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The Effect of Hand Anthropometric Variables on Grip Strength in Grip Elite Athletes and Non-Athletes

Tufan ULCAY[1A], Burcu KAMAŞAK[1B], Kazım KAYA[2C], Ersan KARA[2D]

Ahmet UZUN[3E], Naime M. KONAR[4F]

[1]Kırşehir Ahi Evran University, Faculty of Medicine, Department of Anatomy, Kırşehir, Turkey.

[2]Kırşehir Ahi Evran University, School of Physical Education and Sports, Kırşehir, Turkey.

[3]Ondokuz Mayıs University, Faculty of Medicine, Department of Anatomy, Samsun, Turkey.

[4]Kırşehir Ahi Evran University, Faculty of Medicine, Department of Biostatistics and Medical Informatics, Kırşehir, Turkey.

Address Correspondence to T. Ulcay: e-mail: tufanulcay@gmail.com
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A:Orcid ID: 0000-0003-2203-3850 B:Orcid ID: 0000-0001-5340-1260 C:Orcid ID: 0000-0003-0246-2738
D:Orcid ID: 0000-0003-3815-7276 E:Orcid ID: 0000-0003-4147-3798 F:Orcid ID: 0000-0002-6593-7617

Abstract

In this study, we aimed to determine the anthropometric variables that affect grip strength and to investigate how and to what extent these variables change grip strength in elite athletes and non-athletes. Totally, 74 subjects aged between 18 and 27 participated in this study in two groups including: elite athletes (n=32), and non-athletes (n=42). In our study, 26 hand anthropometric variables were measured on each subject's dominant hand. The selection of the anthropometric parameters was limited only to those that are considered to have an association with handgrip strength. Independent t-test or Mann-Whitney U Test was applied for group comparison. Stepwise multiple linear regression analysis was utilized and Backward selection procedure was also performed to identify the relationship between handgrip strength and anthropometric measurements. Results revealed that some anthropometric measurements of hand significantly higher in elite athlete group than non-athlete group in males and females ($p<0.05$). In conclusion, we found that some hand anthropometric parameters are different in the grip sports and non-athletes, but we cannot exactly determine whether specific sport activities affect these differences or the inherent characteristics of athletes lead them to these sports. Also the handgrip strength of hand related athletes was more than that of non-athletes. This may be because of hand anthropometric parameters. Actually, good positive correlation between handgrip strengths and anthropometric characteristics of hand in grip athletes showed the effect of hand anthropometry on handgrip strength in athletes who use their hands for grasping a ball or opponent.

Keywords: Anthropometry, Handgrip strength, Pinch strength.

Elit Sporcularda ve Sporcu Olmayan Bireylerde El Antropometrik Değişkenlerinin Kavrama Kuvveti Üzerine Etkisi

Özet

Bu çalışmada; kavrama kuvvetini etkileyen antropometrik değişkenleri belirlemeyi ve bu değişkenlerin elit sporcularda ve sporcu olmayan bireylerde kavrama kuvvetini nasıl ve ne ölçüde değiştirdiğini araştırmayı amaçladık. Çalışmaya yaşları 18-27 arasında değişen elit sporcular (n = 32) ve sporcu olmayanlar (n = 42) olmak üzere toplamda 74 denek katıldı. Çalışmamızda, 26 adet el antropometrik parametresi, her bir deneğin baskın elinden alındı. Antropometrik parametrelerin seçimi, yalnızca kavrama kuvveti ile bir ilişkisi olduğu düşünülen parametreler ile sınırlı olarak yapıldı. Grup karşılaştırmaları için bağımsız t-testi veya Mann-Whitney U Testi uygulandı. Aşamalı çoklu doğrusal regresyon analizi kullanıldı ve aynı zamanda, kavrama kuvveti ile antropometrik ölçümler arasındaki ilişkiyi belirlemek için Backward seçim prosedürü uygulandı. El ile ilgili bazı antropometrik ölçümlerin elit sporcu grubunda sporcu olmayan gruba göre erkek ve kadınlarda anlamlı olarak daha yüksek olduğu görüldü ($p <0.05$). Sonuç olarak, bazı el antropometrik parametrelerinin kavrama sporlarında ve sporcu olmayanlarda farklı olduğunu bulduk, ancak belirli spor faaliyetlerinin bu farklılıkları etkileyip etkilemediğini veya sporcuların içsel özelliklerinin onları bu sporlara yönlendirip yönlendirmediğini tam olarak belirleyemedik. Ayrıca el ile ilgili sporcuların kavrama gücü, sporcu olmayanlara göre daha fazlaydı. Bunun nedeni el antropometrik parametreleri olabileceği kanısındayız. Aslında, kavrama kuvveti ile sporcuların antropometrik değişkenleri arasındaki iyi pozitif korelasyon, ellerini bir topu veya rakibi kavramak için kullanan sporcularda el antropometrisinin el kavrama gücü üzerindeki etkisini göstermiştir.

Anahtar Kelimeler: Antropometri, El kavrama kuvveti, Parmak kavrama kuvveti.

INTRODUCTION

Anthropometric measurements are widely used to assess and predict performance in various sports. Anthropometric measurements and morphological characteristics play an important role in determining the success of a sportsperson. An athlete's anthropometric and physical characteristics may represent important prerequisites for successful participation in any given sport. Indeed, it can be assumed that an athlete's anthropometric characteristics can in some way influence his/her level of performance, at the same time helping to determine a suitable physique for a certain sport (21).

The human hand is unique in being free of habitual locomotor duty and devoted entirely to functions of manipulation. Its effectiveness in these activities is due to particular configuration of the bones and muscles which permits opposition of the pulp surface of the thumb to the corresponding surfaces of the other four finger tips in a firm grasp, together with a highly elaborated nervous control and sensitivity of the fingers (4).

Primarily adapted for reaching, grasping and manipulating, the hand functions include activities, such as pushing, adjusting objects, striking blows, and supporting the body in space (16). The grasping of an object is the outcome of simultaneous movements at several joints- transporting the hand to the object, pre-shaping the fingers into an appropriate grip and orienting the wrist. All these movements may differ widely but they all attend the same final purpose: to achieve a stable grasp for holding and manipulating the object. The literature related to the human hand is numerous and related to the structural issues and problems of mobility and forms of grasping (25). The role of the different hand anthropometric variables which produce different force is not well defined.

Handgrip strength is the maximal power of forceful voluntary flexion of all fingers under normal biokinetic conditions (5, 7, 11, 13, 26). Handgrip strength determines the muscular strength of an individual (7). It is a useful indicator of potential declines in physical mobility, cognitive status, health-related quality of life, general physical function and mortality risk (12). This strength is important for catching and throwing the object in different sport branches. In tennis, grip strength when holding a racket is very influential on the results of service punches. In the service stroke the grip strength is the dominant component. Because the greater the grip strength, the racket will not be released or thrown and the greater the power generated in making service punches. In this case it is seen that grip strength is a dominant factor in achieving service accuracy (1). Also, when the fingers are longer and hand surface variables greater than required for grasping an object, fingers will less widely spread, and grasping an object will become more efficient and less fatiguing (7, 24).

With regard to grasping an object, ball or opponent, all sports can be divided into two groups: grasping or grip sports and non-grip sports. In grip sports, like basketball and handball, the greater hand surface, the better the accuracy of the shot or throw. It can be proposed that athletes with greater hand surface also have greater handgrip strength (7, 24). Fallahi and Jadidian (7) stated that handgrip strength was significantly different between handgrip-related athletes and non-athletes. Also, approximately all hand anthropometric characteristics of grip athletes significantly correlated with handgrip strength, which indicates that these variables may have a positive effect on handgrip strength. Visnapuu and Jurimae (24) have indicated that some specific hand anthropometric parameters, especially finger lengths and perimeters, significantly correlated with maximal handgrip strength. Also Otterson and DeBeliso (18) in their study on non-grip athletes such as football players, have indicated that athletes who demonstrated higher ratios of HGS/BM (body mass) performed better in indicators of football performance.

In sports, strength is known to increase sporting success and performance. Especially, handgrip strength is the most important determinant. Handgrip strength is a physical trait that plays an important role providing effectiveness and efficiency during daily work and sports activities. Moreover, in terms of performance, handgrip is an important indicator in many sports (26). For example, during the sambo match, most of the time is spent on gripping the opponent's jacket (sambo uniform), and fighting for adequate grip usually results in high levels of fatigue in the forearms (23). Muscle strength and power are decisive in individual and team sports' successful performance (26).

We hypothesized that maximal handgrip strength is largely determined by hand anthropometric parameters. Assmann et al. stated that athletes displaying both-handedness, large upper forearm circumference as well as strong single pinch force might be promising candidates for the climbing sport, whereas traditional athletes who want to start climbing might benefit from a training which focuses on the upper forearm and pinch grip strength on both hands (3). Therefore, in the current study; we aimed to determine the anthropometric variables effecting the handgrip strength and to investigate how and to what extent these variables change the handgrip strength in grip athletes and non-athletes.

MATERIAL & METHOD

Participants

Totally, 74 subjects aged between 18 and 27 participated in this study in two groups including: handgrip related elite athletes (n=32), and non-athletes (n=42). Of participants, n=37 (50%) were males and n=37 (50%) were females. Congenital anomalies, previous upper limb operations, fractures and injuries that could affect hand were exclusion criteria. Informed consent was obtained from all participants, and the study was approved by the ethics committee of Kırşehir Ahi Evran University, Kırşehir, Turkey (Ethics Apporoval Number: 2019-07/82).

Handgrip related elite athletes (16 male, 16 female players) included basketball (5 male players), volleyball (5 female players), handball (7 male and 7 female players), tennis players (4 female players), and wrestlers (4 male players). An elite athlete defined as one who qualified for a national team at the senior level, or who was a member of a recruiting squad for that team (22). Handball players of both sexes were national players of professional clubs in the Turkish Super League. Basketball and volleyball players have national status in the youth category and are all professional club players. Tennis players were young national team players who participated in international tournaments (International Hitit Cup, International Çukurova Cup). The wrestlers are young national team athletes and have been awarded in top category oil wrestling tournaments. All athletes trained with the frequency as follows: national wrestlers, 8-10 sessions per week and approximately 12-15 hours; national handball, basketball, volleyball and tennis players, 5-6 sessions per week and approximately 7.5-9 hours. Non-athletes (21 male, 21 female) did not participate in any sports.

Anthropometric Measurements

Body height was recorded during inspiration using a stadiometer (to nearest 0.1cm, Seca Wall Mounted Stadiometer) and body weight was measured by digital standing scales (to nearest 0.1 kg, Beurer Glass Scale Removable Display GS 43) and body mass index (BMI) was calculated as the weight per (height)2 in kg/m2 as the general anthropometric variables. The subjects' hand anthropometric dimensions were measured using a digital sliding caliper (to nearest 0.01mm, Yıkoda Vernier Caliper 0-200mm accuracy 0.01mm Ruler Digital Calipers) and a plastic measuring tape.

The grip strength of dominant hand was measured using a standard adjustable digital handgrip dynamometer (Baseline Digital Smedley Hand Dynamometer). The handgrip strength was measured as follows: (a) Each subject was tested while sitting comfortably on a chair without arm rest, with his or her back leaned against the chair; (b) Each subject was instructed to sit with their hips and knees flexed at 90o, shoulders adducted and neutrally rotated, elbow flexed at 90o, forearm rotation at 0o, wrist between 0o and 30o_ of dorsiflexion and between 0o and 15o_ of ulnar deviation. Pinch strength was measured with pinchmeter (Jamar Digital Pinchmeter 50 LB) by tip (two-point) pinch, key (lateral) pinch, and palmar (three-jaw chuck) pinch. Tip pinch is thumb tip to index fingertip. Key pinch is thumb pad to lateral aspect of middle phalanx of index finger. Palmar pinch is thumb pad to pads of index and middle fingers (14). For each strength test the scores of three successive trials were recorded for dominant hand.

In this study, 26 hand variables were measured on each subject’s dominant hand by following the standard procedure outlined by Pheasant (19) and Hall et al. (10). The selection of the anthropometric dimensions was limited only to those that are considered to have an association with handgrip strength.

Hand length (HL) of the dominant hand (the distance from the tip of the middle finger to the midline of the distal wrist crease when the forearm and hand are supinated on a table) (Figure 1b), hand breadth (HB) (the distance between the radial side of the second metacarpal joint to the ulnar side of the fifth metacarpal joint) (Figure 1b), hand circumference (HC) (with the tape passing over metacarpal-phalangeal joints II and V, measure the-circumference of the –hand) (Figure 1c), wrist breadth (WB) (with the sliding caliper, measure the breadth of the wrist at the level of the wrist crease baseline) (Figure 1a), wrist circumference (WC) (with, the tape perpendicular to the long axis of the forearm, measure the circumference of the wrist at the level of the wrist crease) (Figure 1c), fist circumference (FC) (subject makes a tight fist with his/her thumb tucked against the middle phalanges of digits II and III. With the tape passing over the metacarpal-phalangeal joints of all five digits, measure the circumference, of the fist.) (Figure 2a), hand thickness (HT) (with the sliding caliper, measure the maximum thickness of the metacarpal-phalangeal joint of digit III.) (Figure 2b), hand depth (HD) (subject's dominant hand is extended with the thumb lying adjacent to the volar surface of digit II. With the sliding caliper, measure the maximum depth from the volar side of the thenar pad to the dorsal surface of the hand.) (Figure 2c), digit height (D1,2,3,4,5H) (the perpendicular distance from the wrist crease baseline to the midpoint of the tip of digit) (Figure 1b), hand crotch height (HC1,2,3,4H) (the perpendicular distance from the wrist crease baseline to the level of hand crotch) (Figure 1a), digit length (D1,2,3,4,5L) (the distance along the axis of digit from the midpoint of the tip of digit to the level of hand crotch.) (Figure 1b) (8).

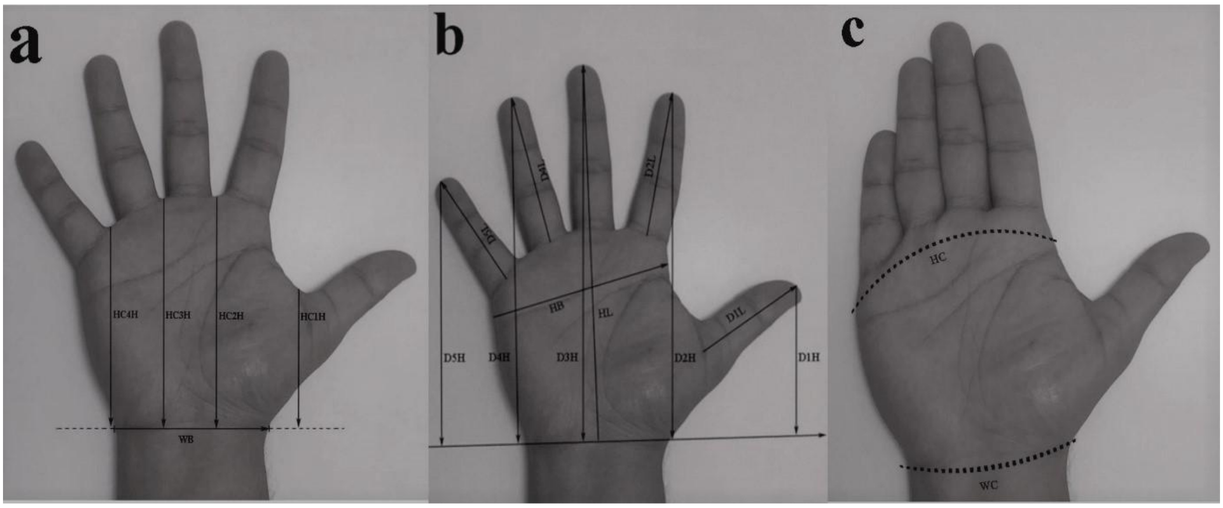

Figure 1. Anthropometric measurements of dominant hand. HL: Hand Length, HB: Hand Breadth, WB: Wrist Breadth, HC1,2,3,4H: Hand Crotch 1,2,3,4 Height, D1,2,3,4,5H: Digit 1,2,3,4,5 Height, HC: Hand Circumference, WC: Wrist Circumference.

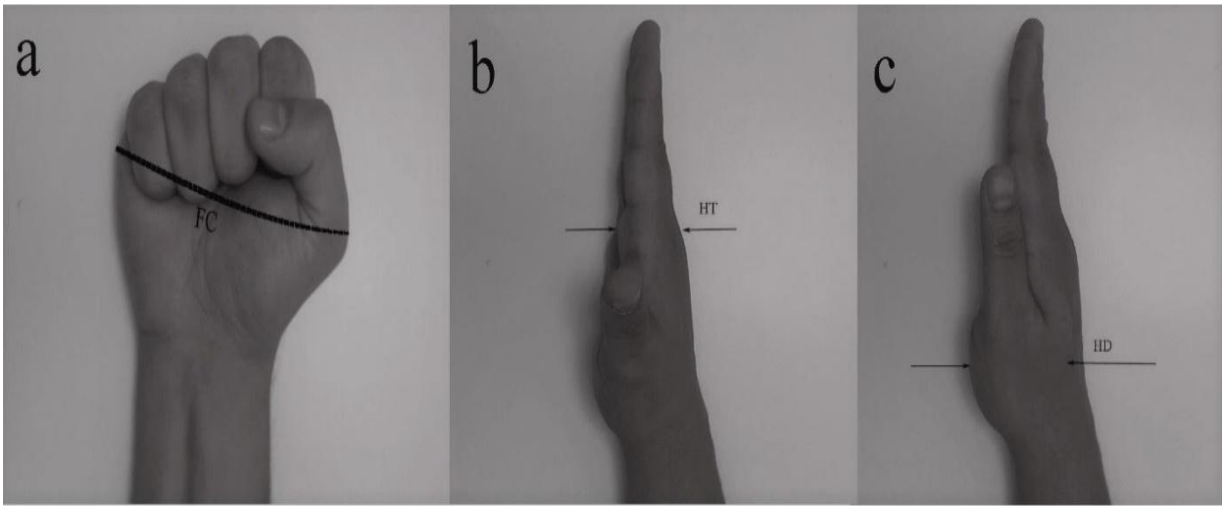

Figure 2. Anthropometric measurements of dominant hand. FC: Fist Circumference, HT: Hand Thickness, HD: Hand Depth.

Statistical Analysis

Numerical variables were reported as mean ± standard deviation; while categorical variables were described as frequency and percentage. Shapiro-Wilk Test was used for normality assumption. Independent Groups t-test was used for normally-distributed data, whereas Mann-Whitney U Test was applied non-normal distributed data for group comparisons. Mean ± standard deviation statistics were reported in case of performing Independent Group t-test, while median, minimum and maximum values were given when Mann-Whitney U Test is used for group comparison. Independent t-test or Mann-Whitney U Test was applied for group comparison. Stepwise multiple linear regression analysis was utilized and Backward selection procedure was also performed to identify the relationship between handgrip strength and anthropometric measurements. Multicollinearity was assessed via Variance Inflation Factor (VIF) values. Adjusted R2 measures were reported for determining regression models' validity. SPSS version 22.0 (IBM Corp. Released 2013. IBM SPSS Statistics for Windows, Version 22.0. Armonk, NY: IBM Corp.) was used in all of the analyses. p-value ≤ 0.05 was considered as statistically significant.

RESULTS

43.2% of the participants were elite-athletes. Basic descriptive statistics were given in Table 1, 2. Results revealed that measurements of hand breadth, fist circumference, wrist circumference, wrist breadth, hand circumference, hand thickness, hand depth, digit 5 height, hand crotch 1 height, digit 1 length, tip pinch, key pinch and palmar pinch were significantly higher in elite-athlete group than non-athlete group in males (p<0.05), while hand length, handgrip strength, hand circumference, digit 1,2,3,4,5 heights, tip pinch, key pinch and palmar pinch significantly higher in female-elite athlete group than female non-athlete group (p<0.05) (Table 1 and Table 2).

Table 1. Group comparisons of anthropometric measurements in males (n=37)

Anthropometric Variable	Non-Athlete Group	Elite – Athlete Group	p-value
Height (m)	1.74 ± 0.01	1.78 ± 0.09	0.084
Weight (kg)	78.82 ± 16.69	85.26 ± 12.24	0.178
BMI (kg/m²)	26.11 ± 5.52	26.92 ± 4.36	0.620
Age	20.67 ± 1.88	21.00 ± 2.73	0.860
Hand Length (HL) (mm)	184.99 ± 8.43	188.09 ± 8.98	0.294
Hand Breadth (HB) (mm)	84.10 ± 3.43	89.66 ± 4.16	<0.001
Hand-grip Strength (kg)	51.93 ± 5.05	55.43 ± 5.67	0.060
Fist Circumference (FC) (mm)	106.633 ± 6.084	105.674 ± 25.305	0.033
Wrist Circumference (WC) (mm)	68.6 ± 4.925	67.713 ± 16.035	0.022
Wrist Breadth (WB) (mm)	56.96 ± 3.64	60.54 ± 3.66	0.006
Hand Circumference (HC) (mm)	82.533 ± 3.925	81.739 ± 19.365	0.026
Hand Thickness (HT) (mm)	28.03 ± 2.13	29.86 ± 2.08	0.013
Hand Depth (HD) (mm)	50.49 ± 3.54	53.76 ± 4.15	0.017
Digit 1 Height (D1H) (mm)	74.20 ± 11.02	80.47 ± 11.36	0.101
Digit 2 Height (D2H) (mm)	172.30 ± 8.77	176.86 ± 9.48	0.145
Digit 3 Height (D3H) (mm)	187.12 ± 7.26	188.59 ± 8.13	0.574
Digit 4 Height (D4H) (mm)	175.07 ± 7.27	178.14 ± 9.51	0.268
Digit 5 Height (D5H) (mm)	142.05 ± 8.96	149.32 ± 10.36	0.032
Hand Crotch 1 Height (HC1H) (mm)	54.41 ± 8.47	60.66 ± 9.47	0.046
Hand Crotch 2 Height (HC2H) (mm)	108.44 ± 14.30	107.98 ± 4.88	0.887
Hand Crotch 3 Height (HC3H) (mm)	106.68 ± 5.95	107.81 ± 4.94	0.528
Hand Crotch 4 Height (HC4H) (mm)	94.98 ± 5.90	100.89 ± 21.66	0.311
Digit 1 Length (D1L) (mm)	64.94 ± 3.36	69.29 ± 4.81	0.002
Digit 2 Length (D2L) (mm)	72.22 ± 3.21	74.39 ± 4.58	0.121
Digit 3 Length (D3L) (mm)	79.71 ± 4.22	80.89 ± 5.40	0.481
Digit 4 Length (D4L) (mm)	74.28 ± 4.15	75.74 ± 4.62	0.329
Digit 5 Length (D5L) (mm)	61.02 ± 3.65	62.66 ± 3.63	0.182
Tip pinch (lbs)	16.54 ± 6.38	24.14 ± 6.17	0.001
Key pinch (lbs)	23.98 ± 7.68	35.00 ± 7.71	0.001
Palmar pinch (lbs)	24.02 ± 7.75	35.81 ± 7.29	<0.001

Table 2. Group comparisons of anthropometric measurements in females (n=37)

Anthropometric Variable	Non-Athlete Group	Elite – Athlete Group	p-value
Height(m)	1.64 ± 0.04	1.68 ± 0.05	0.085
Weight(kg)	59.83 ± 7.75	57.11 ± 4.83	0.229
BMI(kg/m²)	22.24 ± 2.92	20.29 ± 1.00	0.005
Age	20.41 ± 0.93	19.89 ± 0.93	0.157
Hand Length (HL) (mm)	171.96 ± 6.79	177.13 ± 5.69	0.048
Hand Breadth (HB) (mm)	74.19 ± 5.29	77.64 ± 3.23	0.075
Hand-grip Strength(kg)	27.24 ± 4.053	33.73 ± 3.79	<0.001
Fist Circumference (FC) (mm)	94 ± 8.705	96.556 ± 3.812	0.192
Wrist Circumference (WC) (mm)	61.926 ± 3.472	63 ± 2.236	0.541
Wrist Breadth (WB) (mm)	52.673 ± 5.807	52.519 ± 2.355	0.008
Hand Circumference (HC) (mm)	72.167 ± 4.401	76.556 ± 3.712	0.615
Hand Thickness (HT) (mm)	24.37 ± 2.27	25.81 ± 1.41	0.085
Hand Depth (HD) (mm)	189.67 ± 764.92	44.61 ± 3.57	0.577
Digit 1 Height (D1H) (mm)	77.64 ± 11.02	88.82 ± 13.66	0.018
Digit 2 Height (D2H) (mm)	162.43 ± 8.79	164.89 ± 7.32	0.457
Digit 3 Height (D3H) (mm)	171.96 ± 6.59	177.91 ± 6.18	0.023
Digit 4 Height (D4H) (mm)	162.47 ± 7.90	168.62 ± 5.93	0.040
Digit 5 Height (D5H) (mm)	130.29 ± 10.47	141.99 ± 9.19	0.005
Hand Crotch 1 Height (HC1H) (mm)	54.08 ± 5.47	56.24 ± 4.35	0.290
Hand Crotch 2 Height (HC2H) (mm)	97.06 ± 5.26	97.88 ± 3.21	0.664
Hand Crotch 3 Height (HC3H) (mm)	97.23 ± 5.08	100.69 ± 3.75	0.070
Hand Crotch 4 Height (HC4H) (mm)	85.82 ± 5.99	90.13 ± 5.50	0.065
Digit 1 Length (D1L) (mm)	60.25 ± 4.46	61.60 ± 4.64	0.439
Digit 2 Length (D2L) (mm)	69.51 ± 4.36	69.88 ±3.30	0.815
Digit 3 Length (D3L) (mm)	75.09 ± 3.44	76.28 ± 2.82	0.354
Digit 4 Length (D4L) (mm)	69.92 ± 3.90	70.32 ± 3.75	0.786
Digit 5 Length (D5L) (mm)	57.63 ± 3.76	58.63 ±3.91	0.496
Tip pinch (lbs)	9.47 ± 3.78	15.81 ± 5.32	<0.001
Key pinch (lbs)	14.96 ± 4.51	24.98 ± 6.97	<0.001
Palmar pinch (lbs)	14.77 ± 4.52	24.67 ± 6.74	<0.001

Four different stepwise multiple regression models for male non-athlete, male elite athlete, female non-athlete and female elite athlete groups were set to determine the effects of anthropometric measurements on handgrip strength. Also four different regression models were set to investigate the relationship between pinch strengths and handgrip strength. Multicollinearity was not observed in any of the regression models (VIF < 5 for all regression coefficients). Results were shown in following tables (Table 3 and Table 4).

Table 3. Regression analysis results for hand anthropometric variables.

Groups	Parameters	Unstandardized Coefficients	Standardized Coefficients	p-value	95% Confidence Interval for B		VIF
		B	**Beta**		**Lower Bound**	**Upper Bound**	
Male Non-Athletes	(Constant)	-89.674	-	< 0.001	-111.103	-68.245	-
	HB	0.889	0.515	< 0.001	0.514	1.264	2.866
	HT	1.223	0.281	0.009	0.320	2.127	2.610
	HC2H	0.256	0.175	0.028	0.029	0.483	1.466
Male Elite - Athletes	(Constant)	-60.26	-	< 0.001	-92.979	-27.542	-
	HB	0.987	0.605	< 0.001	0.624	1.350	1.109
	HC2H	0.244	0.243	0.033	0.021	0.468	1.109
Female Non-athletes	(Constant)	-95.104	-	< 0.001	-121.579	-68.630	-
	HC	1.306	0.684	< 0.001	0.966	1.645	1.165
	HC2H	0.314	0.268	0.004	0.106	0.522	1.165
Female Elite - Athletes	(Constant)	-79.427	-	< 0.001	-95.025	-63.828	-
	HB	0.96	0.587	< 0.001	0.646	1.275	2.714
	HT	1.538	0.361	< 0.001	0.718	2.358	2.714

HB: Hand Breadth, HT: Hand Thickness, HC2H: Hand Crotch 2 Height, VIF : Variance Inflation Factor

Table 4. Regression analysis results for pinch strengths.

Groups	Parameters	Unstandardized Coefficients B	Standardized Coefficients Beta	p-value	95% Confidence Interval for B Lower Bound	95% Confidence Interval for B Upper Bound	VIF
Male Non-athletes	(Constant)	20.871	-	< 0.001	14.891	26.85	-
	Tip Pinch	0.766	0.449	< 0.001	0.359	1.173	1.831
	Palmar Pinch	2.049	0.335	0.007	0.589	3.509	1.831
Male Elite Athletes	(Constant)	35.528	-	< 0.001	27.312	43.744	
	Key Pinch	0.658	0.286	0.059	-0.025	1.342	1.265
	Palmar Pinch	1.273	0.295	0.051	-0.006	2.553	1.265
Female Non-athletes	(Constant)	19.828	-	< 0.001	11.655	28.001	-
	Tip Pinch	0.571	0.29	0.05	0	1.141	1.358
	Palmar Pinch	2.459	0.304	0.04	0.115	4.804	1.358
Female Elite Athletes	(Constant)	13.096	-	< 0.001	7.969	18.224	-
	Tip Pinch	0.485	0.291	0.039	0.025	0.945	3.544
	Key Pinch	0.791	0.255	0.044	0.021	1.560	2.875
	Palmar Pinch	2.287	0.391	< 0.001	1.07	3.505	2.021

VIF: Variance Inflation Factor

Regression results suggested that hand breadth (β = 0.889; p<0.05), hand thickness (β = 1.223; p<0.05) and hand crotch 2 height (β = 0.256; p<0.05) measurements have statistically significant effects on handgrip strength in male non-athlete group while hand crotch 2 height (β = 0.244; p<0.05) and hand breadth (β = 0.987; p<0.05) measurements were found to be associated with handgrip strength in male elite athlete group. On the other hand, hand circumference (β = 1.306; p<0.05) and hand crotch 2 height (β = 0.314; p<0.05) measurements were observed to have a significant effect on handgrip strength in female non-athlete group; for female elite athlete group however hand breadth (β = 0.960; p<0.05) and hand thickness (β = 1.538; p<0.05) variables were found to be related with handgrip strength (Table 3). Positive correlation was found between hand crotch 2 height mesurements and handgrip strength in male and female non-athlete groups. In overall, hand breadth, hand crotch 2 height and hand thickness measurements in males; hand circumference, hand breadth, hand thickness and hand crotch 2 height measurements increases by and increase of handgrip strength in females (p<0.05) (Table 2). Furthermore, adjusted R2 values were calculated as 0.736 (p<0.05), 0.495 (p<0.05), 0.664 (p<0.05) and 0.803 (p<0.05) for male non-athlete, male elite athlete, female non-athlete and female elite athlete groups, respectively.

Regression analyses which identifies the relationship between tip pinch, key pinch, palmar pinch and handgrip strength had shown that tip pinch (β = 0.766; p<0.05) and palmar pinch (β = 2.049; p<0.05) in male non-athlete group; key pinch (β = 0.658; p = 0.059) and palmar pinch (β = 1.273; p=0.051) in male elite athlete group were found to be associated with handgrip strength. On the other hand, tip pinch (β = 0.571; p=0.05) and palmar pinch (β = 2.459; p<0.05) in female non-athlete group; tip pinch (β = 0.485; p<0.05), key pinch (β = 0.791; p<0.05) and palmar pinch (β = 2.287; p<0.05) were found to have statistically significant effects on handgrip strength in female elite athlete group (Table 4). Adjusted R2 values were calculated as 0.501 (p<0.05), 0.212 (p<0.05), 0.236 (p<0.05) and 0.690 (p<0.05) for male non-athlete, male elite athlete, female non-athlete and female elite athlete groups, respectively. Results showed that palmar pinch measurements were positively correlated in all groups, namely male non-athlete, male elite athlete, female non-athlete and female elite athlete groups. In addition to palmar pinch and tip pinch measurements also increases the handgrip strength in female non-athlete and female elite athlete groups (p<0.05). Key pinch measurements increases the handgrip strength in both male and female elite athletes.

DISCUSSION

The present study was conducted to investigate the effect of hand specific anthropometric measurements and pinch strengths on handgrip strength in grip elite athletes and non-athletes. On the contrary of Visnapuu and Jurimae's (24) study, the major conclusion drawn from this study that some spesific hand anthropometric parameters (Hand Breadth, Hand Thickness and Hand Crotch 2 Height), pinch strengths (tip, key and palmar) are more important than general body anthropometric parameters (body height, weight, and BMI) in affecting handgrip strength in both hand related elite athletes and non-athletes. These variables may have a positive effect on handgrip strength. There are previous studies investigating the parameters affecting the handgrip strength. In these studies, it is mentioned that the effect of the parameters affecting the handgrip strength is positive. But none of these studies indicated the amount of effect. We believe that this amount of effect is so important for grassping in hand related sport branches.

Similar to Fallahi and Jadidian's (7) study, the handgrip strength of elite female athletes was significantly higher in our study than in the control group. Although the same result was found in male subjects, it was not statistically significant. In Fallahi and Jadidian's (7) study, all hand anthropometric characteristics of grip athletes significantly correlated with handgrip strength, which indicates that these variables may have a positive effect on handgrip strength. And they indicated that there was no significant difference in hand shape and palm length between the two groups. Also in their study, general body anthropometric characteristics (body height, body mass, lean body mass, and body fat content) were significantly different between the groups. They found other variables, especially palm width, middle finger length, forearm circumference and wrist circumference were significantly different between the groups. Their results showed that handgrip strength of athletes is greater than that of non-athletes. Also they found that finger lengths have a high positive correlation with handgrip strength of the dominant hand. They stated that hand shape did not correlate with handgrip strength in both groups, so it may not be significant in handgrip strength. And they indicated that hand shape, especially in this method, may not be a useful variable for comparing athletes, who have griping tasks, and nonathletes (7). In our study, we found that hand breadth, fist circumference, wrist circumference, wrist breadth, hand circumference, hand thickness, hand depth, digit 5 height, hand crotch 1 height, digit 1 length, tip pinch, key pinch and palmar pinch were significantly higher in elite-athlete group than non-athlete group in males ($p<0.05$), while hand length, handgrip strength, hand circumference, digit 1,3,4,5 heights, tip pinch, key pinch and palmar pinch significantly higher in female-elite athletes than female non-athletes ($p<0.05$).

Ruiz et al. (20) have stated that the optimal grip span was influenced by hand span in both genders. For males the optimal grip span can be derived from the equation $y = x/7.2 + 3.1$ cm, and for females from the equation $y = x/4 + 1.1$ cm. where y is the optimal grip span and x is the hand-span. Nicolay and Walker (17) have assesed the relationships between anthropometric variation and grip performance for 51 individuals, aged 18–33. They found a significant correlation of finger length with handgrip strength. According to Hager-ross and Schieber (9), investigating children at different ages, hand length and body weight accounted for most of the variability in grip strength.

Everett and Sills (6), in a study conducted on 400 individuals ranging in age from 14 to 29 years (less than 6 percent over 20 years of age), found that weight correlated the highest with handgrip strength, hand width had the second highest correlation with hand grip strength, while hand length and finger length ranked fourth and fifth respectively. Also they indicated that, height ranked third in the zero order correlations with handgrip strength. In the present study, we found that hand thickness correlated the highest with handgrip strength in female elite athletes ($\beta = 1.538$; $p<0.05$), hand circumference correlated the second with handgrip strength in female controls ($\beta = 1.306$; $p<0.05$), hand thickness correlated the third with handgrip strength in male control group ($\beta = 1.223$; $p<0.05$). Hand breadth correlated with handgrip strength in all groups except female control group. So we can say that hand breadth is an important predictor for grassping.

Mullerpatan et al. (15) investigated the normative data of handgrip and pinch strengths for healthy adults (18-30 age range). They found the handgrip strength 33.67 kg in males and 19.51 kg in females. In our study, we found this parameter 51.93 kg in male controls, 55.43 kg in male elite athletes, 27.24 kg in female controls and 33.73 kg in female elite athletes. In males, Mullerpatan et al. (15) found the tip, palmar and key pinch strengths 8.70 lbs, 14.37 lbs and 15.36 lbs respectively, in females, they found these parameters 7.16 lbs, 10.31 lbs and 10.69 lbs respectively. Mullerpatan et al. (15) reported lower data in terms of pinch strength compared to our study and literature (Table 1, 2) (2, 14, 27). The handgrip and pinch strengths in both non-athlete and elite athlete groups obtained in our study were completely consistent with the results of

Mathiowetz et al. (14), Angst et al. (2) and Westropp et al. (27).

In conclusion, we found that some hand anthropometric parameters are different in the grip sports and non-athletes, but we cannot exactly determine whether specific sport activities affect these differences or the inherent characteristics of athletes lead them to these sports. Also the handgrip strength of hand related athletes was more than that of non-athletes. This may be because of hand anthropometric parameters. Actually, good positive correlation between handgrip strengths and anthropometric characteristics of hand in grip athletes showed the effect of hand anthropometry on handgrip strength in athletes who use their hands for grasping a ball or opponent. Intercalarily, some of the hand anthropometric variables (hand breadth, hand circumference, hand thickness, hand depth, hand crotch height and pinch strengths) in athletes may be good predictors of handgrip strength. So, these findings may be useful in the process of sports talent identification in grip sports such as tennis, handball, basketball, volleyball and wrestling, as well as in other sports such as judo, climbing and sambo.

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