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Relationship between the carrying angle and some other parameters related to muscle strength and endurance in healthy young adults

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Abstract

Objectives: The present study aimed to determine whether there is a relationship between carrying angle and some parameters such as the middle part of the deltoid muscle strength, hand grip muscle strength, lateral bridge times and push-up repeats for both genders.

Methods: This study was carried out on 100 (48 male, 52 female) university students aged between 18–30 years. Individuals with known chronic systemic disease, congenital or acquired anomaly of the skeletal system and a body mass index of 30 and above were excluded. Only right-handed participants were included to eliminate the confusion of dominance. The participants' age, gender, height, body weight, and body mass index were recorded. The carrying angles were measured with a goniometer. The middle part of the deltoid muscle strength and hand grip strength measurements were used to evaluate muscle strength, and the lateral bridge test and push-up test were used for endurance.

Results: A statistically significant difference was found between carrying angle values on the right and left sides in males ($p=0.004$), while there was no difference in the females ($p=0.28$). A statistically significant difference was found between the genders on the left carrying angle ($p<0.001$). A statistically significant difference was found in the total group and in both genders on middle part of the deltoid muscle strength and hand grip strength between the sides. In males, a significant positive correlation was found between carrying angle and the middle part of the deltoid muscle strength ($r=0.29$, $p=0.04$) on the right side. In females, a significant negative correlation was found between carrying angle and the hand grip test ($r=-0.29$, $p=0.04$) on the left side. There was no significant correlation between carrying angles and other parameters in both genders.

Conclusion: Our results suggest that the carrying angle may be related to the middle part of the deltoid muscle strength in males on the right side and lateral bridge test in females on the right side, even though they are weak.

Keywords: carrying angle; deltoid muscle strength; endurance; hand-grip strength; lateral bridge test; push-up test

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Introduction

The carrying angle (CA) is the angle between the longitudinal axes of the humerus and the radially deviated forearm in the anatomical position while the elbow is fully extended and supinated. CA is approximately 17°, but the absolute angle varies between individuals.[1] The CA varies depending on age and gender, and also it is considered as one of the secondary sex characteristics in the literature.[2,3] The CA difference according to gender may vary due to laxity of articular ligaments, larger breasts and wider pelvis in females.[4] In addition, there is no consensus in the literature whether the CA is greater on the right or left sides. While some studies mentioned lateralization, no consensus was reached about which dominant or non-dominant sides have a greater CA.[3,5,6] On the other hand, some studies reported that the CA does not differ between the sides.[4,6] Furthermore, in the foetal period, no difference was reported between CA of the right and left sides within both genders, but a significant difference was found between genders.[7]

The deltoid muscle arises from the shoulder girdle and attaches to the lateral surface of the humerus. The middle part of the deltoid muscle allows abduction of the arm and it is more effective at higher abduction angles.

The supraspinatus muscle has a synergistic effect on the deltoid muscle during the first 30º. The deltoid muscle stabilizes the humeral head during abduction.[8] Muscle strength may differ between genders because males usually have more muscle bulk, and also there are some physiological differences between genders.[9,10] Leyk et al.[10] reported grip strength of the females is lower than the male counterparts. Upper extremity muscle strength is also affected by hand dominance. Also, many studies reported that the grip strength is more likely to be higher on the dominant side.[11–13] Patel and Verma[14] reported that grip strength, an indicator of general muscle strength, moderately (Spearman's rho between -0.494 and -0.551) related to CA for both sides. The results of these authors indicate that while CA increases, grip strength decreases, and vice versa. The fact that upper extremity muscle strength and hand grip strength change with hand dominance may raise the question of whether there is a relationship with the CA. However, there is limited evidence regarding the relationships between the CA and upper extremity muscle strength or endurance.

The core of the body includes the abdominals, paraspinals, gluteals, diaphragm, pelvic floor, and hip girdle muscles. Core muscles are central to the functional kinetic chain and these muscles initially power all limb movements.[15] This muscle group provides the proximal stability for the distal mobility and function of the limbs.[16] Contraction of the abdominal muscles increases intra-abdominal pressure, stabilizing the lumbar spine for postural support before limb movement. The thoracolumbar fascia connects the lower and upper extremities so that the core muscles are used in activities such as throwing.[16] Erickson et al.[17] conducted a study on baseball players in which they evaluated the CA. In their study, they reported that the mean CA was statistically significantly different ($p<0.001$) in the throwing arm (12.5°±4.2°) compared to the other arm (9.9°±2.8°).

The core muscles can be evaluated with different tests. Static muscular endurance is based on the ability to sustain a contraction and can be measured through tests such as flexor endurance, lateral bridge and back extensor tests.[18,19] The push-up exercise is one of the exercises used to develop upper body and upper arm muscular endurance. The total number of push-ups is a parameter used as an indicator of upper-arm and shoulder girdle strength and endurance.[19] Although we couldn't find strong evidence regarding the relationships of the CA and core muscle or shoulder endurance in the literature, core and shoulder endurance seems to be related to upper extremity movements and positions. Considering all of these, the present study aimed to investigate whether there is a relationship between CA and some parameters related to muscle strength, shoulder and body endurance.

Materials and Methods

This study was carried out on 100 (48 males, 52 females) university students aged between 18-30. Individuals with known chronic systemic disease, congenital or acquired anomaly of the skeletal system or a history of trauma and individuals with a body mass index of 30 and above were excluded. The dominant hand was determined as inquired by asking the hand used for writing, and only right-handed participants were included in the study.[20]

First, the individuals participating in the study signed an informed consent form. The participants' age, gender, height, body weight, and body mass index (BMI) were recorded in a structured data recording form. While the participants were standing in an anatomical position with their upper extremities fully extended and supinated, the carrying angles were measured with a goniometer (Baseline Stainless Steel Goniometer, USA) as stated in literature.[2]

The upper extremities were evaluated by measuring the middle part of the deltoid muscle strength and hand grip strength. And push-up and lateral bridge tests were assessed for endurance. The middle part of the deltoid muscle strength of the participants was measured by using maximal voluntary isometric contractions (make test) with a hand-held dynamometer (Lafayette 12–0380 Manual Muscle Tester, Lafayette, IN, USA) and a belt which attached to a stable table.[21] Participants were asked to sit upright on a bed with 90° abduction and forearm pronation and to push the arm to the belt toward the hand-held dynamometer. The evaluation was performed with both upper extremities. A 30-second rest was provided between each measurement. Three measurements were performed and the highest result was used in the analysis.

Hand grip strength was measured with the Jamar hand dynamometer (Jamar®, Patterson Medical, Warrenville, IL, USA). Testing was started with the dominant extremity.[22] Measurements were made in a sitting position with the shoulder in adduction and neutral rotation, elbow in 90° flexion, forearm in mid-rotation, and wrist in neutral.[23] Participants were asked to squeeze the dynamometer arm as strongly as possible and verbally encouraged during testing until the highest score was observed on the dynamometer screen. Three measurements were performed with 30-second breaks between each measurement, and the highest value was used in the analysis.[22–24]

The lateral bridge test, a static endurance test of the lateral trunk muscles, was used to evaluate the endurance

of the trunk muscles.[18] Participants were asked to maintain the position for the maximum time by raising their bodies flat on their toes with lower elbows and forearms while in the side-lying position. The time until the deterioration of the position was recorded in seconds.

The push-up test was used in males and the modified push-up test was used in females to measure the endurance of the arm and shoulder girdle muscles. The participants were asked to lift their heads, shoulders and trunk from the ground with the elbows in full extension from a prone position on the bed with their arms and elbows flexed.[25] The test was performed with full extension of the trunk and lower extremities in males and with trunk extension and knee flexion in females. The abdomen was not allowed to touch the mat during the assessment and participants were asked to keep the straight position of their back at all times. The test was stopped when the participants were unable to maintain their position. The maximum number of push-ups performed in a row without rest for one minute was used in the analysis.[26]

In addition, gender groups were divided into two groups as cases with the CA below and above the mean value. Muscle strengths and endurances in these two groups were compared with an independent samples test.

The statistical analysis was performed using SPSS (Version 25.0, IBM Corp., Armonk, NY, USA). The conformity to normal distribution was examined using the Shapiro-Wilk test. Mean and standard deviations of the parameters were obtained according to gender groups and right and left sides. Sides and gender groups were compared using the t-test, and non-conforming groups were evaluated using the Mann-Whitney U test. The correlation between measurements was evaluated with the Pearson correlation test. The statistical significance level was determined as $p<0.05$.

Results

In our study, 100 people (48 males, 52 females) were evaluated in a young population. The mean, standard deviation and p values of demographic data, CA, the middle part of deltoid muscle strength, grip strength, lateral bridge and push-up tests are shown in **Table 1**.

Statistically significant differences were found in the parameters between the genders except for age and right carrying angles (**Table 1**). There was no statistically significant difference between the right and left sides of the whole group CA (p=0.10). However, there was a statistically significant difference between CA values on the right and left sides in males (p=0.004), while there was no difference in the females (p=0.28) (**Table 1**). Middle part of the deltoid muscle strength and hand grip strength between the sides, a statistically significant difference was observed in the total group and in both genders (**Table 1**). In comparing the lateral bridge test between the sides, no statistically significant difference was detected in the whole group

Table 1
Comparison of demographic characteristics, carrying angle and other parameters according to genders and right/left sides.

		Male (n=48) Mean±SD	Female (n=52) Mean±SD	Total (n=100) Mean±SD	p-values for gender comparison	p-values for side comparison
Age (year)		19.54±1.11	19.96±1.04	19.76±1.09	0.055	-
Height (cm)		178.45±5.07	163.69±5.67	170.78±9.15	<0.001*	-
Weight (kg)		75.38±13.07	57.86±9.30	66.27±14.24	<0.001*	-
BMI (kg/m^2)		23.64±3.82	21.57±3.08	22.56±3.59	0.004†	-
Carrying angle (°)	Right	22.06±3.22	23.19±2.77	22.65±3.03	0.064	male p=0.004†
	Left	20.64±3.09	23.55±2.38	22.16±3.10	<0.001*	female p=0.28
Middle part of the deltoid muscle strength (kg)	Right	17.75±6.23	10.38±2.10	13.92±5.86	<0.001*	male p=0.026†
	Left	16.83±5.75	9.73±2.06	13.14±5.53	<0.001*	female p=0.001†
Grip strength (kg)	Right	39.62±6.69	23.71±4.27	31.34±9.71	<0.001*	male p=0.004†
	Left	37.46±7.41	21.68±3.50	29.25±9.75	<0.001*	female p<0.001*
Lateral bridge test (sec)	Right	59.08±23.61	37.96±18.75	48.10±23.63	<0.001*	male p=0.33
	Left	56.74±24.66	38.10±19.55	47.05±23.94	<0.001*	female p=0.94
Push-up test (repeat)		20.62±11.21	15.67±6.52	18.05±9.37	0.009†	-

*p<0.001, †p<0.005. **BMI:** Body mass index.

and in both genders. Males had higher push-up counts than females (**Table 1**, p=0.009). The correlations between the parameters are shown in **Table 2** according to the sides for both genders.

In males, a significant positive correlation was found between CA and the middle part of the deltoid muscle strength (r=0.29, p=0.04) on the right side. In females, a significant negative correlation was found between CA and the hand grip test (r=-0.29, p=0.04) on the left side. There was no significant correlation between carrying angles and other parameters in both genders.

In addition, gender groups were divided into cases with the CA below and above the mean value. Muscle strengths and endurances belonging to these two groups were compared. In males, there was a significant difference in the group's middle part of the deltoid muscle strength with a large CA on the right side (p=0.003). The male group with larger CA also had a stronger middle part of the deltoid muscle on the right side. There was no significant difference between the male groups in other parameters. In females, there was a significant difference between the larger and smaller CA groups; the lateral bridge test results were higher in the group with a smaller CA (p=0.03) on the right side. There was no significant difference between other parameters in females.

Discussion

Studies in the literature reported that the CA varies according to age, gender, dominant hand side, and body characteristics such as weight and height. In our study, we investigated whether the CA is related to muscle strength and endurance.

Numerous studies have reported that the CA is statistically significantly larger in females than males.[2,4,6,27] It was even described as a gender-specific factor. Erdoğan and Malas[7] reported that males had greater CA than females in the fetal period. Another study reported that the CA was greater in males aged between 3–5.[3] On the other hand, studies also reported no difference between genders.[28,29] In our study, there was a significant difference between genders only in the left side CA (p<0.001). CA of the dominant side (right side) were similar in both genders.

Studies in the literature reported that the CA is larger on the right side.[3,27] In some studies, the dominant hand was questioned and they reported that the CA was larger on the dominant side.[17,30,31] Another study revealed that the CA is larger on the non-dominant side.[5] However, studies also report no difference between the CA of both sides.[4,6,29] In our study, left-hand dominant individuals were excluded. There was no difference between the right and left sides on the CA in the whole group, regardless of gender (p=0.10). When the CA of the right and left sides of male individuals were compared, a significant difference was found (p=0.004), but not in females (p=0.28). This result is similar to a study conducted on professional baseball players, where the CA on the dominant side was measured larger than on the non-dominant side.[17] In contrast, there was a significant difference between males and females on the left side CA (p<0.001) but not on the right side (p=0.064). The studies in the literature do not seem to have a consensus on which side has a larger CA.

CA was weak and positively correlated to the middle part of the deltoid muscle strength in males in the present study (r=0.29, p=0.044). However, the correlation between the CA and the hand grip test on the right side was not statistically significant different (r=0.28, p=0.052) in males. According to these results, there was not a strong relationship between the CA and the strength of the upper extremity muscles. This study can be taken further by measuring the strength of different muscles on the dominant side belonging to the upper extremity. Also, it would be useful to make the measure-

Table 2
Correlations betweven carrying angle and other parameters (r).

		Middle part of the deltoid muscle strength		Grip strength		Lateral bridge test		
Gender	Sides	Right	Left	Right	Left	Right	Left	Push-up test
Male	Right CA (°)	0.29*		0.28		-0.21		0.16
	Left CA (°)		0.11		0.15		-0.06	-0.06
Female	Right CA (°)	0.12		-0.09		-0.08		0.18
	Left CA (°)		0.19		-0.29*		-0.03	-0.07

*p<0.05.

ments on a more significant number of subjects to clarify these correlations.

When comparing two groups with CA below and above, the mean value in both genders, in males' middle part of the deltoid muscle strength was higher in the group with a larger CA on the right side (p=0.003). In females, the lateral bridge test results were higher in the group with a smaller CA (p=0.003). This result might be interpreted as a significant functional relationship between CA and the middle part of the deltoid muscle strength and between CA and body endurance on the right (dominant) side.

In a retrospective study comparing individuals with lateral epicondylitis and the control group, it was reported that there was a significant difference in CA. Lateral epicondylitis was found to be associated with the dominant side. In addition, increased CA has been reported to be associated with lateral epicondylitis. It has been stated that, it may contribute to the etiology of lateral epicondylitis by increasing the extensor carpi radialis brevis tendon tension.[32] In our study, a significant relationship between the middle part of the deltoid muscle strength and CA was determined. The middle part of deltoid muscle strength and hand grip strength were evaluated to give an idea about upper extremity muscle strength in general. It seems that the CA may be related to various upper extremity muscles. Examination of the relationship between the other upper extremity muscle strengths and the CA may give an idea about which muscles may have an effect on the CA.

Conclusion

In our study, we aimed to understand whether muscle strength and endurance affect the CA. A statistically significant difference was observed in the total group and in both genders on middle part of the deltoid muscle strength and hand grip strength between the sides. In males, a significant positive correlation was found between CA and middle part of the deltoid muscle strength (r=0.29, p=0.04) on the right side. In females, a significant negative correlation was found between CA and the hand grip test (r=-0.29, p=0.04) on the left side. Although these correlation values were statistically significant, they were weak. Prospective studies may provide more detailed information about whether the change in muscle strength affects the CA. Examination of the relationship between the other upper extremity muscle strengths and the CA may provide insight into which muscles may affect the CA.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

KE: project development, data collection, data analysis, manuscript writing; MAM: data analysis, manuscript writing; DB: data collection; HU: data collection; DÖK: project development.

Ethics Approval

Ethics committee approval was obtained from the Clinical Research Ethics Committee of İzmir Katip Çelebi University (2019-KAE-0277).

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