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Body Mass Index and Anthropometric Characteristics of the Hand as Risk Factors for Carpal Tunnel Syndrome

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A B S T R A C T

Carpal tunnel syndrome (CTS) is the most common peripheral entrapment compressive neuropathy in the upper limbs. It is often correlated with personal factors of individuals, not only with certain medical conditions and jobs. The study aimed at clarifying the association of carpal tunnel syndrome with anthropometric characteristics of the hand and body mass index (BMI) as independent risk factors. A total of 100 subjects participated: 50 patients with electro-diagnostically confirmed CTS and 50 healthy volunteers without CTS symptoms as control group, each group including 37 women and 13 men. Height, weight, BMI, wrist depth and width, wrist index, hand shape index, digit index, palm length, palm width, third finger length and ratio of hand length to body height were assessed in all participants. To determine independent risk factors for CTS, multiple logistic regression was used. Wrist index and wrist width were significantly higher in CTS patients than in the control group. The estimated optimal threshold of wrist index for prediction of CTS was 0.69, above which the odds for CTS were estimated to increase 42-fold. Elevated BMI correlated with bilateral CTS in both genders. The study identified wrist index, BMI and ratio of hand length to body height ratio as independent risk factors for CTS.

***Key words**: carpal tunnel syndrome, risk factors, anthropometric measurements, body mass index, hand, adults, gender differences*

Introduction

Carpal tunnel syndrome (CTS) is the most common peripheral entrapment compressive neuropathy in the upper limbs, affecting yearly about 2.7% of the adult population and being about three times more common in women than in men[1]. It involves entrapment of median nerve under transverse carpal ligament, attributable to various causes and factors[2]. Carpal tunnel is an osteofibrotic tunnel surrounded by carpal bones and the strong transverse carpal ligament. Nine tendons run through the tunnel, as well as the median nerve, which is closest to the surface, and the associated blood vessels. CTS occurs when the ligaments running through the carpal tunnel get inflamed due to relatively small yet lasting or repeated pressure or vibration, which causes swelling of tendon sheaths resulting in elevated pressure in the carpal tunnel and hence entrapment of the median nerve against the transverse carpal ligament[3].

CTS can be triggered by disease (diabetes mellitus, rheumatoid arthritis, amyloidosis), infections, hormonal changes, injuries and fractures of the forearm and wrist, oedema, obesity, work-related factors and psychosocial factors[2–5].

Previous studies[4–9] identified age, gender, body mass index (BMI) and anthropometric characteristics of the hand as major risk factors for CTS. Confirmed CTS occurs in 3.9–12% of persons under the age of 30 years and 12.5–22.7% of persons aged between 30 and 40 years[4]. Between the age of 30 and 70 years, an estimated 15–30% of neurons die, which corresponds to an estimated yearly

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increase in CTS risk of 3%[8,10]. Several studies confirmed persons with high BMI to be a group at high risk for developing CTS[4,6,8,9,11]. It was estimated that obese persons (BMI>29) are 2.5-times more likely to develop CTS than slender persons (BMI<20)[2]. Increase in BMI by 1 kg m^{-2} (corresponding to weight gain of about 3 kg in a person of average height) was estimated to increase the odds for CTS by 8%[12]. Obesity can cause fat deposits in the carpal tunnel and increased density of the synovial fluid, thus leading to increased hydrostatic pressure[9,10]. High BMI is also associated with decreased sensory conductivity of the median nerve[1,4]. A study involving 162 women with high BMI found 43% of them to have conductivity degraded by 20–40% as compared to women with low BMI[6]. Regarding work-related factors, a review of a large number of studies found no association between CTS and profession[4].

Johnson et al. (13) were the first to associate wrist dimensions with CTS. A summary measure is the wrist index, which is calculated from external wrist dimensions at the level of distal flexor crease as the ratio of the medio-lateral diameter (i.e., anterior-posterior depth) to the dorso-volar diameter (i.e., wrist width)[7]. Based on the wrist ratio, Kamolz et al.[7] classified wrist shape either as rectangular (with a wrist index value of 0.65) or square (with a wrist index value above 0.70). Wrist index was found to influence conductivity rate of the median nerve through the carpal tunnel, whereby the value of 0.7 was indicated as the critical shape of the wrist at which sensory latency tend to reach the upper limits of normal (i.e., 3.7 ms)[11,14].

Square wrist shape has also been associated with thicker transverse carpal ligament, narrower carpal tunnel and less space for the tendons, blood vessels and median nerve, thus making the person more prone to CTS[4,14]. Square wrist shape also allows larger flexion and extension of the wrist, which the persons can utilise in working with hands thereby increasing the risk for median nerve entrapment and hence the development of CTS[7]. It has been reported that persons with CTS mainly tend to have a narrower wrist than a deeper one as the cause of the higher wrist index[7]. Persons with CTS have also been found to have shorter fingers[6]. In general, women have a higher wrist index than men, whereby both women and men with CTS have a higher wrist index than persons without CTS[14,15].

Opinions vary regarding the causal link between wrist shape and CTS. Most authors believe that wrist index is not linked to impaired conductivity of the median nerve due to job type or profession, but frequent hand use can trigger CTS signs. Several studies report on the association between wrist index and the possibility to develop CTS[6–8,13,14], but neither are all persons with a wrist index below the 0.7 threshold safe from CTS nor do all persons with wrist index above 0.70 necessarily develop CTS[15].

Other anthropometric characteristics can also be a risk factor for CTS[16,17]. The relevant measures seem to be hand length (distance from the distal flexor crease of the wrist to the distal end of the extended middle finger), third finger length (from its base to the tip), palm length (hand length minus third finger length) and palm width (maximal distance between the heads of the second and fifth metacarpal bone). There is less research on the role of anthropometric characteristics of the hand on CTS development compared to wrist shape.

It has been found that increased severity of clinical symptoms of the CTS is associated with higher wrist index and advanced age, but not BMI. Though higher BMI has regularly been found in persons with CTS as compared to persons without CTS, BMI was not found to be associated with severity of the syndrome among the persons with CTS[8,11].

Hence, the main aim of the study was to establish whether anthropometric characteristics of the hand and body mass index can be considered as independent and substantial risk factors for carpal tunnel syndrome. We also wanted to reassess the role of wrist shape in CTS development and its severity, as well as to explore the possible link of severity of the symptoms with hand dominance.

Materials and Methods

Subjects

The study involved 100 adult subjects, 50 with CTS and 50 healthy controls. The subjects performed various occupations, but the groups were balanced regarding gender (there were 37 women and 13 men in each group) and age, as described below. In all the participants, hand dominance was determined from their answer to the question with which hand do they perform the majority of daily activities. All the participants gave written informed consent to the study.

In all the subjects with CTS, the diagnosis was confirmed clinically as well as electrophysiologically thorough EMG. Subjects meeting any of the following exclusion criteria were excluded from the study: diabetes mellitus, rheumatoid arthritis, thyroid disease, neuropathy, infections, thoracic outlet syndrome, neck pain or paraesthesia (tingling) in upper limbs, pregnancy, past injury or surgery of the wrist or the neck.

The control group consisted of subjects who had no signs or symptoms of CTS, nor had they had any wrist injury or surgery in the past. They were selected through a combination of convenience and random sampling in order to perfectly match the CTS group regarding gender and match it as closely as possible regarding age (in total as well as within both genders). In addition, the proportion of broad occupation type (office *vs.* manual) was nearly matched between the groups (about 50% of each in both groups).

Procedure

For measuring anthropometric characteristics of the hand and the wrist, a standard engineering calliper was used (Vernier Calliper, China). Measurements of wrist shape, medio-lateral and dorso-volar diameter were performed as described by Johnson et al.[13]. Measurements of the hand were performed as described by Kouyoumdjian et al.[11] and Chroni et al.[16].

All the measurements of anthropometric characteristics of the hand were performed three times and the mean was used for further analysis. After the measurements of the wrist and the hand, body mass and body height were measured. Based on the obtained measurements, the following quantities were calculated:

- Hand length (mm) = palm length (mm) + third finger length (mm);
- Wrist index = medio-lateral diameter (mm) / dorso-volar diameter (mm);
- Hand shape index = 100 × palm width (mm) / hand length (mm);
- Digit index = 100 × third finger length (mm) / hand length (mm);
- Ratio of hand length to body height = hand length (cm) / body height (m);
- Body mass index (kg m^{-2}) = body mass (kg) / body height^2 (m^2)

Statistics

Statistical analyses were performed using SPSS for Windows 15.0 software (SPSS Inc., Chicago, IL, USA). For comparing numerical variables between the two groups, independent samples t test was used. For assessing association between numerical variables, Pearson correlation (r) was used, while association between binary variables was tested using Fisher's exact test. Optimal threshold for separating the groups based on wrist index was determined using ROC analysis. For predicting CTS based on selected variables, multiple logistic regression was used. In all statistical analyses, two-sided p-values of 0.05 or less were considered significant.

Results

The comparison of age and basic anthropometric characteristics between the two groups is summarised in Table 1. In the total sample as well as among women, the groups differed statistically significantly regarding body mass, BMI, wrist index (on both sides) and hand shape index (also on both sides), while in men a statistically significant difference was observed only regarding wrist index (and marginally regarding hand shape index).

For the purpose of the multivariable prognostic model of CTS, mean value of the right and left side was calculated for wrist index, hand shape index, digit index and ratio of hand length to body height. The selected variables were then screened for collinearity (Table 2), whereby the absence of very high correlations made it feasible to include all these variables in the model.

Since the difference between the groups was most pronounced regarding wrist index, we conducted further analyses of this variable. First, the difference between the groups was visualised using boxplots (Fig. 1). Then

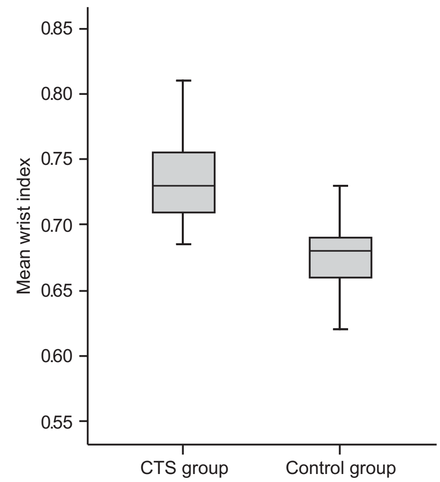

Fig. 1. Difference between groups in mean wrist index (boxplots: thick line denotes median, box denotes inter-quartile range, whiskers denote non-outlier range).

we sought a threshold value that would separate the groups as well as possible using ROC analysis. The area under the ROC was 0.92 ($p<0.001$ for testing the null hypothesis of the area being 0.5; 95% confidence interval 0.87–0.97). The optimal wrist index threshold, defined as the value maximising the sum of sensitivity and specificity (thus providing a simple yet reasonable compromise between as fewer false positive and false negative classifications as possible) above which CTS should be expected was estimated to be 0.69. The estimated sensitivity and specificity using such threshold were 90% and 82%, respectively. It should be noted that statistical literature demonstrates that such threshold estimation need not be optimal and that the resulting sensitivity and specificity are optimistically biased, but the approach sufficed for the purpose of the study and the resulting threshold agreed with previous findings[7].

Based on the ROC analysis, mean wrist index was entered into the multiple logistic regression model as a dichotomous variable. The model proved to be statistically significantly better than the null model ($p<0.001$ from the likelihood ratio test) and the data did not statistically significantly depart from the model ($p=0.202$ from Hosmer-Lemeshow test). Parameter estimates from the model are listed in Table 3. High wrist index (i.e., above the threshold), low hand length to body height ratio and high BMI were found to be independent risk factors for CTS.

Among the two wrist dimensions, dorso-volar diameter (mean of right and left wrist) was higher in subjects with CTS (mean 38.72, SD 3.77) than in the control group (mean 35.98, SD 4.11; $p=0.001$), while there were no differences between the groups regarding mean of right and left medio-lateral diameter (CTS group: mean 53.98, SD 4.67; control group: mean 53.08, SD 5.73; $p=0.970$).

Comparison between groups stratified by gender regarding palm length, palm width and third finger length of the dominant hand is summarised in Table 4. Palm

TABLE 1
COMPARISON OF AGE AND ANTHROPOMETRIC CHARACTERISTICS BETWEEN GROUPS

			CTS group	Control group	p
All subjects (2 × 50)	Age		53.28 (11.61)	54.02 (12.23)	0.757
	Body mass		82.75 (12.92)	74.06 (13.28)	0.001
	Body height		1.65 (0.10)	1.66 (0.09)	0.543
	BMI		30.37 (3.71)	26.75 (3.80)	<0.001
	Wrist index	Right	0.73 (0.03)	0.67 (0.04)	<0.001
		Left	0.74 (0.04)	0.68 (0.03)	<0.001
	Hand shape index	Right	46.77 (2.42)	45.01 (2.10)	<0.001
		Left	46.21 (2.39)	44.69 (2.10)	0.001
	Digit index	Right	43.68 (1.19)	43.72 (2.17)	0.924
		Left	43.59 (1.34)	43.41 (1.14)	0.473
	Ratio of hand length to body height	Right	10.42 (0.43)	10.54 (0.46)	0.186
		Left	10.44 (0.38)	10.52 (0.46)	0.390
Women (2 × 37)	Age		52.62 (12.07)	54.43 (12.67)	0.531
	Body mass		80.69 (10.82)	69.53 (11.03)	<0.001
	Body height		1.61 (0.07)	1.62 (0.06)	0.742
	BMI		30.94 (3.49)	26.54 (4.12)	<0.001
	Wrist index	Right	0.73 (0.04)	0.67 (0.04)	<0.001
		Left	0.74 (0.04)	0.68 (0.03)	<0.001
	Hand shape index	Right	46.28 (2.28)	44.57 (1.91)	0.001
		Left	45.83 (2.34)	44.37 (2.03)	0.005
	Digit index	Right	43.55 (1.24)	43.75 (2.45)	0.650
		Left	43.44 (1.34)	43.39 (1.19)	0.872
	Ratio of hand length to body height	Right	10.39 (0.45)	10.50 (0.41)	0.304
		Left	10.37 (0.39)	10.49 (0.42)	0.185
Men (2 × 13)	Age		55.15 (10.41)	52.85 (11.29)	0.593
	Body mass		88.61 (16.74)	86.94 (10.60)	0.764
	Body height		1.75 (0.10)	1.78 (0.05)	0.330
	BMI		28.76 (3.98)	27.33 (2.74)	0.298
	Wrist index	Right	0.74 (0.03)	0.68 (0.03)	<0.001
		Left	0.73 (0.04)	0.68 (0.02)	0.001
	Hand shape index	Right	48.16 (2.37)	46.26 (2.19)	0.045
		Left	47.30 (2.29)	45.63 (2.07)	0.063
	Digit index	Right	44.08 (0.97)	43.62 (1.12)	0.279
		Left	44.03 (1.29)	43.48 (1.00)	0.234
	Ratio of hand length to body height	Right	10.50 (0.36)	10.66 (0.58)	0.407
		Left	10.66 (0.28)	10.58 (0.57)	0.655

CTS – carpal tunnel syndrome; BMI – body mass index; all variables reported as mean (standard deviation)

length was s statistically significantly larger and third finger length statistically significantly smaller in subjects with CTS than in the control group only among women.

We also investigated whether high BMI was associated with bilateral CTS. Difference in BMI between subjects with bilateral CTS ($\overline{X}$ 30.9, SD 3.7) and those with unilateral CTS ($\overline{X}$ 28.3, SD 3.0) was statistically significant ($p=0.048$). On the other hand, we found no statistically significant association between gender and bilateral CTS (Table 5; $p=0.420$).

Association between side with more severe CTS symptoms and side with larger wrist index is presented in Table 6. The association was statistically significant ($p=0.001$). Analogous associations of side with more severe CTS symptoms and side with higher hand shape index ($p=1.000$), higher digit index ($p=0.840$) and higher ratio of hand length to body height ($p=1.000$) were not

TABLE 2
ASSOCIATION BETWEEN SELECTED ANTHROPOMETRIC CHARACTERISTICS

		MHSI	MDI	MRHLBH	BMI
Mean wrist index	r	0.228	0.036	–0.164	0.369
	p	0.022	0.721	0.103	<0.001
Mean hand shape index (MPI)	r		0.079	0.041	0.332
	p		0.432	0.684	0.001
Mean digit index (MDI)	r			-0.034	–0.091
	p			0.737	0.370
Mean ratio of hand length to body height (MRHLBH)	r				0.220
	p				0.028

Mean – of right and left side; r – Pearson correlation

TABLE 3
RESULTS OF MULTIPLE LOGISTIC REGRESSION FOR PREDICTING CTS

Predictor	b	p	OR	95% CI for OR
Mean wrist index >0.695	3.76	<0.001	42.89	(9.22, 199.60)
Mean hand shape index	0.20	0.154	1.22	(0.93, 1.61)
Mean digit index	0.11	0.692	1.12	(0.64, 1.96)
Mean ratio of hand length to body height	–1.71	0.040	0.18	(0.04, 0.92)
BMI	0.36	0.001	1.43	(1.16, 1.76)

Mean – of right and left side; b – regression coefficient; OR – estimated odds ratio; CI – confidence interval

TABLE 4
COMPARISON OF PALM LEGTH, PALM WIDTH AND LEGTH OF THIRD FINGER ON THE DOMINANT HAND BETWEEN GROUPS

		CTS group	Control group	p
All subjects	Palm length	98.10 (6.54)	100.78 (7.57)	0.061
	Palm width	80.74 (6.40)	78.24 (7.07)	0.067
	Length of third finger	74.46 (5.35)	76.42 (5.94)	0.086
Women	Palm length	95.67 (4.95)	97.40 (3.47)	0.086
	Palm width	77.94 (3.73)	75.22 (4.26)	0.005
	Length of third finger	72.32 (3.57)	74.16 (4.08)	0.043
Men	Palm length	105.00 (5.58)	110.38 (7.96)	0.057
	Palm width	88.69 (5.75)	86.85 (6.44)	0.448
	Length of third finger	80.53 (4.96)	82.85 (5.80)	0.286

statistically significant. Association between hand dominance and side with more severe CTS symptoms was close to statistical significance (p=0.082).

Discussion

The study compared subjects with CTS with well-matched controls regarding age, body mass, body height, BMI, wrist index, hand shape index, digit index, ratio of hand length to body height and hand dimensions. The two groups were found to differ in body mass, BMI, wrist index and hand shape index. No statistically significant differences were found regarding age, body height, digit index and ratio of hand length to body height. When the comparisons were stratified by gender, the same differences were observed in women as in the total sample, while in men only the difference in wrist index was statistically significant and the difference in hand shape index was marginally significant. Our results are in line with the known fact that women are more prone to develop CTS, which was also reflected by the fact that there were nearly three time as many women as men among our CTS subjects. Other studies have identified age as an important risk factor for CTS[8,16], but our sample was too homogeneous regarding age to be able to confirm this.

TABLE 5
ASSOCIATION BETWEEN GENDER AND BILATERAL CTS

		CTS presence		Total
		Unilateral	Bilateral	
Women	No.	6	31	37
	(proportion)	(16%)	(84%)	(74%)
Men	No.	4	9	13
	(proportion)	(31%)	(69%)	(26%)
Total	No.	10	40	
	(proportion)	(20%)	(80%)	

TABLE 6
ASSOCIATION BETWEEN SIDE WITH MORE SEVERE CTS SYMPTOMS AND SIDE WITH LARGER WRIST INDEX

Side with larger wrist index		Side with more severe symptoms		Total
		Right	Left	
Right	No.	19	5	24
	(proportion)	(79%)	(21%)	(48%)
Left	No.	8	18	26
	(proportion)	(31%)	(69%)	(52%)
Total	No.	27	23	
	(proportion)	(54%)	(46%)	

TABLE 7
ASSOCIATION BETWEEN HAND DOMINANCE AND SIDE WITH MORE SEVERE CTS SYMPTOMS

Dominant hand		Side with more severe symptoms		Total
		Right	Left	
Right	No.	26	18	44
	(proportion)	(59%)	(41%)	(88%)
Left	No.	1	5	6
	(proportion)	(17%)	(83%)	(12%)
Total	No.	27	23	
	(proportion)	(54%)	(46%)	

We could only confirm that CTS is most common in middle-age and older persons[1] indirectly through the average age of our CTS subjects, which was 54 years.

Multiple logistic regression identified high wrist index, low ratio of hand length to body height and high BMI as independent risk factors for CTS. Digit index and hand shape index did not prove to be statistically significant predictors of CTS. Our findings agree with previous research regarding wrist index and BMI, while we identified low ratio of hand length to body height as an independent risk factors for CTS contrary to previous research[6,8,10,18]. Because of sample size limitations, we could not fit the same model stratified by gender and thus explicitly test the conjecture from the literature about wrist index, hand shape index and anthropometric characteristics of the hand being risk factors for CTS only in women and not in men[6].

Wrist index was the independent risk factor in which the CTS subjects (with a mean of 0.73) differed most notably from the controls (with a mean of 0.67). For predicting risk of CTS, an appropriately determined wrist index threshold is essential, whereby our estimate was 0.69. We estimated that if CTS is predicted in subjects with wrist index above 0.69, sensitivity is 90% and specificity is 82%. Our findings regarding wrist index are in line with previous research[13] that established it as a major risk factor for CTS and highlighted the threshold value of about 0.70.

External dimensions of the wrist are related to dimensions of the carpal tunnel due to the geometry of carpal bones. Wrist shape is related to the shape, cross-sectional area and depth of the carpal tunnel. The tunnel is not parallel to the medio-lateral and dorso-volar direction of the wrist but rotated by 30 degrees. Wrist movement causes changes in size and shape of the tunnel in terms of reducing the cross-sectional area, which can me a mechanism leading to CTS[19]. It has been established that wrist index is related to the depth of the carpal tunnel, while the dorso-volar diameter of the wrist is related to its cross-sectional area. This implies that through wrist index one can predict pathophysiological changes in the carpal tunnel in terms of slower capillary circulation, hypoxia of nerve fibres, oedema and increased pressure inside the carpal tunnel, and consequently reduced median nerve conductivity[19].

Our study indicates the odds for CTS to be drastically higher for subjects with a wrist index over 0.69. However, to obtain a more reliable estimate of the odds ratio, a larger study with more elaborate statistical modelling would be required. Nevertheless, those a wrist index larger than about 0.70 are undoubtedly under much higher risk for CTS than those with a lower wrist index. As already mentioned, wrist index as an indicator of wrist shape is closely related to the proneness to develop CTS, whereby a wrist index of 0.65 (rectangular wrist shape) is associated with normal nerve conductivity while a wrist index over 0.70 is associated with impaired conductivity of the median nerve[20]. In other words, the larger the wrist index, the more square shaped the wrist and higher odds for CTS[6,13]. Regarding individual wrist dimensions, we found that the dorso-volar wrist diameter was larger in subjects with CTS (mean about 39 mm) as compared to controls (mean about 36 mm), while we found no difference between the groups regarding the medio-lateral diameter despite the literature[7] reporting on smaller medio-lateral diameter in persons with CTS. The different findings could be related to the square wrist shape arising either from a thicker transverse carpal ligament or a narrower carpal tunnel.

Our study paid particular attention to anthropometric characteristics of the hand. The differences between the CTS group and the control group regarding palm width, palm length and third finger length did not reach statistical significance. However, among women, the difference in palm width and third finger length was statistically significant (and the difference in palm length was close to statistical significance), while there were no statistically significant differences among men. In general, wider palms and shorter finger are associated with shorter hands, and shorter hands relative to body height were confirmed as an independent risk factor for CTS in our study. We can therefore conclude that size and shape of the hand are relevant for CTS development at least in women: This is in line with the literature reporting on relatively coarse hands and short fingers as risk factors for CTS[6,16], though contradicting the claim of the ratio of hand length to body height not being associated with CTS[6].

We found significantly higher BMI in CTS subjects than in controls only among women (where the means were 31.0 and 26.5, respectively) and not among men. Contrary to our findings, higher BMI was previously found to be associated with CTS in both genders[10]. Although it is generally accepted that high BMI is a risk facto for CTS, BMI was not found to be correlated with severity of CTS symptoms[11]. Our study was not designed to test this association since we would have had to classify CTS severity according to electrodiagnostic tests. As already mentioned, the association of BMI with CTS is attributed to fat deposits in the carpal tunnel and increased density of the synovial fluid leading to increased hydrostatic pressure and thus to median nerve compression[9–11]. A potentially practically useful estimate from our study is that increase in BMI by one unit (which typically corresponds to increase in body weight by 2–3 kg) increases the odds for CTS 1.4 times. We also found that bilateral CTS was associated with higher BMI (the mean in subjects with bilateral and unilateral CTS being 30.9 and 28.1, respectively), which is in accordance with a previous study[21].

It is presumed that personal factors, such as BMI, age and dimensions of the wrist and hand, have more influence on median nerve conductivity and thus on CTS development than work-related factors, such as repetitive hand strain, duration of employment and job type[11,22]. Our study confirmed this in the sense that we found no association of hand dominance with severity of CTS symptoms even though it is reasonable to assume that dominant hand is more strained during work than the non-dominant hand. For comparison, we also assessed the association between the side with the larger wrist index and the side with more severe symptoms, and we found it to be highly significant. Previous studies[8,10,11] reported on the severity of electrophysiological changes of the median nerve being positively associated with wrist index and age and not being associated with BMI. Since wrist index and shape of the carpal tunnel are related, we can assume that a higher wrist index corresponds to more severe clinical signs, while clinical signs and severity of the symptoms are related to the grade of median nerve impairment. In summary, our study supported the notion that anthropometric characteristics of the hand, the wrist and the carpal tunnel provide the preconditions for median nerve entrapment, while hand movement, especially repetitive one at work, can only trigger or aggravate development of CTS.

If a square shaped wrist, high BMI and low ratio of hand length to body height are observed in a person, it is very likely that the person could develop CTS. While the anatomy of the hand and the wrist cannot be changed, we can influence BMI through weight loss, which should be highly recommended in such cases in order to reduce the risk for CTS at least to some extent. It is also important to regularly relax hands and wrists at work in order 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 index in professions requiring repetitive hand movements, so that in persons with a wrist index of 0.70 or higher appropriate workplace set-up measures could be taken and an exercise programme undertaken in order to prevent or at least delay CTS development.

There are some important limitations to our study. The first one is the lack of detailed data on occupational history and life style of the participants. Further limits to the interpretation are posed by the omission of some possibly relevant exclusion criteria (e.g., pareneoplastic syndromes and use of medications affecting the nervous system). Regarding the lack of association of severity of clinical CTS symptoms with hand dominance, it should be noted that the assumption that the dominant hand is more strained during work may not be necessarily true, as well as that the subjectively reported hand dominance may not be perfectly reliable.

Conclusions

Based on our study, the following conclusions can be reached:

- High wrist index, high body mass index and low ratio of hand length to body height proved to be independent risk factors for carpal tunnel syndrome;
- The optimal threshold of wrist index above which the prognosis of CTS can be made is 0.69, whereby the estimated odds in such persons may be over 40 times higher than in persons with wrist index below the threshold;
- Subjects with CTS had statistically significantly larger dorso-volar diameter of the wrist compared to the health controls;
- Anthropometric characteristics of the hand, such as palm length, palm width and third finger length were confirmed as substantial risk factors for CTS only in women but not in men, whereby women with CTS had shorter and wider palms and shorter third finger compared to their health controls;
- High BMI was statistically significantly associated with CTS only in women, whereby the increase in BMI by

one unit was estimated to increase the odds for CTS by a factor of 1.4;

- High BMI was associated with bilateral SCP in both genders;
- Subjectively assessed severity of clinical signs in a given hand was associated with elevated wrist index on that side but not with hand dominance.

Hence, despite some limitations, our study sheds further light on aetiology and risk factors for CTS, highlighting the role of individual's characteristics in addition to work-related factors and the general health condition.

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INDEKS TJELESNE MASE I ANTROPOMETRIJSKA OBILJEŽJA RUKU KAO ČIMBENICI RIZIKA ZA SINDROM KARPALNOG TUNELA

SAŽETAK

Sindrom karpalnog tunela najčešća je kompresivna neuropatija u području šake i podlaktice. Često se povezuje sa osobnim čimbenicima pojedinaca, ne samo s određenim zdravstvenim uvjetima i radnim mjestima. Studija je usmjerena na razumijevanju veze sindroma karpalnog tunela s antropometrijskim karakteristikama ruke i indeksom tjelesne mase (BMI) kao nezavisnim faktorima rizika. Ukupno je sudjelovalo 100 ispitanika: 50 pacijenata s electro-dijagnostički potvrđenim CTS i 50 zdravih dobrovoljaca bez CTS simptoma kao kontrolne skupine, dok je svaka skupina uključivala 37 žena i 13 muškaraca. Kod sudionika su izmjereni visina, težina, BMI, dubina i širina zgloba, zglobni indeks, indeks oblika ruku, dužina dlana, širina dlana, dužina trećeg prsta i omjer duljine ruku prema visini tijela. Pri utvrđivanju neovisnih rizičnih čimbenika za CTS, korištena je višestruka logistička regresija. Zglobni indeks i širina zgloba su značajno viša kod CTS pacijenata nego u kontrolnoj grupi. Procijenjeni optimalni prag zglobnog indeksa za predviđanje CTS-a bio je 0.69, iznad kojeg su izgledi za CTS procijenjeni za povećanje od 42 puta. Povišeni BMI korelira sa bilateralnim CTS-om kod oba spola. Studija je identificirala zglobni indeks, BMI i odnos dužine ruku prema tjelesnoj visini kao neovisne rizične čimbenike za CTS.