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The association between hand dimensions and handgrip strength: a preliminary study

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Abstract

Grip strength of the hand is defined as the voluntary flexion of all fingers in maximum strength under normal bio-kinetic circumstances. Handgrip strength is an important parameter in terms of the efficient use of the hand in addition to being a reliable marker of the physical strength of the individual. The aim of this study was to evaluate the association between the anthropometric measurements of the hand and handgrip strength. A total of 150 students from Baskent University aged 18 to 25 years participated in this study. The participants' height, weight, length of upper extremity, arm, forearm and hand, arm circumference, wrist circumference, elbow and wrist width and hand width were measured in this study. In addition, the distance from the distal wrist line to the distal end of each finger and the distances from each fingertip to the peak point of the thumb were measured with the fingers in abduction. The measurements for the fingers were obtained from scanned images of the hands. Handgrip strength, however, was measured using a hand dynamometer. The handgrip strength of the males was found to be greater compared to the females. A statistically significant association between handgrip strength and all upper extremity parameters was found. The most significant of all the parameters was the distance between the wrist and thumb of the right and left hand (WT). This study is a preliminary one and may be seen in terms of treatment approaches to the hand, clinical follow-up, and hand rehabilitation.

Introduction

The hand is the part of the upper extremity from the radiocarpal joint to the end of the fingers and has a key role in terms of all upper extremity functions. The anatomic structure of the hand provides the hand with both fine and coarse grip motion through interactions that are sometimes agonist and sometimes antagonist. Therefore, the anatomy of the hand should be studied as a whole including the skin, tendons, muscles, bones, joints, vessels and nerves (Gövsa, 2008).

Complex movements of the hand are formed by means of good coordination between the balanced muscle system of the hand and the central nervous system (Snell, 2011).

The thumb is more important functionally compared to the other fingers. Functional loss of the thumb results in a 40% decrease in the hold and grip functions (Gövsa, 2008).

Among the functions of the hand, handgrip strength is important for the execution of daily activities. Grip strength of the hand is defined as the voluntary flexion of all fingers of the hand in maximum power under normal bio-kinetic circumstances (Fallahi and Jadidian, 2011). It has been accepted as an objective measure of upper extremity performance in addition to being a reliable marker that provides general information on a person's nutritional status, physical power and general health status. A hand's grip strength is a physiological variable affected by age, sex and bodily dimensions (Jurimae et al., 2009; Koley and Pal Kaur, 2011). Knowing the functional structure of the hand and handgrip strength is important for surgical approaches to the hand, postsurgical performance evaluations and clinical follow- up in patients with upper extremity injuries or undergoing hand rehabilitation. Handgrip strength is not only a good predictor for evaluating the efficiency of a treatment procedure and the rehabilitation process of hand disorders, it is also a good predictor for neuromuscular and chronic metabolic diseases (Fallahi and Jadidian, 2011; Otto et al., 2014). Handgrip strength is also an important and required parameter in the evaluation of performance in some sports such as tennis, basketball, volleyball, athletics and wrestling. Previous studies have so far only been made on healthy children or on different sports groups and studies on the reference values of handgrip strength in young adults are limited. On the other hand, studies on various sports groups have demonstrated the effect of hand dimensions on handgrip strength in athletes who use their hands for grasping (Fallahi and Jadidian, 2011).

We hypothesized that maximum handgrip strength is largely related to the anthropometric parameters of the hand, in particular, the distance between the distal wrist line and the distal end of the fingers. Increased finger length will increase the surface of the hand and therefore increase handgrip strength.

The aim of this study was to evaluate handgrip strength in healthy young adults and its association with upper extremity anthropometric measurements. The results of the present study may lead the investigators to study the correlation between handgrip strength and upper extremity dimensions in various sports groups as well.

Materials and methods

In this study, a total of 150 (66 females and 84 males) students from Baskent University aged 18-25 years were tested. The mean age of the male participants was 20.33 ± 1.59 and 19.89 ± 1.45 for the female participants. Students with any deformity or function loss in the upper extremities were excluded from the study.

In addition to the age, sex, height and weight of the participants, their upper extremity measurements such as the length of the entire upper extremity, the arm, forearm and hand, the circumference of the arm, forearm and wrist, and the width of the elbow, wrist and hand were measured using an anthropometer and Vernier caliper (Oliver, 1969). Body mass index (BMI) was calculated as a general anthropometric variable according to the weight/(height)^2 formula. Skin thickness was measured three times in four different locations: the biceps, triceps, subscapular and suprailiac regions (using a Holtain Skinfold Caliper which can measure in intervals of 0.2mm) and their mean was calculated. Lean body mass (LBM) measurement was calculated using the formula (LBM = 13.782 - (0.018 x age) + (0.064 x height) + (0.697 x weight) - (5.842 x log of total of 4 skinfold thicknesses) using height, weight and 4 measurements of skinfold thickness (Kulkarni et al, 2013).

The distances between the distal wrist line and the distal end of each finger and between each fingertip and the peak point of the thumb were measured on the scanned images of the right and left hands (Visnapuu and Jurimae, 2007).

Handgrip strength was measured using a Jamar hand dynamometer (Lafayette Instruments, USA) with the individual sitting in a standard position as recommended by the American Society of Hand Therapists (ASHT). The shoulders were in adduction and in a neutral position. The elbows were in 90° flexion. The forearm was in mid-rotation and supported, and the wrist was in a neutral position (Jurimae et al., 2009). In order to determine handgrip strength, three measurements were performed with 10-second intervals between each measurement and the average of the three was recorded.

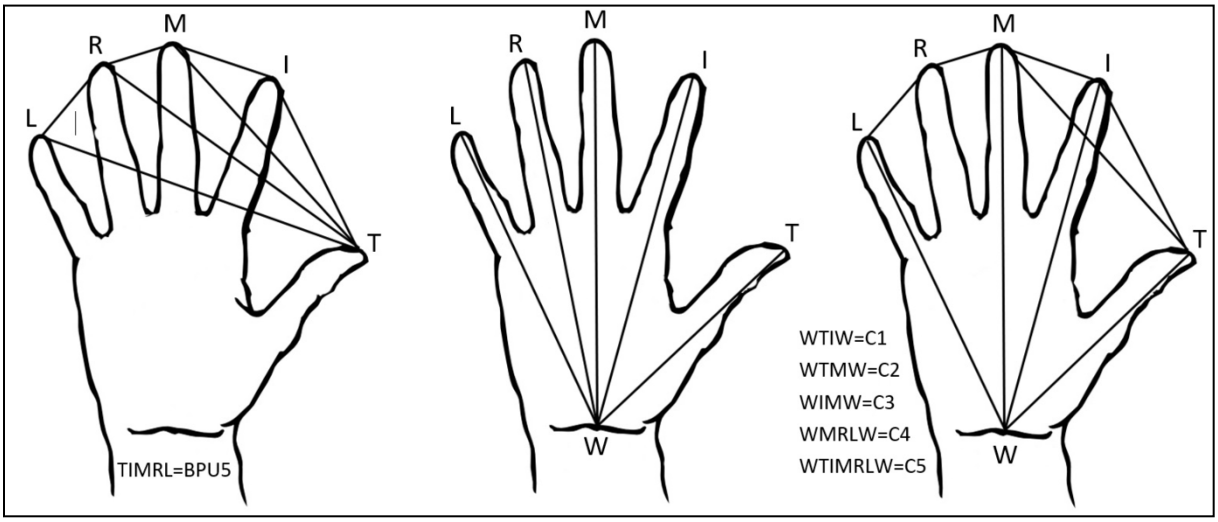

Figure 1. Designation of anthropometric points and distances in the hand (T: thumb; I: index finger; M: middle finger; R: ring finger; L: little finger; W: wrist line; C: perimeter)

Statistical methods

Normal distribution was tested using the Shapiro-Wilk test. The homogeneity of the group variances was calculated using the Levene test. Since it was observed that the preliminary conditions for parametric tests were not met the Mann Whitney U test was used to compare two independent groups and the Kruskal-Wallis H test was used to compare three independent groups. Spearman's Correlation Coefficient was used to determine the correlation between the variables. A value of $P < 0.05$ was accepted as significant. Analysis of the data was performed using the SPSS 17.0 (SPSS Ver. 17.0, Chicago IL, USA) statistical package program.

This study was approved by the Medical and Health Sciences Research Board and Ethics Board of Baskent University (Project no: KA 16/48).

Table 1. Descriptive properties of male and female participants

	Males	Females	*P*
Age (year)			
mean ± std	20.33 ± 1.59	19.89 ± 1.45	<0.001
median (minimum - maximum)	20 (18-25)	20 (18-25)	
range	7	7	
Height (mm)			<0.001
mean ± std	1779.39 ± 68.91	1634.23 ± 53.21	
median (minimum - maximum)	1779 (1591-1950)	1634 (1500-1780)	
range	359	280	
Weight (kg)			<0.001
mean ± std	75.65 ± 12,48	60.62 ± 11.5	
median (minimum - maximum)	76 (49-116)	61 (34-112)	
range	67	78	
BMI			<0.001
mean ± std	23.85 ± 3.41	22.68 ± 3.90	
median (minimum - maximum)	24 (16-35)	23 (15-40)	
range	19	25	
LBM			<0.001
mean ± std	68.18 ± 8,41	55.84 ± 7.78	
median (minimum - maximum)	68 (46-95)	56 (38-90)	
range	48	52	
Right handgrip strength			<0.001
mean ± std	46.32 ± 10,34	25.78 ± 6.45	
median (minimum - maximum)	47.16 (80-24)	25.66 (39.33-11.33)	
range	56	28	
Left handgrip strength			<0.001
mean ± std	42.66 ± 9,09	23.72 ± 5.87	
median (minimum - maximum)	42.66 (81.33-16.67)	24.33 (36-8)	
range	64.67	28	

std: standard deviation
BMI: body mass index
LBM: lean body mass

Table 2. Association between BMI and LBM values and right and left handgrip strengths

		Right handgrip strength	Left handgrip strength	BMI	LBM
Right handgrip strength	Correlation coefficient	1.000	0.948**	0.312**	0.696**
	Sig. (2-tailed)	.	0.0001	0.0001	0.0001
Left handgrip strength	Correlation coefficient	0.948**	1.000	0.339**	0.710**
	Sig. (2-tailed)	0.0001	.	0.0001	0.0001
BMI	Correlation coefficient	0.312**	0.339**	1.000	0.776**
	Sig. (2-tailed)	0.0001	0.0001	.	0.0001
LBM	Correlation coefficient	0.696**	0.710**	0.776**	1.000
	Sig. (2-tailed)	0.0001	0.0001	0.0001	.

Table 3. Correlation of right handgrip strength with right upper extremity anthropometric measurements

		Right handgrip strength	Right upper extremity	Right arm perimeter	Right forearm perimeter	Right wrist perimeter	Right arm length	Right forearm length	Right hand length	Right humerus bicondylar	Right wrist width	Right hand width
Right handgrip strength	Correlation coefficient	1.000	0.712**	0.602**	0.674**	0.723**	0.666**	0.728**	0.725**	0.804**	0.734**	0.796**
Right upper extremity	Correlation coefficient	0.712**	1.000	0.453**	0.557**	0.675**	0.826**	0.830**	0.779**	0.748**	0.651**	0.794**
Right arm perimeter	Correlation coefficient	0.602**	0.453**	1.000	0.865**	0.743**	0.438**	0.552**	0.486**	0.564**	0.521**	0.637**
Right forearm perimeter	Correlation coefficient	0.674**	0.557**	0.865**	1.000	0.836**	0.536**	0.636**	0.605**	0.684**	0.638**	0.724**
Right wrist perimeter	Correlation coefficient	0.723**	0.675**	0.743**	0.836**	1.000	0.630**	0.694**	0.687**	0.731**	0.792**	0.765**
Right arm length	Correlation coefficient	0.666**	0.826**	0.438**	0.536**	0.630**	1.000	0.791**	0.700**	0.710**	0.644**	0.716**
Right forearm length	Correlation coefficient	0.728**	0.830**	0.552**	0.636**	0.694**	0.791**	1.000	0.782**	0.779**	0.656**	0.790**
Right hand length	Correlation coefficient	0.725**	0.779**	0.486**	0.605**	0.687**	0.700**	0.782**	1.000	0.718**	0.682**	0.735**
Right humerus bicondylar width	Correlation coefficient	0.804**	0.748**	0.564**	0.684**	0.731**	0.710**	0.779**	0.718**	1.000	0.720**	0.866**
Right wrist width	Correlation coefficient	0.734**	0.651**	0.521**	0.638**	0.792**	0.644**	0.656**	0.682**	0.720**	1.000	0.710**
Right hand width	Correlation coefficient	0.796**	0.794**	0.637**	0.724**	0.765**	0.716**	0.790**	0.735**	0.866**	0.710**	1.000

Table 4. Correlation of left-hand grip strength with left upper extremity anthropometric measurements

		Left handgrip strength	Left upper extremity	Left arm perimeter	Left forearm perimeter	Left wrist perimeter	Left arm length	Left forearm length	Left hand length	Left humerus bicondylar	Left wrist width	Left hand width
Left handgrip strength	Correlation coefficient	1.000	0.708**	0.615**	0.707**	0.731**	0.694**	0.734**	0.689**	0.798**	0.737**	0.790**
Left upper extremity	Correlation coefficient	0.708**	1.000	0.428**	0.528**	0.671**	0.846**	0.858**	0.763**	0.768**	0.695**	0.748**
Left arm perimeter	Correlation coefficient	0.615**	0.428**	1.000	0.892**	0.744**	0.426**	0.557**	0.479**	0.539**	0.520**	0.613**
Left forearm perimeter	Correlation coefficient	0.707**	0.528**	0.892**	1.000	0.829**	0.532**	0.633**	0.578**	0.672**	0.629**	0.706**
Left wrist perimeter	Correlation coefficient	0.731**	0.671**	0.744**	0.829**	1.000	0.631**	0.713**	0.689**	0.720**	0.782**	0.756**
Left arm length	Correlation coefficient	0.694**	0.846**	0.426**	0.532**	0.631**	1.000	0.834**	0.690**	0.747**	0.679**	0.690**
Left forearm length	Correlation coefficient	0.734**	0.858**	0.557**	0.633**	0.713**	0.834**	1.000	0.761**	0.805**	0.694**	0.748**
Left hand length	Correlation coefficient	0.689**	0.763**	0.479**	0.578**	0.689**	0.690**	0.761**	1.000	0.685**	0.714**	0.690**
Left humerus bicondylar width	Correlation coefficient	0.798**	0.768**	0.539**	0.672**	0.720**	0.747**	0.805**	0.685**	1.000	0.759**	0.825**
Left wrist width	Correlation coefficient	0.737**	0.695**	0.520**	0.629**	0.782**	0.679**	0.694**	0.714**	0.759**	1.000	0.753**
Left hand width	Correlation coefficient	0.790**	0.748**	0.613**	0.706**	0.756**	0.690**	0.748**	0.690**	0.825**	0.753**	1.000

Table 5. Association between anthropometric measurements of the right hand and right handgrip strength

Right	Right handgrip strength Correlation coefficient	*P*
Handgrip strength	1.000	
WT	0.767**	0.0001
WI	0.718**	0.0001
WM	0.718**	0.0001
WR	0.711**	0.0001
WL	0.707**	0.0001
TI	0.288**	0.0001
TM	0.297**	0.0001
TR	0.269**	0.001
TL	0.302**	0.0001
IM	0.000	0.995
MR	0.048	0.558
RL	0.144	0.079
BPU5	0.194*	0.017
C1	0.636**	0.0001
C2	0.681**	0.0001
C3	0.662**	0.0001
C4	0.616**	0.0001
C5	0.585**	0.0001

Table 6. Association between anthropometric measurements of the left hand and left handgrip strength

Left	Left handgrip strength Correlation coefficient	*P*
Handgrip strength	1.000	
WT	0.741**	0.0001
WI	0.702**	0.0001
WM	0.709	0.0001
WR	0.708**	0.0001
WL	0.679**	0.0001
TI	0.091	0.265
TM	0.159	0.052
TR	0.131	0.111
TL	0.186	0.023
IM	0.018	0.826
MR	0.033	0.689
RL	0.189*	0.020
BPU5	0.099	0.229
C1	0.545**	0.0001
C2	0.603**	0.0001
C3	0.661**	0.0001
C4	0.613**	0.0001
C5	0.513**	0.0001

Results

The age, height, weight, BMI, LBM values, right and left handgrip strength of the male and female participants are seen in Table 1. Associations between the handgrip strength of the right and left hands and BMI and LBM are illustrated in Table 2. No significant difference was found between the handgrip strengths of the right and left hand. The correlation between the handgrip strength of both the right and left hands and LBM was more powerful than the correlation with BMI.

The mean handgrip strengths of the right and left hands were 25.78 ± 6.45 kg and 23.72 ± 5.87 kg respectively in females and 46.32 ± 10.34 kg and 42.66 ± 9.09 kg respectively in males. The handgrip strengths of the right and left hands were significantly different between males and females ($P = 0.001$). The right and left handgrip strengths were higher in males.

The handgrip strengths of the right and left hands, as well as the unilateral upper extremity parameters, are compared in Table 3 and Table 4. In addition, the association between the right and left upper extremities is also seen in these tables. A statistically significant association is present between the handgrip strength and all the parameters measured in the upper extremity ($P = 0.001$). The associations between handgrip strength and the distance between the humerus and the bicondylar and between grip strength and hand width were found to be more significant.

The measurements in the hand were named as demonstrated in Figure 1. The right handgrip strength and right hand measurements are compared in Table 5. The correlation between the distance between the wrist and thumb (WT) of the right hand and right handgrip strength was found to be the most powerful correlation. The association between the distance between tip of index and middle finger (IM), the distance between tip of middle and ring finger

(MR) and the distance between tip of ring and little finger (RL) values of the right hand and right handgrip strength was not statistically significant ($P > 0.05$).

The left handgrip strength and left hand measurements are compared in Table 6 and the correlation between the left WT and left hand grip strength was found to be the most powerful correlation, just as in the right hand. No statistically significant association was found between the distance between tip of thumb and index finger (TI), the distance between tip of thumb and middle finger (TM), the distance between tip of thumb and ring finger (TR), IM, MR, and the perimeter of tip of thumb, index, middle, ring and little fingers (TIMRL = BPU5) values of the left hand and left handgrip strength ($P > 0.05$).

Discussion

Handgrip strength has mainly been studied in connection with various sports. In the present study, it was looked at with respect to hand dimensions and certain anthropometric characteristics of the human body on non-athletes. As was reported in the literature, handgrip strength was significantly higher in male subjects compared to females ($P < 0.001$). Anakwe et al. reported that handgrip strength was greater for males than females in a healthy population. Leyk et al. reported that the mean maximal handgrip strength between highly trained male and female athletes showed the expected clear difference ($P < 0.001$) (Anakwe et al., 2007; Leyk et al., 2007; Montalcini et al., 2013; Sartorio et al., 2002; Wu et al., 2009). By contrast, Jurimae et al. (2008) did not show any significant differences between males and females aged between 8 and 11 years.

There are some studies in which it was noted that handgrip strength could be estimated using LBM, unaffected by hand dimensions (Leyk et al., 2007; Sartorio et al., 2002). In the present study apart from the anthropometric characteristics of the upper extremity, a strong correlation was also observed between handgrip strength and BMI and LBM in young adults. The association with LBM was significantly higher than with BMI ($P_{BMI}<0.001$, $P_{LBM}<0.001$).

A strong correlation was also observed between LBM and handgrip strength independent of sex in a study performed by Sartorio in healthy children (Sartorio et al., 2002). In another study by Jurimae, it was reported that body height was the factor that most affected handgrip strength (Jurimae et al., 2008). However, the last two studies were conducted on prepubertal children, and height is one of the important parameters of development in prepubertal ages.

In an earlier age-dependent study performed by Visnapuu and Jurimae (2007) on children and youth playing handball and basketball, associations of height, weight, and BMI with handgrip strength were found to be more significant than associations of anthropometric measurements and handgrip strength. Fallahi and Jadidian (2011) found a significant difference in handgrip strength and the correlation between handgrip strength with the height between male athletes and a control group. However, they found no significant difference in the correlation between handgrip strength with weight.

When handgrip strength was studied in relation to the anthropometric dimensions of the upper extremities the highest correlation in this study was observed between hand width and the bicondylar width of the humerus for both hands ($P = 0.001$). However, since the data was statistically distributed abnormally, handgrip strength prediction was not made using upper extremity anthropometric measurements in this present study. The association of handgrip strength and forearm circumference was evaluated in a study performed on healthy adults by Anakwe et al. (2007) and it was reported that forearm circumference can be used to predict handgrip strength. The study of volleyball players conducted by Koley et al. (2011) reported that all parameters except the right upper extremity length and the right arm circumference were statistically significantly different from the control group. In the study performed by

Fallahi and Jadidian (2011) the effect of hand length, forearm length, forearm circumference, wrist circumference on handgrip strength was evaluated and the athletes were compared with a control group. A significant difference was observed between the two groups.

In the present study the most powerful correlation was found between left WT and left handgrip strength, just as with the right hand (P = 0,001). The association between right handgrip strength and IM, MR, and RL of the right hand was not statistically significant. Also, no statistically significant association was found between TI, TM, TR, IM, MR, and BPU5 of the left hand and left handgrip strength. Wu et al. (2009) reported that palm length was the most significant factor among the parameters analyzed after sex and age. They surmised that this was associated with an increase in palm muscle mass. Visnapuu and Jurimae (2007) found statistically significant correlations between handgrip strengths and the length and circumference of fingers among the hand measurements taken from young handball and basketball players. In their study, in which they compared the effect of hand dimensions on handgrip strength in male athletes and a control group, Fallahi and Jadidian (2011) found significant differences in the BPU5, the distance between wrist and tip of index finger (WI), and perimeter between wrist and five fingers (C5) measurements. They concluded that those hand measurements could be used to predict handgrip strength and could be helpful in selecting a sports branch to participate in.

In conclusion, this study, which was performed using handgrip strength and upper extremity anthropometric measurements, is a preliminary study in the evaluation of medical approaches regarding the treatment hand injuries, clinical follow-up and hand rehabilitation. In addition, this study may be helpful in selecting athletes, evaluating the suitability of players to particular sports branches and in the arrangement of training programs.

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