Body, wrist, and hand anthropometric measurements as risk factors for carpal tunnel syndrome

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Aim
The aim of this study was to identify cut-off values for body, hand, and wrist measurements in order to correctly identify individuals with increased risk of carpal tunnel syndrome (CTS).
Patients and methods
This study included 30 patients with clinically diagnosed and electrophysiologically confirmed idiopathic CTS and 30 age-matched and sex-matched healthy volunteers as the control group. Both groups performed sensory and motor conduction studies of the median nerve. Body, hand, and wrist anthropometric measurements were taken including weight, height, waist circumference, hip circumferences, wrist depth/width, third digit length, palm length/width, and hand length. Obesity indicators and hand/wrist ratios were calculated. Area under the ROC curve (AUC), confidence intervals, cut-off values, sensitivity, and specificity were calculated separately for each measured parameter.
Results
There were statistically significant differences among the studied participants regarding all measured anthropometric parameters ($P<0.001$). As a result, all studied patients had squarer wrists and shorter hands than healthy participants. The AUC values for all studied measurements showed high accuracy (AUC<95) except for hip circumference, waist-to-hip ratio, palm length, third digit length, and digit index which showed moderate accuracy. In the studied patients there were positive significant correlations between BMI, wrist depth, wrist ratio, and shape index with an electrophysiological severity grading of CTS of the studied patients; on the other hand, there were negative significant correlations between palm length, hand length, and hand ratio with electrophysiological severity grading of CTS.
Conclusion
The cut-off values for body, wrist, and hand anthropometric measurements are useful tools to assess the risk factors for CTS.

Keywords:
anthropometric measurements, carpal tunnel syndrome, risk factors

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Introduction

Carpal tunnel syndrome (CTS) is the most common upper limb compression neuropathy [1,2]. It accounts for nearly 90% of all entrapment neuropathies [3]. Women are almost three times more likely to develop CTS than men [4,5].

Its occurrence is due to localized compression of the median nerve under transverse carpal ligament at the wrist that can be explained by several interacting pathophysiologic mechanisms which include: increased carpal tunnel pressure, median nerve microcirculation injury, median nerve connective tissue alteration as well as synovial tissue inflammation and hypertrophy [1,6]. CTS may be primary (idiopathic) that is considered to be the most frequently occurring form or secondary due to either external factors (obesity, pregnancy, hypothyroidism) or internal factors (tumor compressing median nerve in the carpal tunnel) [7–9].

CTS is a clinical syndrome which means that its diagnosis is eminently clinical, but it should be confirmed by means of neurophysiological methods, which are sensitive measures of detecting compression of the median nerve by routine methods or even by sensitive techniques that can detect very mild CTS [1,10–12].

Mechanical irritation caused by repetitive wrist movements in an occupational setting has been implicated as a risk factor, but it does not explain why under the same conditions CTS occurs in some and not in other individuals. In several studies, hand and wrist dimensions and other anthropometric characteristics such as body weight, height, and BMI have been assessed in order to define the tendency of a particular individual to develop CTS under given conditions, or even without any predisposing factors [7,13–17].

Hence, this study aimed to determine the optimal cut-off values for body, wrist, and hand anthropometric measurements to identify participants at an increased risk of CTS and to study the association between these measurements and severity of CTS.

Patients and methods

The study was carried out on 30 patients diagnosed clinically as having idiopathic CTS according to the criteria proposed by the American Association of Electrodiagnostic Medicine (AAEM) [18] and the diagnosis was confirmed electrophysiologically [19]. Another 30 participants with no symptoms or signs of CTS, with matched age, sex, and occupation to the patients group were selected to constitute the control group. An informed written consent was taken from all the participants and the study was approved by the local ethics committee.

Patients were excluded if they had previous hand/wrist surgery or trauma, subclinical or clinical polyneuropathy, or intake of any medications considered toxic to the peripheral nerves such as anticonvulsants, some blood pressure drugs as amiodarone, etc. [20].

Methods

The following was done for all the participants.

Electrophysiological studies

Sensory and motor conduction studies of median and ulnar nerves were done to confirm the presence of CTS in the enrolled patients, and to exclude CTS in the controls as well as to exclude associated peripheral neuropathy. Sensitive comparative techniques were resorted to when median sensory and motor studies were normal. Electrophysiological grading of the severity of CTS was performed according to the Bland scale [21]. Electrophysiological studies were done using Nihon Kohden MEB-7102K apparatus (Tokyo, Japan). All studies were done at a room temperature of 32°C on warm hands.

Anthropometric measurements

Weight and height were measured and BMI was calculated (weight/height^2) [22]. Waist circumference (WC) was measured in centimeters at a level parallel to the floor at midpoint between the top of the iliac crest and the lower margin of the last palpable rib in the midaxillary line [22,23]. Patients with WC greater than 94 cm in men and greater than 80 cm in women were considered to have central obesity according to the WHO [23]. Hip circumference (HC) was measured in centimeters at a level parallel to the floor at the largest circumference of the buttocks [23]. External hand and wrist dimensions were measured from the palmar side of the hand using a sliding caliper calculating palm length (measured as the distance of the volar surface between the distal flexor crease of the wrist to the proximal crease of the third digit), third digit length (measured as the distance of the proximal flexor crease of the third digit to the tip of the same digit), palm width (measured as the maximum distance of the volar surface between the second and fifth metacarpal heads), wrist depth (measured as the anteroposterior depth at the level of the distal flexor wrist crease), wrist width (measured as the maximum transverse distance between the borders at the level of the distal flexor wrist crease), hand length (measured as the distance of the volar surface between the distal flexor crease of the wrist to the tip of the third finger).

From the previously measured data, the following ratios and indices were calculated.

Wrist ratio

Wrist ratio: wrist depth/wrist width [7,15,23–26]. Hand ratio: hand length/palm width [13,27]. Shape index: (palm width×100)/hand length [14]. Digit index: (third digit length×100)/hand length [14]. Wrist-to-palm ratio: wrist depth/palm length [16,27]. Waist-to-hip ratio (WHR) was calculated as WC divided by HC, considering a high WHR (WHR >0.95 in men and >0.85 in women) as a mirror of abdominal fat accumulation [22,23].

Results

This study included 30 clinically and electrophysiologically proven CTS patients. Their mean (SD) age was 45.27 (6.02) years, ranging between 37 and 60 years. Ninety percent of the patients were housewives. The study also included 30 healthy controls, their mean (SD) age was 43.40 (5.75) years, ranging between 34 and 56 years; 83.3% of them were housewives. There was no statistically significant difference between both groups as regards age, sex, and occupation (P>0.05).

According to the electrophysiological data obtained from the studied patients, 54% were classified as having grade III, 23% grade II, 15% grade V, and 10% as grade I.

Anthropometric measurements of all studied participants are demonstrated in Table 1. The mean values of weight, BMI, WC, HC, WHR, wrist depth, wrist ratio, palm width, shape index, digit index, and wrist-to-palm ratio were significantly larger in patients than in controls. On the other hand, the mean values of wrist width, palm length, third digit length, hand length, and hand ratio were significantly smaller in patients than in controls. Only the mean height of the studied patients did not differ significantly from that of the controls.

Values for the anthropometric measurements were used to construct ROC curves that were used to examine the accuracy of each measurement to discriminate participants with CTS from those without CTS. The optimal cut-off values for each measurement was chosen based on maximization of the sensitivity and specificity product as shown in Table 2. The highest area under the ROC curve (AUC) value of 1.000 which represents the highest accuracy was calculated for wrist ratio and its cut-off value was measured to be greater than 0.59 with 100% sensitivity and 100% specificity. This means that when wrist ratio is greater than 0.59, there is an increased risk of having CTS.

The correlation between body, wrist, and hand measurements with electrophysiological severity grading of CTS among the studied patients are displayed in Table 3. There were significant positive correlations between BMI, wrist depth, wrist ratio, and shape index with electrophysiological severity grading of CTS of the studied patients. Meanwhile, there were significant negative correlations between palm length, hand length, and hand ratio with electrophysiological severity grading of CTS of the studied patients. There was no statistically significant correlation between other body, wrist, and hand measurements with electrophysiological severity grading of CTS of the studied patients.

Discussion

CTS is the most common entrapment neuropathy in the upper limbs, with the majority of cases being idiopathic. Some studies implicated some body, wrist, and hand anthropometric measurements in the development of CTS.

This work was carried out to identify cut-off values for body, wrist, and hand measurements in order to correctly identify individuals with an increased risk of CTS.

Optimal assessment of body, wrist, and hand anthropometric measurements among our studied participants were performed and by using ROC curves the cut-off values for these measured parameters were detected in order to correctly identify individuals with an increased risk of CTS.

Cut-off values of all the measured parameters in our study showed moderate and high level of accuracy. Wrist ratio with a cut-off value greater than 0.46 was the only value that showed the highest level of accuracy (AUC=1.000). Mondelli *et al.* [28] reported a low level of accuracy for all calculated cut-off values (AUC≤0.64) except for the hand ratio, shape index, and wrist-to-palm ratio in the men's group which showed a moderate level of accuracy (AUC=0.75). This difference may be attributed to the difference in genetic and racial factors between both studies' patients as well as to the small number of our studied participants (60 participants) in comparison to the other study which comprised 1117 participants.

The current study showed statistically significant differences between patient and control groups regarding all measured anthropometric parameters except height. Regarding body anthropometric measurements, our studied patients had significantly higher weight, BMI, WC, HC, and WHR than the control group. It was found that the higher the value of BMI, the more severe the electrophysiological grading of CTS. These findings were in agreement with the results of many previous studies [12,14,24,27–30].

The relation between BMI and CTS is unclear. The deposition of adipose tissue within the carpal tunnel might increase the hydrostatic intracarpal pressure and impair the blood circulation of the median nerve leading to median nerve ischemia, local demyelination, and finally axonal loss [31,32]. Moreover, the high carpal tunnel pressure may lead to fibrosis and thickening of the subsynovial connective tissue in the canal [31,33]. On the other hand, Werner *et al.* [34] found that obesity did not influence carpal canal pressure but is supposed to be a localized metabolic mechanism causing endoneural edema and intra-fascicular swelling of the median nerve, which results in the delay of sensory conduction velocity of the median nerve in obese participants.

Regarding wrist measurements, we found that wrist ratio had the highest level of accuracy (AUC=1.000) and the calculated cut-off value (>0.46) can precisely discriminate participants with CTS from those without with 100% sensitivity and 100% specificity. In addition,

Table 1 Comparison between patients and control groups as regards anthropometric measurements

Anthropometric measurements	Patients (*n*=30)	Control (*n*=30)	*t*	*P*
Weight (kg)				
Minimum–Maximum	66.50–86.0	60.0–89.0	3.492	<0.001*
Mean±SD.	76.22±6.15	70.95±5.52		
Median	76.0	70.50		
Height (m)				
Minimum–Maximum	156.0–172.0	1.62–190.0	0.210	0.835
Mean±SD	161.7±4.62	162.85±31.12		
Median	160.0	167.50		
BMI (kg/m^2)				
Minimum–Maximum	26.0–33.0	23.0–27.10	10.852	<0.001*
Mean±SD	28.98±1.76	25.03±0.93		
Median	28.80	24.90		
Waist circumference (cm)				
Minimum–Maximum	87.0–114.0	75.0–89.0	11.172	<0.001*
Mean±SD	97.93±7.03	81.22±4.21		
Median	97.0	80.0		
Hip circumference (cm)				
Minimum–Maximum	100.5–131.0	96.50–107.0	6.467	<0.001*
Mean±SD	111.2±7.89	101.33±2.81		
Median	109.8	101.25		
Waist-to-hip ratio				
Minimum–Maximum	0.85–0.96	0.75–0.89	8.329	<0.001*
Mean±SD	0.88±0.03	0.80±0.04		
Median	0.87	0.79		
Wrist depth (cm)				
Minimum–Maximum	3.50–4.20	2.70–3.60	15.328*	<0.001*
Mean±SD	3.80±0.18	3.0±0.22		
Median	3.80	3.0		
Wrist width (cm)				
Minimum–Maximum	5.90–6.50	6.50–7.10	13.281*	<0.001*
Mean±SD	6.18± 0.18	6.78±0.17		
Median	6.20	6.80		
Wrist ratio				
Minimum–Maximum	0.58–0.66	0.41–0.50	33.174*	<0.001*
Mean±SD	0.61±0.02	0.61±0.02		
Median	0.61	0.44		
Palm length (cm)				
Minimum–Maximum	9.70–10.60	10.0–11.30	10.498*	<0.001*
Mean±SD	10.07±0.23	10.91±0.37		
Median	10.0	11.0		
Palm width (cm)				
Minimum–Maximum	8.30–9.0	7.80–8.50	11.050*	<0.001*
Mean±SD	8.74±0.20	8.17±0.20		
Median	8.80	8.20		
Third digit length (cm)				
Minimum–Maximum	7.60–8.50	7.80–8.50	4.358*	<0.001*
Mean±SD	7.97±0.19	8.18±0.19		
Median	8.0	8.20		
Hand length (cm)				
Minimum–Maximum	17.60–18.60	18.30–19.80	11.511*	<0.001*
Mean±SD	18.04±0.26	19.09±0.42		
Median	18.05	19.10		
Hand ratio				
Minimum–Maximum	2.0–2.10	2.10–2.40	16.764*	<0.001*
Mean±SD	2.06±0.03	2.32±0.08		
Median	2.05	2.30		

(*Continued*)

Table 1 (*Continued*)

Anthropometric measurements	Patients (*n*=30)	Control (*n*=30)	*t*	*P*
Shape index				
Minimum–Maximum	46.10–49.70	40.80–46.10	19.396*	<0.001*
Mean±SD	48.39±0.83	42.80±1.34		
Median	48.55	42.85		
Digit index				
Minimum–Maximum	42.30–46.0	41.0–45.30	5.345*	<0.001*
Mean±SD	44.12±0.84	42.84±1.01		
Median	44.10	42.80		
Wrist-to-palm ratio				
Minimum–Maximum	0.35–0.40	0.25–0.35	20.827*	<0.001*
Mean±SD	0.38±0.01	0.27±0.02		
Median	0.38	0.27		

t. Student's *t*-test. *$P \leq 0.05$, significant.

Table 2 Area under the receiver operating characteristic curve, the confidence intervals, and cut-off values with their corresponding sensitivity and specificity values for different anthropometric measurements of the studied participants

Body measurements	AUC	*P*	95% CI	Cut-off	Sensitivity	Specificity
Weight (kg)	0.736	0.002*	0.610–0.862	>73	60.0	76.7
Height (cm)	0.793	<0.001*	0.672–0.913	≤162	66.67	86.67
BMI (kg/m^2)	0.990	<0.001*	0.922–1.000	>26.5	100.00	80.0
Waist circumference (cm)	0.994	<0.001*	0.929–1.00	>88.5	96.67	96.67
Hip circumference (cm)	0.920	<0.001*	0.820–0.974	>103	90.00	80.00
Waist–hip ratio	0.907	<0.001*	0.803–0.966	>0.83	100.00	73.33
Wrist depth (cm)	0.988	<0.001*	0.918–1.00	>3.1	100.00	90.00
Wrist width (cm)	0.993	<0.001*	0.928–1.00	≤6.4	90.00	100.00
Wrist ratio	1.000	<0.001*	0.940–1.000	>0.46	100	100
Palm length (cm)	0.947	<0.001*	0.856–0.988	≤10.5	96.7	83.3
Palm width (cm)	0.976	<0.001*	0.898–0.998	>8.4	90.0	90.0
Third digit length (cm)	0.791	<0.001*	0.666–0.885	≤8	73.3	76.7
Hand length (cm)	0.979	<0.001*	0.903–0.999	≤18.6	100.0	83.3
Hand ratio	0.997	<0.001*	0.935–1.00	≤2.1	100.0	96.67
Shape index	0.999	<0.001*	0.939–1.000	>45.9	100.0	96.67
Digit index	0.847	<0.001*	0.730–0.928	>43.1	86.21	80.00
Wrist-to-palm ratio	0.966	<0.001*	0.883–0.996	>0.35	96.67	96.67
Hand ratio	0.997	<0.001*	0.935–1.00	≤2.1	100.0	96.67

AUC, area under the curve; CI, confidence intervals. *$P \leq 0.05$, statistically significant.

we found that wrist ratio had a significant positive correlation with CTS severity grading. These results were supported by many investigators [16,24,33,35] who found that square-shaped wrist is associated with slower impulse traveled along the sensory and motor fibers of the median nerve through the carpal tunnel.

Regarding hand ratio, it was significantly lower in the patients group. The studied patients had shorter and wider hands than healthy participants. Hand ratio was negatively correlated with CTS severity grading. These results are in agreement with many authors [7,13,24,33,35].

Regarding shape and digit indices, they were significantly greater in our studied patients than in the control group. So, a relatively coarse hand and short digits can be considered as a risk factor for CTS. These hands are more sensitive to tasks which require repetitive hand movement, the more square the hand shape and the shorter the digits, the greater the volar extension or flexion for a given motion. Thus, such people may need to exert extra force, which leads to more pressure in the intracarpal area leading to CTS development [35–38].

Regarding wrist-to-palm ratio, it was significantly higher in the patients group than in the control group. This confirms the original proposition of Kouyoumidjian *et al.* [27], and El-Emary [39] that the wrist-to-palm ratio is another risk factor for CTS.

Lastly, we can conclude that the anatomic differences of body, wrist, and hand anthropometric measurements can be considered as risk factors for the development of CTS in individuals under the same occupational

Table 3 Correlation between body, wrist, and hand measurements with electrophysiological severity grading of carpal tunnel syndrome in the studied patients

Different body, wrist, and hand measurements	Grading	
	r_s	P
Weight (kg)	0.226	0.229
Height (m)	–0.037	0.847
BMI (kg/m^2)	0.423*	0.020*
Waist circumference (cm)	0.263	0.160
Hip circumference (cm)	0.138	0.468
Waist-to-hip ratio	0.281	0.132
Wrist depth (cm)	0.389*	0.034*
Wrist width (cm)	0.088	0.642
Wrist ratio	0.421*	0.021*
Palm length (cm)	–0.442*	0.014*
Palm width (cm)	–0.050	0.791
Third digit length (cm)	–0.137	0.469
Hand length (cm)	–0.568*	0.001*
Hand ratio	–0.456*	0.011*
Shape index	0.442*	0.014*
Digit index	0.192	0.309
Wrist-to-palm ratio	–0.115	0.544

r_s, Spearman's coefficient. *$P\leq0.05$, statistically significant.

settings and stresses. On the basis of this, it would be advisable to preventatively determine body, wrist, and hand anthropometric measurements in professions requiring repetitive hand movements, so that in persons with squared wrists, short wide hands, or overweight participants appropriate workplace setup measures could be taken to prevent or at least delay CTS development [35].

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Conflicts of interest
There are no conflicts of interest.

References

1 Mondelli M, Giannini F, Giacchi M. Carpal tunnel syndrome incidence in a general population. Neurology 2002; 58:289–294.

2 Gelfman R, Melton LJ, Yawn BP, Wollan PC, Amadio PC, Stevens JC, *et al.* Long-term trends in carpal tunnel syndrome. Neurology 2009; 72:33–41.

3 Aroori S, Spence RA. Carpal tunnel syndrome. Ulster Med J 2008; 77:6–17.

4 Thatte MR, Mansukhani KA. Compressive neuropathy in the upper limb. Indian J Plast Surg 2011; 44:283–297.

5 Bongers FJ, Schellevis FG, van den Bosch WJ, van der Zee J. Carpal tunnel syndrome in general practice: incidence and the role of occupational and non-occupational factors. Br J Gen Pract 2007; 57:36–39.

6 Aboonq MS. Pathophysiology of carpal tunnel syndrome. Neurosciences 2015; 20:4–9.

7 Kamolz LP, Beck H, Haslik W, Högler R, Rab M, Schrögendorfer KF, *et al.* Carpal tunnel syndrome: a question of hand and wrist configurations? J Hand Surg Br 2004; 29:321–324.

8 MacDermid JC, Doherty T. Clinical and electrodiagnostic testing of carpal tunnel syndrome: a narrative review. J Orthop Sports Phys Ther 2004; 34:565–588.

9 Ibrahim I, Khan W, Goddard N, Smitham P. Carpal tunnel syndrome: a review of the recent literature. Open Orthop J 2012; 6:69–76.

10 Firestein GS, Budd RC, Harris ED, Innes IB, Ruddy S, Sergent JS. Kelleys textbook of rheumatology. In: Ruddy S, editor. Common etiology for hand and wrist pain. 8th ed. Philadelphia: Elsevier Butterworth- Heinemann 2008. 255–281

11 Joseph J, Blundo JR. Regional rheumatic pain syndromes. In: Klippel JH, Stone JH, Crofford LJ, White PH, editors. Primer on the rheumatic diseases. 13th ed. New York: Springer 2008. 69–87

12 Becker J, Gomes I, Stringari F, Seitensus R, Juliana S, Panosso J. An evaluation of gender, obesity, age and diabetes mellitus as risk factors for carpal tunnel syndrome. Clin Neurophysiol 2002; 11: 1429–1434.

13 Chroni E, Paschalis C, Arvaniti C, Zotou K, Nikolakopoulou A, Papapetropoulos T. Carpal tunnel syndrome and hand configuration. Muscle Nerve 2001; 24:1607–1611.

14 Boz C, Ozmenoglu M, Altunayoglu V, Velioglu S, Alioglu Z. Individual risk factors for carpal tunnel syndrome: an evaluation of body mass index, wrist index and hand anthropometric measurements. Clin Neurol Neurosurg 2004; 106:294–299.

15 Farmer JE, Davis TR. Carpal tunnel syndrome: a case-control study evaluating its relationship with body mass index and hand and wrist measurements. J Hand Surg Eur Vol 2008; 33:445–448.

16 Lim PG, Tan S, Ahmad TS. The role of wrist anthropometric measurement in idiopathic carpal tunnel syndrome. J Hand Surg Eur Vol 2008; 33: 645–647.

17 Zyluk A, Dabal L, Szlosser Z. Association of anthropometric factors and predisposition to carpal tunnel syndrome. Chir Narzadow Ruchu Ortop Pol 2011; 76:193–196.

18 American Association of Electrodiagnostic Medicine, American Academy of Neurology, and American Academy of Physical Medicine and Rehabilitation. Practice parameters for electrodiagnostic studies in carpal tunnel syndrome: summary statement. Muscle Nerve 2002; 25: 918–922.

19 Preston D, Shapiro B, editors. Electromyography and neuromuscular disorders: clinical-electrophysiologic correlations. 3rd ed. London: Elsevier 2013.

20 Ole JV, Alex AC, Ahmed HZ, Mostafa I. Drug-induced peripheral neuropathy. Basic Clin Pharmacol Toxicol 2014; 115:185–192.

21 Bland JD. A neurophysiological grading scale for carpal tunnel syndrome. Muscle Nerve 2000; 23:1280–1283.

22 World Health Organization. Obesity preventing and managing the global epidemic: report of a WHO cosultation on obesity. Geneva: World Health Organization 1998.

23 World Health Organization. Waist circumference and waist–hip ratio, report of a WHO expert consultation. 8–11 December 2008.

24 Moghtaderi A, Izadi S, Sharafadinzadeh N. An evaluation of gender, body mass index, wrist circumference and wrist ratio as independent risk factors for carpal tunnel syndrome. Acta Neurol Scand 2005; 112: 375–379.

25 Kouyoumdjian JA, Zanetta DM, Morita MP. Evaluation of age, body mass index, and wrist index as risk factors for carpal tunnel syndrome severity. Muscle Nerve 2002; 25:93–97.

26 Johnson EW, Gatens T, Poindexter D, Bowers D. Wrist dimensions: correlation with median sensory latencies. Arch Phys Med Rehabil 1983; 64:556–557.

27 Kouyoumdjian JA, Morita MP, Rocha PR, Miranda RC, Gouveia GM. Wrist and palm indexes in carpal tunnel syndrome. Arq Neuropsiquiatr 2000; 58: 625–629.

28 Mondelli M, Curti S, Farioli A, Aretini A, Ginanneschi F, Greco G, *et al.* Anthropometric measurements as a screening test for carpal tunnel syndrome: receiver operating characteristic curves and accuracy. Arthritis Care Res 2015; 67:691–700.

29 Komurcu HF, Kilic S, Anlar O. Relationship of age, body mass index, wrist and waist circumferences to carpal tunnel syndrome severity. Neurol Med Chir 2014; 54:395–400.

30 Shiri R. A square-shaped wrist as a predictor of carpal tunnel syndrome: a meta-analysis. Muscle Nerve 2015; 52:709–713.

31 Bland JD. Carpal tunnel syndrome. BMJ 2007; 335:343–346.

32 Shiri R, Pourmemari MH, Falah-Hassani K, Viikari-Juntura E. The effect of excess body mass on the risk of carpal tunnel syndrome: a meta-analysis of 58 studies. Obes Rev 2015; 16:1094–1104.

33 Chiotis K, Dimisianos N, Rigopoulou A, Chrysanthopoulou A, Chroni E. Role of anthropometric characteristics in idiopathic carpal tunnel syndrome. Arch Phys Med Rehabil 2013; 94:737–744.

34 Werner RA, Jacobson JA, Jamadar DA. Influence of body mass index on median nerve function, carpal tunnel pressure, and cross-sectional area of the median nerve. Muscle Nerve 2004; 30:481–485.

35 Gerald E, Claude G. The motor unit and muscle action. In: Kandel ER, Schwartz JH, Jessell TM editors. Principles of neural sciences. New York: McGraw-Hill 2001. 674–693

36 Sharifi-Mollayousefi A, Yazdchi-Marandi M, Ayramlou H, Heidari P, Salavati A, Zarrintan S. Assessment of body mass index and hand anthropometric measurements as independent risk factors for carpal tunnel syndrome. Folia Morphol (Warsz) 2008; 67:36–42.

37 Werner RA, Andary M. Carpal tunnel syndrome: pathophysiology and clinical neurophysiology. Clin Neurophysiol 2002; 113: 1373–1381.

38 El-Badawy MA. Electrophysiological and clinical comparison of local steroid injection by means of proximal versus distal approach in patients with mild and moderate carpal tunnel syndrome. Egypt Rheumatol Rehabil 2015; 42:120–127.

39 El-Emary WS. Relation of anthropometric hand measurements to idiopathic carpal tunnel syndrome. Egypt Rheumatol Rehabil 2017; 44: 69–76.