EREDETI KÖZLEMÉNY

ORIGINAL ARTICLE

Association of upper extremity anthropometry and subcutaneus adipose tissue with carpal tunnel syndrome

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Background and purpose – Body mass index (BMI) is positively correlated with the frequency of carpal tunnel syndrome (CTS). However, there are different types of obesity, and the localization of adipose tissue differs between the genders. In this study, we purposed to investigate whether there was an association between the amount of local adipose tissue thickness and anthropometry in upper extremity with the presence and/or electrophysiological severity of CTS on both genders.
Methods – Our study included 150 patients who were diagnosed with CTS clinically and electrophysiologically and 165 healthy controls. The biceps and triceps skinfold thickness, the diameters of the wrist and metacarpal joints, and the upper arm circumferences over the belly of the biceps muscle were measured by using skinfold caliper and measuring cylinder. All data were analyzed by using the Statistics Open For All package (SofaStats) programme. To detect the role of anthropometric indexes, we used multivariable multinomial logistic regression models.
Results – We revealed that BMI, biceps and triceps adipose tissue thicknesses were higher in females and also in patients with CTS. There was a positive correlation between electrophysiological grades of CTS and BMI with logistic regression analyzes. The mean Wrist circumference/Metacarpopharengeal Circumference ratio and biceps circumference were higher in moderate CTS groups. Metacarpofarengeal circumference

A felső végtag antropometriájának és subcutan zsírszövetének a carpalis alagút szindrómával való összefüggése
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Háttér és cél – A testtömegindex (BMI) pozitívan korrelál a kéztőalagút-szindróma (CTS) gyakoriságával. Mindazonáltal, az elhízásnak különböző típusai vannak, és a zsírszövet lokalizációja eltérő a nemek között. Ebben a tanulmányban azt kívántuk megvizsgálni mindkét nem esetében, hogy van-e összefüggés a felső végtag zsírszövetének vastagsága és antropometriai adatai, valamint a CTS kialakulása és/vagy annak elektrofiziológiai súlyossága között.
Módszerek – Vizsgálatunkban 150 olyan beteg vett részt, akiknél klinikailag és elektrofiziológiailag CTS-t diagnosztizáltak, valamint 165 egészséges kontrollszemély. A bicepsz- és a tricepszbőrredő vastagságát, a csukló és a kézközépcsont ízületeinek átmérőjét, valamint a bicepszizom hasa feletti felkarkörfogatot skinfold-kaliper és mérőhenger segítségével mértük. Valamennyi adatot a Statistics Open For All (SofaStats) program segítségével elemeztük. Az antropometriai indexek szerepének kimutatására többváltozós multinomiális logisztikus regressziós modelleket használtunk.
Eredmények – Kimutattuk, hogy a BMI, a bicepsz- és a tricepsz-zsírszövet vastagsága magasabb volt a nőknél és a CTS-ben szenvedő betegeknél is. A CTS elektrofiziológiai fokozatai és a BMI között pozitív korrelációt találtunk a logisztikus regressziós elemzésekkel. Az átlagos csuklókörfogat/metacarpophalangealis körfogatarány és a bicepszkörfogat magasabb volt a közepesen súlyos CTS-csoportokban, míg a metacarpophalangealis kerület kisebb volt az enyhe

was smaller in mild and moderate CTS cases compared to healthy ones.
Conclusion – We suggest that the differences between the anatomical bone structure and local adiposity between the genders may play an important role in the occurrence of CTS. Moreover, the structures of proximal muscle groups and distal metacarpal joints may contribute both to the development and severity of CTS.

Keywords: adipose tissue thickness, anthropometry, gender, carpal tunnel syndrome

és a közepesen súlyos CTS-es esetekben az egészségesekhez képest.
Következtetés – Az eredmények arra utalnak, hogy a nemek közötti anatómiai csontstruktúra- és helyi zsírszövet-vastagságbeli különbségek fontos szerepet játszhatnak a CTS kialakulásában. Továbbá a proximális izomcsoportok és a distalis metacarpalis ízületek struktúrája egyaránt hozzájárulhat a CTS kialakulásához és súlyosságához.

Kulcsszavak: zsírszövetvastagság, antropometria, nemek, kéztőalagút-szindróma

Carpal tunnel is defined as the space formed by the transverse ligament on the volar aspect and on the dorsal and lateral aspects of the wrist bones.The tendons of the hand flexor muscles and the median nerve pass through this tunnel and reach the fingers. Carpal tunnel syndrome (CTS) is the most prevalent entrapment neuropathy, and generally occurs due to the compression of the nerve during its passage under a thickened transverse carpal ligament in the distal part of the wrist[1]. Normal carpal tunnel pressure is 2-10 mmHg[2]. Activities including repetitive flexion and extension of the wrist cause the increase of pressure inside the tunnel. Prolonged high pressure results densed synovial fluid around the flexor tendons passing through the tunnel and compression of the median nerve. Inflammatory changes resulting from chronic compression lead to reactive neural edema and fibrosis and occurence of the clinical symptoms[2, 3]. Numbness in the median nerve distribution, nocturnal numbness, weakness/atrophy of the thenar muscles, Tinel's sign and Phalen's sign could be seen.

The most frequently reported risk factors for CTS in epidemiological studies are: female gender, obesity, high body mass index (BMI), advanced age, and working with long-lasting repetitive hand movements[4, 5]. Risk factors are classified as external and internal factors that cause an increase in pressure inside the tunnel (pregnancy, obesity, menopause, etc.), deteriorate the contours of the tunnel (tumor, fracture, etc.), and result in neuropathic changes (diabetes, alcoholism, toxicity, etc.)[5, 6]. Although CTS could be seen in all age groups, it is more common in adults between the ages of 40-60; CTS's diagnosis is made by electrophysiologic studies with EMG[7]. The severity of CTS could be graded as mild, moderate, and severe based on electrophysiologic findings[8]. Determining the degree of CTS is important for the selection of the treatment protocol. Night splinting, local steroid injection and decompression surgery are among the treatment options.

The most important factor that increases intracarpal pressure by mainly affecting the fluid balance of the body is obesity[9]. So obesity and having a BMI over 30 have been reported as the most important anthropometric risk factor for CTS in many studies[10, 11]. In addition, there are many studies reporting that the increase in BMI is correlated with the electrophysiological severity of CTS[10, 12, 13]. Waist/hip ratio is another unit of measurement used in obesity grading besides BMI[14]. However, all of these anthropometric measurements evaluating obesity provide information about whole body adiposity but could not give information about the upper extremity adipose tissue distribution. There are various other methods of measuring adiposity or obesity giving suggestive metrics regarding body fat distribution, one of which is the skinfold thickness measurement. Measurement of subcutaneous fat thickness is a method that was first used by *Durnin* and *Rahaman*[15] in the 1960s to determine the body fat ratio, however, it is still preferred in clinical studies because it is an easy and cheap method[16]. In this study, we investigate whether there is an association between the estimated upper extremity adipose tissue thickness determined by skinfold thickness measurement and the severity of CTS. In addition, there are many studies investigating the relationship between different anthropometric measurements such as wrist ratio, hand ratio, shape index, digit index, wrist/palm ratio, wrist depth/length, hand length/height and CTS[14]. These studies reported that increased wrist ratio (>0.7), (wrist squareness in other terms) and wrist/palm ratio, the shape index, and the waist/stature ratio were more frequent in patients with CTS compared to controls[14, 17]. We aimed to investigate the probable correlation of electrophysiological severity of CTS with the novel upper extremity anthropometric measurements such as wrist circumference (WC), the metacarpophalangeal joint circumference (MC), WC/MC ratio in the distal part of the arm and biceps circumference (BC) in the proximal part of the arm.

Methods

Patients

Our study included the patients who were referred to our electroneurophysiology laboratory with a preliminary diagnosis of CTS between July and December, 2021**.** Among them**,** the right-handed patients diagnosed with CTS clinically and electrophysiologically were included in the disease group, and the right-handed patients who were not found to have CTS as a result of detailed physical examination and electrophysiological study were included in the control group.

Exclusion criteria

Patients having coexisting peripheral nervous diseases (cervical radiculopathy, polyneuropathy, thoracic outlet syndrome, brachial plexus injury), previous median nerve trauma, arterial injury or thrombosis, and incision history were excluded.

Anthropometric measurements

BMI

BMI was calculated and stratified by use of the classification recommended by the World Health Organization for adults in 2020[18]. Height and weight were measured directly, and BMI was calculated as weight/height^2 (kg/m^2).

Wrist, metacarpal and biceps circumference measurements

Wrist, metacarpal joint and biceps muscle circumference were measured with a measuring cylinder. The measurement was done from the styloid process of the radius on the right hand for WC and from the line where the metacarpal bones and the first phalanges meet between the 2nd and 5th fingers for MC, and from the largest diameter of biceps muscle for BC by the first author.

Triceps and biceps skinfold thickness measurements

Skinfold thickness was measured on the skin part covering the biceps and triceps muscles by using AEGems Skinfold Digital Calipers (Range: 0-6 Inches, Size: 9.2 × 3 × 0.6 Inches, Resolution: 0.0005 Inch. Standardized skinfold measurement techniques were applied for upper extremities skinfold measurement sides[19, 20]. The first author measured the skinfold thicknesses by grasping the skin between her thumb and forefinger, and placing the skinfold caliper approximately 1 cm from her thumb and forefinger.

Electroneuromyographic (ENMG) measurements

Electrodiagnostic tests were performed on both upper extremities of all participants in a room with a temperature of 24 °C approximately with the Medelec Premiere apparatus by the same technician. Normative values used for median and ulnar nerve traditional conduction parameters used in our laboratory were as follows: median nerve wrist-to-APB muscle motor latency, 4.20 ms, ulnar nerve wrist-to-ADM muscle motor latency, 3.30 ms, antidromic median nerve wrist-to-digit II (over 14 cm) sensory conduction velocity, 49 m/s, antidromic ulnar nerve wrist-to-digit V (over 12 cm) sensory conduction velocity, 49 m/s, median and ulnar nerve forearm MCV, 50 m/s. We used the American Association of Electrodiagnostic Medicine (AAEM) scale for grading CTS[21].

The electrophysiological severity was defined as: Mild CTS grade represents the cases with delayed median nerve sensory responses and normal motor responses. In moderate CTS, both median nerve sensory and motor responses are delayed. The severe CTS grade indicates delayed median nerve motor responses with unelicitable sensory responses or decreased compound muscle action potential.

Statistical analysis

All data were analyzed by using SofaStats-the Statistics Open For All package- programme (Paton–Simpson and Associates Ltd, New Zealand). After the test for normality, the statistical significance of the difference between the averages of two groups by the use of the independent sample t-test for normally distributed and the Mann–Whitney U-test for not normally distributed data. Analysis of variance (ANOVA) and Kruskal–Wallis H-test were used for multiple group comparisons. Chi-Square test and Fisher's exact probability test were used to consider the distribution of the categorized variables for normally distributed and not normally distributed data, respectively. Then, to detect the role of anthropometric indexes considered together, we used multivariable multinomial logistic regression models including following covariates: age, sex, MC, BC, WC/MC ratio, and BMI. A p-value< 0.05 was considered as statistically significant.

Table 1. *Distribution of gender and the mean age among the study subgroups*

	Number (percentage)	Gender (Male/Female) *	Mean Age ± S.D. #
Healthy	165 (52.4%)	41/124	46.0± 13.1
Mild CTS	56 (17.8%)	11/45	49.3± 11.2
Moderate CTS	70 (22.2%)	17/53	52.0± 11.8
Severe CTS	24 (7.6%)	9/15	52.3± 10.5
Total	315 (100%)	78/237	48.4± 12.5

*p=0.409 (Chi-Square), # p=0.183 (ANOVA)

Results

Demographics

Totally, 315 individuals were involved in our study. Seventy-eight (24.8%) of them were male and 237 (75.2%) of them were female. CTS was detected in 150 (47.6%) individuals. Gender distribution was similar between healthy and CTS groups in our study population. There were 41 males and 124 females in the healthy group, whereas 37 males and 113 females in the CTS group (p=0.970). The mean age of the patients with CTS was older than that of healthy individuals (51.0 ±11.4 vs. 46.0±13.1, respectively; p< 0.001). The median BMI of the patients with CTS (29.67, min: 20.81- max: 45.19) was higher than that of the healthy individuals (27.12, min: 19.27- max: 45.19) (p< 0.001). According to the electrophysiological grading scheme of AAEM, there were 56 (37.3%) patients with mild CTS, 70 (46.7%) with moderate CTS, and 24 (16.0%) with severe CTS **(Table 1)**. The mean ages of the study subgroups were similar (p=0.18).

Although the males had a higher median weight and higher mean height than females (p<0.001), the median BMI was higher in females (p=0.04). Males had longer WC and MC than females (p<0.001). WC/MC ratio was higher in females (p<0.001). Skinfold thickness over the biceps and triceps muscles was higher in females than males (p<0.001) **(Table 2).**

The median weight (p=0.002), BMI (p<0.001) and mean BC (p=0.002) of the patients with CTS were significantly higher than that of the healthy individuals. Although the mean WC (p=0.122) and MC were not different (p=0.244), the mean WC/MC ratio was higher in patients with CTS than in healthy individuals (p< 0.001). The mean skinfold thickness over the biceps and triceps region was significantly higher in patients with CTS than in healthy individuals (p<0.01) **(Table 3)**.

The statistical analyses presented in **Table 4** revealed 1., the BMI: the difference between 'Healthy group and the mild, moderate and severe CTS groups' (p<0.001); 2., Biceps Skinfold: the difference between the 'Healthy group and the mild CTS group' (p=0.033); 3., Triceps Skinfold: the difference between the 'Healthy group and the mild CTS group' (p=0.063); 4., BC: the difference between the 'Healthy and mild CTS group' and the

Table 2. *Distribution of anthropometric measurements between the genders*

	Male [mean ± S.D.] / [median (min-max)]	Female [mean ± S.D.] / [median (min-max)]	p value
Weight (kg)	*80* (52–153)	74 (48–128)	*< 0.001 #*
Height (m)	*1.720*±0.073	1.598 ± 0.063	*< 0.001 **
BMI (kg/m²)	27.6 (19.3–45.2)	29.3 (19.5–51.9)	*0.04 #*
BC-Biceps Circumference (cm)	30.6±3.6	29.9±3.5	*0.17 **
WC-Wrist Circumference (cm)	18.5 (12.0–22.0)	17.0 (14.5–30.0)	*< 0.001 #*
MC-Metacarpal Circumference (cm)	*22.2±1.6*	20.1±1.5	*< 0.001 **
WC/MC	0.84 (0.63–0.98)	*0.86 (0.73–1.36)*	*< 0.001 #*
Biceps Skinfold (mm)	11.1±4.4	*14.3±4.3*	*< 0.001 **
Triceps Skinfold (mm)	16.6±6.0	*21.5±5.4*	*< 0.001 **

* Student T test, # Mann Whitney U Test

Table 3. *Distribution of anthropometric measurements among healthy individuals and patients with CTS*

	Healthy [mean ± S.D.] / [median (min-max)]	Patients with CTS [mean ± S.D.] / [median (min-max)]	p-value
Weight (kg)	74 (48–153)	*78 (50–128)*	*0.002 #*
Height (m)	1.637±0.085	1.618±0.081	0.046 *
BMI (kg/m²)	27.1 (19.3–45.2)	*29.3 (20.8–51.9)*	*0.001 #*
BC (cm)	29.4±3.6	*30.7±3.5*	*0.002 **
WC (cm)	17.6±1.6	17.9±1.7	0.122 *
MC (cm)	20.8±1.9	20.5±1.6	0.244 *
WC/MC Ratio	0.850±0.055	*0.874±0.071*	*0.001 **
Biceps Skinfold (mm)	12.9±4.3	*14.1±4.7*	*0.023 **
Triceps Skinfold (mm)	19.5±5.9	*21.1±5.8*	*0.018**

* Student T test, # Mann Whitney U Test

'Healthy with the moderate CTS group' (p=0.019); 5., MC: the difference between the 'mild CTS and severe CTS group' and 'moderate CTS group and severe CTS group' (p=0.048); 6., WC/MC Ratio: the difference between 'Healthy and mild CTS group' and 'Healthy and moderate CTS group' (p=0.011).

Table 5 presents the related risk ratios (RRRs) estimated through the multinomial logistic regression models. Compared to healthy controls, it can be said that the age and BMI related risk ratio (RRRs) is 1.036 and 1.067 times higher in patients with mild CTS respectively and the metacarpal circumference is with [(1-0.621)×100]=37.9% less than that of healthy controls **(Table 5)**. Compared to healthy controls, it can be said that the BC, WC/MC and BMI RRRs are 1.147, 1.131 and 1.020 times higher in patients with moderate CTS, respectively and the metacarpal circumference is with [(1-0.757)×100]=24.3% less than that of the healthy ones (**Table 5**).

Discussion

In our study, the ages of female and male patients having complaints of CTS and had been admitted to the clinic were similar which is compatible with the data in the literature. The mean age was 48 years. Most probably, these findings resulted from the similar age ranges of active working life regardless of gender. In our study, most of the patients had moderate CTS, and the number of female patients was higher in this group. In the severe grade group, the male/female ratio was higher than in the other groups. Considering that comorbid factors such as polyneuropathy and radiculopathy were excluded in the patients participating in the study, we can associate this result with the fact that men applied to the hospital later and worked in hard jobs for a longer period of time than women.

Normally anthropometric characteristics such as height, weight, and bone structure are different between

Table 4. *Distribution of anthropometric measurements among the study subgroups*

	Healthy	Mild CTS	Moderate CTS	Severe CTS	p
Weight (kg)	74 (48–153)	77.5(50–128)	78 (60–117)	79.5 (50–113)	*0.018#*
Height (m)	1.637±0.08	1.612±0.075	1.621±0.080	1.626±0.097	0.212*
BMI (kg/m²)	27.1 (19.3–45.2)	29.5 (22.2–51.9)	29.6 (23.9–44.3)	31.5 (20.8–42.0)	*< 0.001 #*
BC (cm)	29.5±3.6	30.9±3.5	30.7±3.5	30.4±3.3	*0.019**
WC (cm)	17.6±1.6	17.7±1.5	17.9±1.9	18.4±1.4	0.110*
MC (cm)	20.8±1.9	20.3±1.6	20.5±1.5	21.4±1.8	*0.048**
WC/MC Ratio	0.850±0.05	0.874±0.057	0.876±0.086	0.865±0.050	*0.011**
Biceps Skinfold (mm)	12.9±4.3	15.0±5.2	13.6±4.4	13.5±3.7	*0.033**
Triceps Skinfold (mm)	19.5±5.8	21.9±6.5	20.7±5.7	20.4±5.4	0.063*

*ANOVA, # Kruskal-Wallis H test

Table 5. *Multivariable multinomial logistic regression models of anthropometric characteristics and electrophysiological severity grades of CTS (base outcome: people without CTS)*

Assessment by CTS grade									
	Mild (n= 56)			Moderate (n= 70)			Severe (n= 24)		
Variables	RRRs	95% CI	P	RRRs	95% CI	P	RRRs	95% CI	P
Age (per year)	1.036	(1.007–1.066)	*0.013*	1.011	(0.987–1.035)	0.371	1.033	(0.994–1.074)	0.099
Gender	1.246	(0.502–3.112	0.632	0.900	(0.400–2.021)	0.798	2.669	(0.821–8.680)	0.103
MC (cm)	0.621	(0.461–0.836)	*0.002*	0.757	(0.591–0.970)	*0.028*	0.771	(0.499–1.191)	0.241
BC (cm)	1.134	(0.996–1.299)	0.058	1.147	(1.021–1.288)	*0.021*	1.039	(0.867–1.246)	0.678
WC/MC	0.078	(0.986–1.206)	0.078	1.131	(1.000–1.278)	*0.050*	1.041	(0.866–1.252)	0.666
BMI	1.067	(1–1.139)	*0.048*	1.020	(0.931–1.117)	*0.021*	0.870	(0.729–1.039)	0.057

the genders. Most probably from their natural anatomy, we observed that height, weight, WC, and MC were significantly higher in men than women participating in our study as could be expected. The WC/MC ratio was significantly higher in the females, which was thought to be related to the peculiar anatomy of the wrist in the female gender.

Anthropometric studies have indicated that the increased wrist index[22, 23] and the anatomically squareness in the shape of the wrist[24, 25] are the risk factors for CTS. In our study, non-classical anthropometric measurements such as WC/MC ratio and BC were found to be higher in patients diagnosed with CTS than in healthy individuals. We revealed that there were significant differences between the patients with mild or moderate CTS and healthy individuals in these two different measurements. In logistic regression analysis, we found that MC in mild CTS and BC, MC and WC/MC ratio in moderate CTS are more effective indicators of risk. This indicates that the anatomical structure of the hand joints may be a facilitating factor in CTS. The more common presence of hypertrophic biceps muscles in physically hard-working people and/or working with repetitive hand movements may explain our findings regarding BC. According to these results, we offer the WC/MC ratio, BC and MC as novel anthropometric measurements that affect the grade of CTS.

Fat distribution regions in the body show differences according to heredity and gender. Body adiposity is concentrated in different regions in men and women, and the different types of obesity are defined accordingly. While android-type fat distribution, called central fat deposits is common in men, gynecoid-type fat distribution, which is prominent in the hips and thighs, is seen mostly in women. In addition to being widely used in the evaluation of obesity and adiposity, BMI alone may cause incomplete and incorrect results in determining the increased risk of CTS. It would be more accurate to evaluate the lubrication in the upper extremity when determining the frequency and risk increase of CTS. To the best of our knowledge, there is no study revealing the difference in the regional adiposity rate in the upper extremity between the genders. Therefore, we suggest that this study will contribute to the existing literature in terms of the relationship between obesity and CTS.

In our study, we found that BMI, and triceps and biceps subcutaneous adipose tissue thickness were higher in women than in men regardless of CTS. This result may indicate that obesity in general and regional fat deposition in the upper extremities are more prominent in women than in men. Therefore, it indicates that the female gender, which is one of the leading risk factors for CTS, is actually in correlation with the rate of upper extremity adiposity. Moreover, we revealed that BMI and subcutaneous adipose tissue thickness in the upper extremity are higher in patients with CTS than in healthy individuals. Therefore, it is possible to say that both obesity and regional adiposity in the upper extremity are positively correlated with CTS.

In opposite to a few previous studies suggesting that BMI was not associated with the electrophysiological severity of CTS[26, 27] we showed a positive correlation between BMI and electrophysiological grades of CTS with logistic regression analyses. The anterior part of the carpal tunnel is anatomically composed of connective and adipose tissues, and therefore the thickness of this part is related to the thickness of the subcutaneous adipose tissue on the anterior (biceps) surface of the upper extremity. However, there is a bony roof behind the carpal tunnel, and the thickness of the connective tissue and adipose tissue behind the upper extremity (triceps) is not expected to be associated with CTS. Therefore, it would be a more accurate approach to consider biceps skinfold measurements when evaluating the relationship of upper extremity local adipose tissue with CTS. In addition, these results show that regional adiposity in the upper extremity is not a primary risk factor for moderate to severe CTS and does not correlate with electrophysiological severity, except for mild CTS.

All of these results indicate that not only the anatomical factors regarding the wrist joint and obesity, but also the structures of proximal muscle groups, the distal metacarpal joint, and regional adipose tissue in the upper extremity may contribute to the development and severity of CTS.

Conclusion

In difference from the previous studies revealing obesity and female gender as the primary risk factors in CTS, we draw attention to the regional differences in adiposity between the genders. Our study revealed that the rate of adiposity in the upper extremity is higher in women, and that the increase in local adiposity in the upper extremity poses a risk for CTS. We suggest that the differences between the anatomical bone structure and local adiposity differences between the genders may play an important role in the occurrence of CTS in females with a higher frequency than in males. Future studies with different aspects of upper extremity anatomy are warranted to better highlight this issue.

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DATA ACCESS STATEMENT – The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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