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Assessment of body mass index and hand anthropometric measurements as independent risk factors for carpal tunnel syndrome

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The goal of this study was to clarify the role of body mass index (BMI) (weight divided by square of height; kg/m^2) and hand anthropometric measurements as independent risk determinants in the development of carpal tunnel syndrome (CTS) and their relationship to the severity of CTS. A total of 131 patients with clinical symptoms of CTS and 131 normal subjects were enrolled, of whom 121 were female both in the CTS cases and the controls. All cases were electrodiagnostically confirmed and assigned to three severity groups. BMI, wrist ratio, shape index, digit index and hand length/height ratio were measured in all participants. Mean values for each item were compared between cases and controls and severity subgroups. A logistic regression analysis was performed to determine independent CTS risk factors. The mean values of BMI, wrist ratio and shape index were significantly higher in all CTS patients and females compared to controls, whereas in males only BMI and wrist ratio were higher. The patients in the mild severity subgroup had a significantly lower age and wrist ratio. BMI, wrist ratio and shape index were found to be independent risk factors of CTS development in all patients and females. Our study showed BMI, wrist ratio and shape index as independent risk factors for CTS. These findings are of potential anatomical and clinical importance and outline the risk factors of anatomical malfunction of the wrist in CTS. (Folia Morphol 2008; 67: 36–42)

Key words: carpal tunnel syndrome, body mass index, anthropometric, risk factor

INTRODUCTION

Compression of the median nerve at the wrist, which is called carpal tunnel syndrome (CTS), is the most common entrapment neuropathy [6, 17]. It frequently affects women, and the female: male ratio is 3:1 [5]. The contribution of a variety of risk factors to the development of CTS has been studied. Ischaemia, mechanical factors, ectopic impulse generation, tendonitis and elevated carpal tunnel pressure are all involved in the pathophysiology

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of CTS [31]. Systemic disease, pregnancy, age and female gender are also well known contributing factors [6]. There is much evidence for the contribution of body mass index (BMI) to the development of CTS [4, 6, 7, 19]. Although the majority of cases are idiopathic, some studies have implicated hand anthropometric measures in the development of CTS. Johnson et al. [13] described the association between wrist ratio and CTS emergence. Successive studies have shown similar findings [6, 14, 17, 19], three of which have found an association between wrist ratio and the severity of CTS [6, 17, 19]. The study by Boz et al. [6] also revealed shape index and digit index as determinant factors in the development of CTS. Most of the previous studies are limited, since they lack a well-matched control group, gender matching comparison or comparison by severity subgroups. Others have had a small sample size or ignored some individual risk determinants. Accordingly, the results of these studies should be interpreted cautiously. Moreover, relatively little is known about the contribution of the common risk factors in Iranian community. The aim of this study was to determine the contribution of BMI, wrist ratio, shape index, digit index, and hand length/ /height ratio to the development and severity of CTS in both sexes in the Iranian population.

MATERIAL AND METHODS

From June 2005 to July 2006 131 patients, comprising 121 females and 10 males with clinically and electrodiagnostically confirmed CTS, and 131 (121 female and 10 male) age-matched individuals, were enrolled in the study. All participants were right handed. They were investigated thoroughly for signs and symptoms of general medical conditions. Routine laboratory batteries failed to show any abnormality in either group. No signs or symptoms were displayed of cervical radiculopathy or ulnar nerve entrapment. In addition, the control group had no sign or symptoms suggestive of CTS. The cases were all residents of the same local area of Tabriz and the controls were their accompanying relatives, who lived in the same neighbourhood. The occupation distribution was the same for both groups. Most of the female participants were housewives, followed by nurses, office workers, sales staff, and librarians in groups of decreasing size. The males comprised equal numbers of office workers and sales staff.

This study was approved by the Ethics Committee of Tabriz University of Medical Sciences and informed consent was obtained from all the patients. After this had been given, the participants were asked about age, gender, occupation, handedness, any previous or current general medical condition, pregnancy, cervical radiculopathy, previous trauma to the neck or upper extremities or surgery involving these regions, history of neuropathy, demyelinating disease and thoracic outlet syndrome. A thorough review was made of systems and a physical examination was performed and appropriate laboratory data was obtained for participants with findings that aroused suspicion. Participants with abnormalities in any of the above areas, local wrist conditions (such as ganglion) or whose work needed repetitive wrist flexion (including secretaries, typists and weavers) were excluded from the study.

All measurements were made by one investigator. Weight and height were measured using the same device for all the participants. BMI was calculated as weight divided by the square of the height and expressed in kg/m^2. Hand width (the maximum distance between second and fifth metacarpal bones), palmar length (the distance between the middle of the distal palmar crease and the mid-point of the third finger proximal crease), third finger length (middle of the third finger proximal crease to the tip of the third finger) and wrist depth (the maximum anteroposterior distance at the distal palmar crease) were measured using a compass with 0.1 mm sensitivity and the second and fifth fingers in 20 degree abduction, while the fingers were extended on a flat surface. Hand length was defined as palmar length plus third finger length. These measurements yielded a wrist ratio [wrist depth (mm)/wrist width (mm)], shape index [hand width (mm)/hand length (mm) × 100], digit index [third finger length (mm)/hand length (mm) × 100] and hand length/height ratio [hand length (cm)/height (m)] [6]. CTS diagnosis was based on clinical and electrodiagnostic criteria. The electrodiagnostic studies were performed using a four-channel Toennis NeuroScreen Plus apparatus with the participants laid on a bed. The room temperature was kept between 24°C and 26°C. The electrodiagnostic tests were allowed when the palmar temperature, measured using a digital thermometer, was more than 32°C. Nerve stimulation studies where performed using a standard bipolar surface electrode. Nerve compound muscle action potentials (CMAP) were recorded using two silver surface electrodes placed on the thenar muscles 7 cm apart for the median nerve and on the hypothenar muscles 5 cm apart for the ulnar nerve. The recording was made 8 cm distal to the stimulation point at the wrist. The recording of sensory nerve action potentials was made antidromically on the second and fifth fingers for the median and ulnar nerves respectively, while the stimulus was implemented at the wrist 14 cm proximal to the recording point. The patients were considered to have CTS if they had prolonged median nerve distal sensory latency > 3.6 ms; prolonged median sensory nerve action potential (SNAP) compared to ulnar SNAP ≥ 0.5 ms, or prolonged median motor distal latency > 4.2 ms, while having normal median conduction along the forearm [10]. Median nerve distal sensory latency prolongation or median distal sensory latency prolongation compared to that of the ulnar nerve were considered as mild CTS [2]. Moderate CTS was defined as a reduced SNAP amplitude of the median nerve < 25 mV or < 50% in comparison with the unaffected side (in unilateral cases) or distal motor latency prolongation of the median nerve [2]. Severe CTS was characterised as reduced CMAP amplitude of the median nerve < 4 mV or < 50% in comparison with the unaffected side (in unilateral cases), or denervation of the muscles supplied by the median nerve on needle examination [2]. In the cases of bilateral CTS, severity was defined by the hand with the more severe involvement in electrodiagnostic studies.

Statistical analysis was performed using SPSS 13.0. After evaluation for normal distribution, Student's t-test was applied for comparison of each continuous variable between each gender group. When normal distribution was not achieved by using routine transformation methods, we applied non-parametric tests. Analysis of variance (ANOVA) was used to compare continuous variables between each gender severity subgroup. To evaluate risk factors for CTS, a logistic regression model was used in which CTS was the dependent factor and BMI, wrist ratio, shape index, digit index, and hand length/ /height ratio were independent factors. Considering age to be a group-matching factor, the authors did not use age in this model. P-values less than 0.05 were considered significant.

RESULTS

Of the 131 patients enrolled in the study (121 female, 10 male), 126 had bilateral CTS and 5 had unilateral CTS (3 right-sided and 2 left-sided). All male patients had bilateral CTS. The defining parameters were compared in normal female and male controls. Males had a significantly higher wrist ratio compared to females (0.73 ± 0.03 *vs*. 0.70 ± 0.04, $p = 0.0018$). There was no significant difference between male and female groups in the parameters of the study including age, weight, height, BMI, shape index, digit index and hand length/height ratio.

The differences between the two groups were significant in weight, wrist ratio, shape index, and BMI mean values, although the differences in age, height, digit index and hand length/height ratio were not significant (Table 1).

The same statistically significant differences were also seen in the comparison of female cases and controls, but this failed to show any significant difference in weight and shape index between male cases and controls (Table 1). Analysis of variance showed significant differences for age ($p < 0.05$) and wrist ratio ($p < 0.01$) between severity subgroups, when both males and females were considered together. It also showed significant differences between severity subgroups for wrist ratio ($p < 0.01$) in females and for age ($p < 0.05$) in males (Table 2).

A multiple comparison of age, weight, BMI and hand indices between severity groups with a post hoc Tukey test showed a significant difference between the mild and severe subgroups for age ($p < 0.05$), and mild and moderate subgroups for wrist ratio ($p < 0.01$), when all the patients were considered together. It also showed significant differences between the mild and moderate subgroups for age in males ($p < 0.05$) and for wrist ratio in females ($p < 0.05$). The correlation of left and right upper limb anthropometric measures was specified using Spearman's correlation coefficient. There was a strong correlation of hand indices between right and left hands

A logistic regression analysis for the estimation of risk factors for CTS was performed on all the patients and the female group, which showed that wrist ratio, shape index, and BMI are risk factors for CTS, while digit index and hand length/height ratio are not. It also showed that wrist ratio is the strongest factor in the development of CTS, and BMI and shape index follow respectively (Table 3). Logistic regression analysis was not performed on the male group because of its small size ($n = 10$).

DISCUSSION

There have been few studies to date that have specifically studied the correlation between hand anthropometric indices and the development of CTS, and the results of the studies that have been conducted are somewhat inconsistent. In a recent study

Table 1. Comparison of age, weight, height, body mass index, and hand indices between different cases and control groups

Variables		Cases	Controls	P-value
All patients	Age	43.83 ± 12.00	42.92 ± 9.2	0.49
	Weight	76.6 ± 9.41	65.65 ± 11.26	< 0.001*
	Length	155.46 ± 6.14	156.83 ± 6.90	0.09
	Body mass index	31.70 ± 3.48	26.74 ± 4.74	< 0.001*
	Wrist ratio	0.76 ± 0.04	0.70 ± 0.04	< 0.001*
	Shape index	44.90 ± 2.02	42.87 ± 2.02	< 0.001*
	Digit index	42.72 ± 1.46	42.74 ± 1.19	0.867
	Hand length/height	11.00 ± 0.60	11.04 ± 0.45	0.509
Female patients	Age	44.02 ± 11.97	42.20 ± 8.91	0.108
	Weight	76.72 ± 9.41	65.32 ± 11.41	< 0.001*
	Length	155.51 ± 6.10	156.70 ± 6.84	0.154
	Body mass index	31.73 ± 3.51	26.65 ± 4.79	< 0.001*
	Wrist ratio	0.75 ± 0.04	0.70 ± 0.04	< 0.001*
	Shape index	43.95 ± 2.55	42.89 ± 2.08	< 0.001*
	Digit index	42.69 ± 1.28	42.76 ± 1.22	0.679
	Hand length/height	11.03 ± 0.56	11.04 ± 0.45	0.803
Male patients	Age	41.5 ± 12.78	51.6 ± 9.82	0.197
	Weight	75.2 ± 9.72	69.6 ± 8.92	0.196
	Length	154.8 ± 6.97	158.4 ± 7.91	0.225
	Body mass index	31.35 ± 3.28	27.86 ± 4.12	0.026*
	Wrist ratio	0.76 ± 0.03	0.73 ± 0.03	0.042*
	Shape index	44.21 ± 2.78	43.05 ± 1.44	0.270
	Digit index	43.19 ± 3.03	43.07 ± 1.09	0.593
	Hand length/height	10.56 ± 0.82	11.03 ± 0.52	0.143

*Significant values

Moghtaderi et al. [19] revealed that wrist ratio could be an independent risk for CTS development, while wrist circumference might have a protective effect. Boz et al. [6] showed that wrist ratio, shape index and digit index were independent risk factors in females, but failed to show statistically any significant difference between male cases and controls in these measurements. There are several other studies that have depicted wrist ratio as the prime suspect in the establishment of CTS [11, 17, 18, 20, 22], while yet others have failed to demonstrate this [1, 24, 26]. In the current study we found wrist ratio a major determinant in CTS development in all the patients and in the female groups, which is consistent with the results of the previous studies [6, 14, 17–19, 22]. We also found it significant in males. The role of wrist ratio in CTS development is not fully understood but several explanations have been proposed. There may be potential link between wrist ratio and variations in carpal stenosis in the dynamic and static relationship of structures and median nerve abnormalities [12, 13, 17]. Specific wrist shapes may increase the potential for CTS to develop because of an increase in repetitive hand movements, making the subject more susceptible to CTS [27, 29, 31].

We also found a higher shape index to be an independent risk in all patients and females (as confirmed by logistic regression analysis) and this is consistent with the findings of Boz et al. [6] and Chroni et al. [7] This finding also lends support to the hypothesis that coarse hands are at increased risk for the development of CTS. The mechanism remains to be elucidated but it seems that these hands exert a much higher force for a given motion of the

Table 2. Age, weight, height, body mass index (BMI), and hand indices among carpal tunnel syndrome (CTS) severity groups and controls

	N	Age	Weight	Height	BMI	Wrist ratio	Shape index	Digit index	Hand length/height
Control	131	42.92 ± 9.29	65.65 ± 11.26	156.83 ± 6.90	26.74 ± 4.74	0.70 ± 0.04	42.87 ± 2.02	42.74 ± 1.19	11.04 ± 0.45
Mild CTS	17	37.65 ± 10.50	74.26 ± 8.01	155.18 ± 4.68	30.86 ± 3.29	0.73 ± 0.04	43.63 ± 2.59	43.40 ± 2.24	10.79 ± 0.65
Moderate CTS	75	43.69 ± 11.82	75.73 ± 8.94	155.11 ± 6.00	31.46 ± 3.15007	0.76527 ± 043	43.95 ± 2.53	42.69 ± 1.27	10.98 ± 0.61
Severe CTS	39	46.79 ± 12.17	79.29 ± 10.43	156.26 ± 6.98	32.52 ± 4.05	0.76 ± 0.04	44.25 ± 2.61	42.47 ± 1.33	11.12 ± 0.54

The values presented as mean ± standard deviation

hand, which increases intracarpal fluid pressure [27, 29, 31]. This is especially true for repetitive hand movements. We failed to show digit index to be an independent risk determinant, which is contrary to the findings of Boz et al. [6] and Chroni et al. [7]. This should be clarified by further investigation. We found no significant difference in terms of hand length/height ratio between CTS cases and controls, either in males or in females, as was observed by Boz et al. [6] The mean value of the wrist ratio was significantly lower in the mild severity subgroup than in the moderate subgroup in all patients and also in females ($p < 0.01$ and $p < 0.05$, respectively). This finding is consistent with the findings of Kouyoumdjian et al. [17]. In contrast, Boz et al. [6] found no such difference between severity subgroups. These differences could be the result of sample size, severity subgroup distribution or variations in the electrodiagnostic criteria applied for grouping. This obviates the calls for studies with an even distribution of subjects among severity subgroups and with standard universal electrodiagnostic criteria for sub grouping.

BMI was significantly higher among all patients, female and male. This was also confirmed by logistic regression analysis in all patients and the female group, with an odds ratio of 1.323 and 1.330 respectively. There was no significant difference between the three severity subgroups. This is totally consistent with the results of Kouyoumdjian et al. [16] and Moghtaderi et al. [19]. Boz et al. [6] found not only a relationship between a higher BMI and CTS development but also a statistically significant difference among severity subgroups. Thus many other studies have targeted BMI as a risk factor in CTS development [8, 15, 25, 28, 30]. Nordstrom et al. [21] showed that the chance of developing CTS will increase by 8% with a one-unit increase in BMI. In contrast, one study scrutinised the relationship of BMI as an independent risk factor and showed that univariate and multivariate analyses demonstrated that increased BMI is a significant independent risk factor for CTS in patients under the age of 63 years, but is less important in older patients. Patients over the age of 63 years have a different pattern of risk factors for CTS than younger patients [4]. One proposed factor might be increased carpal tunnel fat content in fat people, which in turn causes the hydrostatic pressure to rise [3, 30, 31]. Another theory is water accumulation in the connective tissue of the carpal tunnel [9]. In people with high BMI increased blood volume shifts to the upper extremities in a recumbent

Table 3. Risk factors for carpal tunnel syndrome in the logistic regression analysis model for all patients and females

	Variable	Coefficient	Odds ratio	P-value
All patients	Digit index	0.000	1.000	0.830
	Shape index	0.056	1.058	< 0.001*
	Wrist ratio	0.301	1.351	< 0.001*
	Hand length/height ratio	0.002	1.002	0.446
	Body mass index	0.280	1.323	< 0.001*
Females	Digit index	0.001	1.001	0.689
	Shape index	0.049	1.050	0.001*
	Wrist ratio	0.287	1.332	< 0.001*
	Hand length/height ratio	0.0001	1.000	0.746
	Body mass index	0.285	1.330	< 0.001*

*Significant values

position, which in turn causes venous congestion in the flexor synovial sheets of the carpal tunnel and causes the intracarpal pressure to increase [23].

Age was significantly higher in the severe subgroup compared to the mild subgroup among all patients and in the moderate subgroup compared to the mild subgroup among males. This is consistent with the findings of Kouyoumdjian et al. [17], which associated CTS severity with increased age.

In this study we tried to match the cases and controls precisely in accordance with age, occupation, and socioeconomic status. The limitations of this study could be the small number of male subjects, which made logistic regression analysis impractical and limited the applicability of the results to the female patients.

In conclusion, a higher body mass index, wrist ratio and shape index were found to be independent risk factors for carpal tunnel syndrome in females and in all patients. Digit index and hand length/height ratio were not shown to be independent risk factors. Wrist ratio and body mass index were found to be significantly higher among male patients than among the controls. Age and wrist ratio were found to have a determinant effect on carpal tunnel syndrome severity in all patients. Wrist ratio had an effect on carpal tunnel syndrome severity among females and age among males. To further elucidate the role of hand anthropometrics on the development of carpal tunnel syndrome we propose that future studies should have a greater sample size of male subjects, an even distribution of patients among severity subgroups and use universal electrodiagnostic criteria.

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