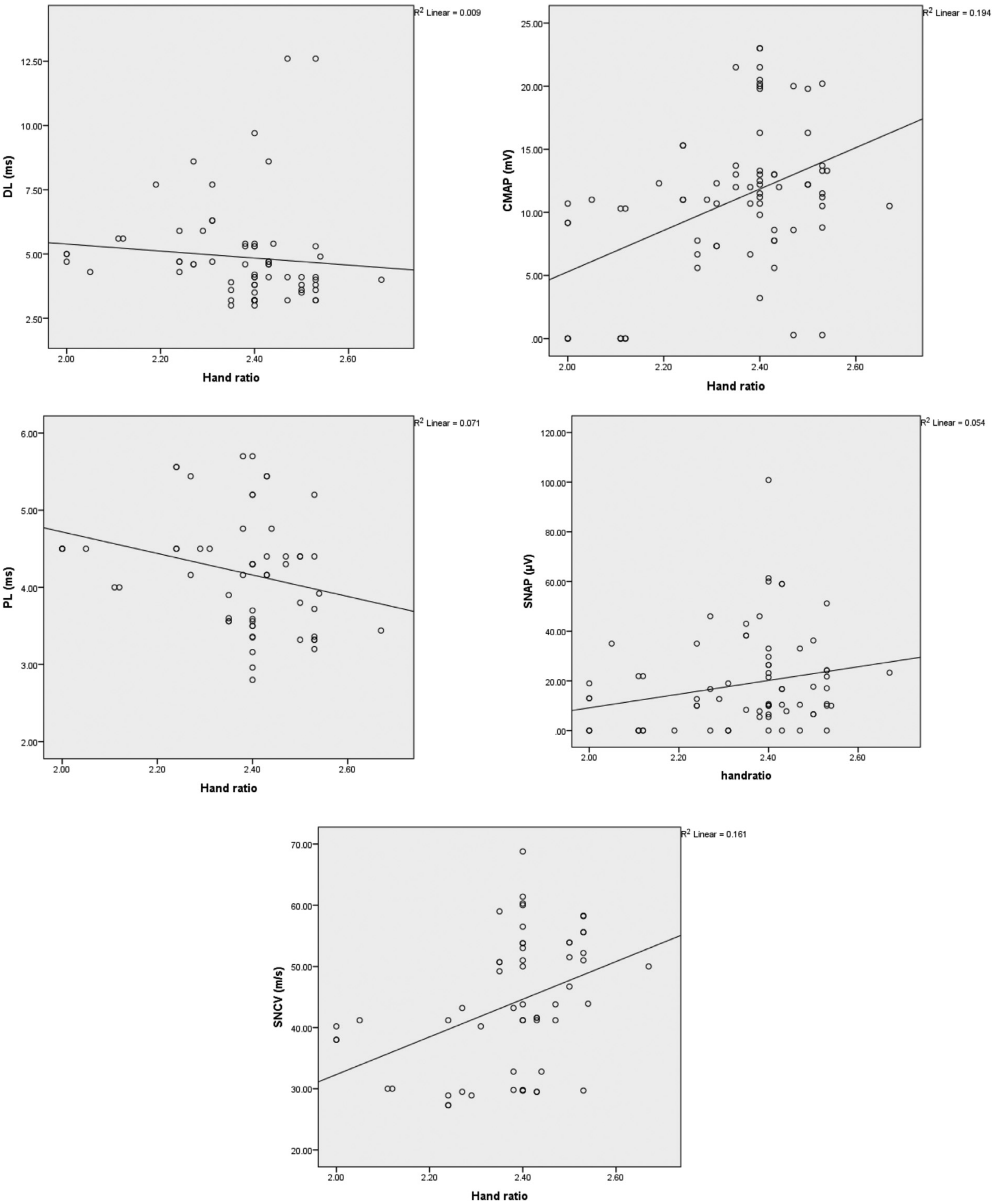
Figure 1



Correlation analysis of wrist ratio with median nerve electrophysiological parameters. CMAP, compound muscle action potential; DL, distal latency; PL, peak latency; SNAP, sensory nerve action potential; SNCV, sensory nerve conduction velocity.

With regard to HR, there was a statistically significant negative correlation between HR and both median DL (*r*=−0.315, *P*=0.01) and PL (*r*=−0.332, *P*=0.01) (Fig. 2). In addition, there was a positive correlation between HR and median CMAP amplitude (*r*=0.372, *P*=0.001), SNAP amplitude (*r*=0.2391, *P*=0.039), and SNCV (*r*=0.431, *P*=0.001). Palm width was negatively correlated with CMAP amplitude (*r*=−0.234, *P*=0.043). Otherwise, there was no statistically significant correlation between other wrist and hand measurements, and median nerve conduction study parameters.

Figure 2



Correlation analysis of hand ratio with median nerve electrophysiological parameters. CMAP, compound muscle action potential; DL, distal latency; PL, peak latency; SNAP, sensory nerve action potential; SNCV, sensory nerve conduction velocity.

Discussion

Several studies attempted to find an explanation for ICTS. Some authors suggested that BMI and stature are risk factors [15,19]. Others reported that the cross-sectional area of the carpal tunnel [20] and even wrist dimensions are important factors in the development of ICTS [21]. It is also well known that nerve conduction parameters are affected by age, weight, and height [22,23]. This study aimed at assessing the relation of hand and wrist anthropometric measurements to median nerve conduction study parameters in ICTS. It was observed that many individuals with CTS have square wrists [18,24]. This observation led to correlating wrist dimensions with median sensory latencies. To our knowledge, few studies attempted to assess the comprehensive relation of hand and wrist dimensions to ICTS electrophysiologic parameters [25,26].

The current study showed statistically significant differences between patients and control regarding many of the wrist and hand measurements. Patients had more square-shaped wrist and shorter hand configuration. In addition, some of the wrist and hand anthropometric measurements showed clear association with median nerve conduction study parameters across the carpal tunnel. Wrist depth and WR were directly correlated with median motor and sensory onset latencies, and inversely correlated with median motor and sensory response amplitudes, and sensory conduction velocity. In addition, HR was inversely correlated to median motor and sensory latencies, and directly correlated to median motor and sensory amplitudes and sensory conduction velocity. These findings suggest that square-shaped wrists and short-hand anatomy are associated with slower conduction of impulses along median nerve sensory and motor fibers through the carpal tunnel. This indicates that certain hand and wrist configurations predispose to the development of CTS, and that these anatomical hand measurements could, to a certain degree, predict median nerve conduction across the carpal tunnel [26]. In agreement with the current study, Johnson *et al.* [27] was the first to study WR in relation to CTS and demonstrated that patients with a more square-shaped wrist could have a greater tendency to develop CTS. These results were supported by many investigators [28,29]. In addition, Chiotis *et al.* [26] found that the wider and shorter hand shape and square-shaped wrist are associated with slower impulse traveled along the sensory and motor fibers of the median nerve through the carpal tunnel. Similarly, Radecki [30] studied 1472 CTS patients referred with upper-extremity symptoms. An increased WR was associated with prolongation of median latencies regardless of work-related complaints. Many other investigators reported similar results [31–34]. However, other studies did not support these results [35–37]. Sposato *et al.* [35] studying railroad maintenance workers found no significant linear relationship between both nerve latency and WR, suggesting that median motor and sensory nerve conduction latency values do not increase as wrist–squareness ratios increase. On the other hand, Mondelli *et al.* [24] confirmed the associations between several hand anthropometric characteristics and the risk of CTS, but reported that they had limited accuracy for discriminating patients with CTS from controls, especially among women.

In the present study, patients had statistically significant low HR and significantly high WR compared with the control group. These findings were in agreement with the results of previous studies [15,17,29,31]. This indicates that anatomic differences appeared to be an important factor in the occurrence of CTS in individuals under the same occupational settings and stresses. This could be because of narrow carpal tunnel anatomy, and consequently more predisposition to CTS, in individuals having squared wrist and short hand [26]. The pathophysiology of CTS involves compression-induced nerve ischemia and/or mechanic-induced nerve deformation resulting in focal demyelination [38]. This indicates that certain tunnel shape leads to limited free space around the nerve during wrist movements, thus making the nerve more prone to trauma under any mechanical pressure or overuse exerted on it. Squarer wrists may reflect squarer carpal tunnel dimensions. This may in turn cause more median nerve compression during flexion and extension movements of the digits and wrist [39]. Another explanation is that any activity involving forced, prolonged, and repetitive flexion of the fingers may result in compression of the median nerve by the lumbrical muscles [24,40]. In a short and wide hand during flexion, the lumbrical muscles of the fingers may occupy part of the carpal tunnel, compressing the median nerve within or just outside the carpal canal more than in a long hand [24,40]. Specific wrist shapes may increase the potential for developing CTS, because these hands exert a much higher force for a given motion of the hand, which increases intracarpal fluid pressure [41–43]. This is especially true for repetitive hand movements. It is thus recommended to regularly relax hands and wrists at work to reduce the tension of the flexor muscles tendons, thus preventing excessive pressure in the carpal tunnel. It would be advisable to preventatively determine wrist and hand anthropometric measurements in professions requiring repetitive hand movements, so that in persons with squared wrists and hands appropriate workplace setup measures could be taken to prevent or at least delay CTS development [1].

It can be concluded that anthropometric characteristics of the wrist and hand may be important in the development of ICTS by providing the preconditions for median nerve compression. These measurements could be used in certain occupations to screen for those individuals who have increased liability to develop CTS.

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Conflicts of interest
There are no conflicts of interest.

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