Grip and Pinch Strengths in Young Adults Residing in Tehran (2017): Development of Prediction Models

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ABSTRACT

Hand strength is necessary for many daily, working and leisure activities. The aim of this study was to determine the predictors of handgrip and pinch strengths among Iranian young adults. A cross-sectional study was designed in which 716 young adults (354 males, 24.1 years ± 3.2; 362 females, 23.1 years ± 3.6) participated. Demographic characteristics, as well as the length of the hand, palm and forearm, the palm width, and the circumference of wrist and forearm, were measured. A tape meter (± 0.1cm), and a digital Caliper (± 0.1 mm) were used to measure anthropometric dimensions. Jamar hydraulic dynamometer and pinch gauge were used to measure Hand Grip Strength (HGS) as well as Tip (TP), Key (KP) and Palmar (PP) pinch strengths. Mean values of HGS, TP, KP and PP varied from 25.6 to 80, 4.1 to 8.7, 6.4 to 14.7 and 5.4 to 12.7Kg in men and from 14 to 39, 3.2 to 6.0, 4.7 to 8.1 and 3.4 to 9.3Kg in women, respectively. Multiple linear regression analysis showed gender, age, height and BMI as the best predictors of hand strengths. The values of hand strengths are easily predictable using a few readily available individual attributes. Results may serve as a benchmark for job selection.

Keywords: Hand Strengths, Jamar Dynamometer, Pinch Gauge, Grip

INTRODUCTION

Handgrip strength (HGS) and pinch strengths (PSs) are known as essential variables reflecting the functionality of hand and upper extremities. Testing of hand strength is conducted for different goals including evaluation of neuromuscular disorders [1], assessment of hand and upper extremities functions as well as disease severities [2,3], cardiovascular disorders [4] and ageing consequences like general illnesses and inabilities [5].

Some factors, such as gender, age, height, weight, body mass index (BMI), muscle size, and hand dominancy are the most important parameters found to be related to hand strength. For instance, stronger grip strength is reported for males compared to females [6,7], and for dominant hand compared to the non-dominant one [8]. Adequate scientific evidences exist which support the correlation between grip and pinch strengths with hand anthropometric dimensions and upper extremities postures among them, many revealed a meaningful correlation at a significance level of 0.01 between palm width, hand length, palm length and wrist circumference with hand strengths [9,10]. Palm width, hand length, and forearm circumference have been introduced as the best predictors of hand strength even in comparison with individual height and weight [11–13]. However, the fact that hand sizes vary according to the ethnicity and nationality could at least partly explain the existed differences in the HGS of different populations; which are not likely to follow the similar profile [14–16].

Population-specific data on hand strength is required if measurements are to be correctly interpreted. In addition, recognizing easily measurable cofactors provide an accurate prediction of grip and pinch strengths, applicable both in clinical settings and in design procedures. A limited number of studies has attempted to predict grip and pinch strength. Focusing on this topic, the present study intends to provide specific benchmarks and to investigate related factors with hand strengths. Four types of hand strengths (power grip, tip, key and palmar pinches) were measured in both hands for both men and women while the relationship of each one with demographic and anthropometric factors (i.e., age, weight, height, BMI, hand length, palm width, palm length, forearm length, wrist circumference and forearm circumference) was examined. Accordingly, the most

appropriate predictor regression equations for grip and pinch strengths are presented.

MATERIALS AND METHODS

The present cross-sectional study was carried out from May to June 2017. Students of a large public university in Tehran were invited to participate. Measurements took place on the campus of the university. Participants were asked to remove all extra objects (e.g. jewellery and wristwatch). Those with long fingernails were excluded from testing, in order to prevent distortion of the results. The ethical consent for this research was filled out by each participant before testing.

Participants

A minimum sample size of 664 was reached at using the formula: $n \geq Z^2_{1-\alpha/2} P(1-P)/d^2$, where α (type I error) = 0.01, p (estimated proportion) = 0.5, and d (estimation error)= 0.05 [17]. Finally, to handle the eventual problem with missing data, 716 students (354 males and 362 females), came from across the country to Tehran, were participated in the study. None of them was involved in manual work or had joint problems in hand, elbow, wrist; cervical/thoracic/lumbar spine pathologies; neurological disorder; the history of fracture in hand/arm areas or upper limb injury/deformities over the past one year.

Anthropometric measurements

Hand dimensions (hand length, palm length, palm width, forearm length, waist circumference, and forearm circumference) were measured based on the standard technique of National Aeronautics and Space Administration (NASA), as following [18]:

- *Hand Length (HL):* The distance from the base of the hand at wrist crease to the tip of the middle finger, measured along the long axis of the hand.
- *Palm Length (PL):* The distance from the base of the hand at wrist crease to furrow at the base of the middle finger.
- *Palm Width (PW):* Measure from the edge of the hand on one side, across the palm to the edge of the hand on the other side, at the level of the metacarpophalangeal joints, with the fingers parallel and extended.
- *Wrist Circumference (WC):* The circumference of the wrist, measured at the level of the tip of the styloid process of the radius.
- *Forearm Length (FL):* Length of the forearm or middle (mesomelic) segment of the arm
- *Forearm Circumference (FC):* The circumference of the forearm at approximately 3.8-5 cm below the distal crease of the elbow.

For measurement of the abovementioned dimensions, a digital Caliper (±0.1mm) and a tape meter (±0.1cm) were used. Using a stadiometer, height and weight were recorded to the nearest 0.1 cm and 0.1 kg, respectively. Body mass index (BMI) was calculated in kg/m^2. The age of participants was recorded from their identity cards. Hand dominancy was determined by asking the following question: "Are you left-handed or right-handed dominant?"

HGS and PSs measurements

Measurements were made by a trained expert using the hydraulic Jamar dynamometer (set at level II) and the pinch gauge (Hersteller/manufactures; SEHAN Corporation, Masan-Korea; Distributer Rehaforum Medical GmbH, Elmshorn-Germany). Following the criteria proposed by the American Society of Hand Therapy (ASHT) for the evaluation of grip and pinch strengths [20], participants were asked to sit on a chair with adducted and neutrally rotated shoulders; 90 degrees flexed elbow and neutral positioned forearm and wrist. In this position, they were requested to apply as much pressure as possible on the grip dynamometer as well as on the pinch gauge. Three types of pinch strength (i.e. Tip, Key and Palmar strength) were measured. The procedure was repeated three times for each hand with a 1-minute interval (as rest time), and the average was recorded in kilograms for further analysis. Since HGS and PSs do not seem to vary from morning to afternoon, all measurements were carried out during the day without any concern [21]. Equipment was calibrated prior to and throughout the testing by setting the dynamometer dial to zero in order to ensure accuracy of the procedure.

Data Analysis

Measurements were made using the hydraulic Jamar dynamometer (set at level II) and the pinch gauge (Hersteller/manufactures; SEHAN Corporation, Masan-Korea; Distributer Rehaforum Medical GmbH, Elmshorn-Germany). Following the criteria proposed by the American Society of Hand Therapy (ASHT) for the evaluation of grip and pinch strengths [19], participants were asked to sit on a chair with adducted and neutrally rotated shoulders; 90 degrees flexed elbow and neutral positioned forearm and wrist. In this position, they were requested to apply as much pressure as possible on the grip dynamometer as well as on the pinch gauge. Three types of pinch strength (i.e. Tip, Key and Palmar strength) were measured. The procedure was repeated three times for each hand with a 1-minute interval (as rest time), and the average was recorded in kilograms for further analysis. Since HGS and PSs do not seem to vary from morning to afternoon, all measurements were carried out during the day without any concern [20]. The equipment was regularly calibrated in order to ensure the accuracy of the results.

Data Analysis

Mean, standard deviation (SD), median and range of variables (maximum and minimum values) were measured via descriptive statistics. Normality assumption and homogeneity of variance were performed using a Shapiro-Wilks test prior to t-testing. The results of this test demonstrated that the distribution of HGS and PSs are relatively normal for the dominant and non-dominant hand of male and female at 1% significant level. Independent and paired-samples t-test was carried out to compare the mean values of HGS and PSs between groups (gender: male, female; hand dominancy: left, right). Pearson Correlation test was performed in order to examine the relation between hand strength with demographic characteristics and hand anthropometric selected dimensions (age, weight, height, BMI, hand length, palm length, palm width, forearm length, waist circumference, and forearm circumference) for each gender.

To formulate prediction equations and solve the problem of multicollinearity, anthropometric variables (height, weight, BMI, hand width, hand length, waist circumference, forearm length, forearm circumference) were initially reduced via principal components analysis. Factors with eigenvalues more than 1 were then extracted. Varimax rotation algorithm was utilized to produce a rotated component matrix. For each rotating component, the original variables with the highest factor loading as "lead variables" were identified to be included in the linear regression models. Variable selection relied on a p-based forward selection algorithm. Separate models were formulated for dominant and non-dominant hand grip and pinch strengths. Finally, to test the relation between HGS and PSs with the selected variables, the multivariate linear regression analysis was used. SPSS version 23 was used for statistical analysis with a significance level of < 0.05, throughout.

RESULTS

Descriptive statistics of participants are presented in Table 1. Among all participants, 626 (87.43%) were right-handed dominant.

Table 1: Demographic characteristics of participants (n=716**)**

Variables	Males (n=354)		Females (n=362)	
	Mean±SD	**Min-Max**	***Mean±SD***	**Min-Max**
Age (years)	24.10±3.26	18-30	23.18±3.69	18-30
Weight (kg)	74.95±9.10	50-105	59.45±8.56	42-93
Height (cm)	178.1±5.76	162-204	163.95±5.10	140-178
BMI (kg/m^2)	23.55±2.96	15.6-31.1	22.03±2.83	15.8-33.2

BMI: Body Mass Index.

Table 2 presents the Mean, SD and range values of HGS and PSs for both males and females. Mean values of hand strengths (HGS and PSs) were greater in male compared to female ($P<0.01$). The results also showed that the dominant handgrip strength was significantly higher than non-dominant hand for both genders (%10.2 for male and %9.5 for female, $P<0.01$). However, any type of pinch strength (tip, key and palmar) was not statistically different between the dominant and non-dominant hands.

Table 2: Average grip and pinch strengths values (kg) of Iranian youth by gender and hand dominancy.

	Hand	**Males (n=354)**		**Females (n=354)**	
		Mean±SD	**Min-Max**	***Mean±SD***	**Min-Max**
Power grip	D	50.0±7.9	34.0 - 80.0	28.08±4.4	18.0 - 39.0
	ND	44.9±7.8	25.6 - 72.0	25.41±4.9	14.0 - 37.5
Tip pinch	D	6.6±0.7	4.80 - 8.7	4.63±0.55	3.6 - 6.0
	ND	6.2±0.8	4.16 - 8.3	4.15±0.67	3.2 - 5.9
Key pinch	D	11.4±1.3	8.0 - 14.7	6.65±0.71	4.7 - 8.1
	ND	10.3±1.2	6.4 - 7.0	6.16±0.61	4.7 - 7.6
Palmar pinch	D	8.7±1.3	6.1 -12.7	6.48±0.88	4.3 - 8.5
	ND	8.2±1.3	5.4 -12.00	5.97±1.04	3.4 - 9.3

SD: Standard Deviation; D: Dominant; ND: Non-Dominant.

Correlations between Anthropometric variables and Hand Strengths

Table 3 presents Pearson correlation coefficients between dominant hand strengths (HGS and PSs) with demographic characteristics and hand-selected dimensions, for both genders. Age had a negative significant correlation with all four types of hand strength; suggesting that as age increases, grip and pinch strengths decrease. Other individual variables (weight, height, BMI) were positively related to grip as well as three types of pinch strength. Concerning grip strength, a meaningful positive correlation was found between HGS and all other variables ($P<0.05$); meaning that the greater is an individual's weight, height, BMI, hand length, palm width, palm length, waist circumference, forearm circumferences and

forearm length, his/her hand grip is expected to be much stronger. However, the highest correlation was observed with palm width ($p < 0.001$, $r=0.6$ for both genders).

Concerning pinch strength, forearm circumference was found as the most correlated factor with all three types of pinches (see Table 3). Tip and key pinch strengths were also correlated with palm width and wrist circumference; while palmar pinch strength was associated with hand length, palm length and wrist circumference, too. No significant relationship was found between other hand anthropometric dimensions and any types of pinch strengths.

Regression Equations

The factor analysis solution showed the presence of two components with eigenvalues of above 1 with variances of nearly 85%. The first factor revealed a close correlation to height followed by hand length and forearm length, respectively; presenting a substitute for the body length. For the second factor, BMI was correlated as the best variable followed by forearm circumference; presenting a substitute parameter for obesity. Therefore, in addition to the gender and age, height and BMI were also entered in the regression analysis.

Enter regression analysis was performed on the following variables (gender, age, age^2, age^3, height, heigth^2, heigth^3, BMI, BMI^2, and BMI^3). Finally, the best linear regression equations were provided based on the highest adjusted R^2 and the lowest standard error (see Table 4).

Table 3: Pearson's correlation coefficients between the strengths of the dominant hand (HGS, PSs) with demographic and hand-selected dimensions for both genders.

Variable	Power grip		tip pinch		key pinch		palmar pinch	
	Male	Female	Male	Female	Male	Female	Male	Female
Age	-0.13*	-0.17*	-0.27**	-0.23**	-0.15*	-0.27**	-0.17*	-0.15*
Weight	0.20**	0.19*	0.24**	0.22**	0.22**	0.19**	0.15*	0.08
Height	0.28**	0.35**	0.21**	0.28**	0.25**	0.20**	0.17*	0.16*
BMI	0.13*	0.19*	0.19*	0.17*	0.15*	0.19**	0.14*	0.17*
HL	0.36**	0.41**	0.09	0.05	0.11	0.10	0.17*	0.15*
PW	0.61**	0.60**	0.21**	0.20**	0.30**	0.25**	0.09	0.02
PL	0.41**	0.30**	0.08	-0.02	-0.04	0.02	0.18*	0.14*
WC	0.24**	0.32**	0.17*	0.15*	0.18*	0.15*	0.15*	0.18*
FC	0.34**	0.24**	0.34**	0.37**	0.37**	0.31**	0.24**	0.20**
FL	0.21**	0.19**	0.05	-0.017	0.04	0.02	0.07	-0.01

HGS: handgrip strength; **BMI**: body mass index; **HL**: hand length; **PW**: palm width; **PL**: palm length; **WC**: Wrist Circumference; **FC**: Forearm Circumference; **FL**: Forearm Length.
*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table 4: Grip and pinch strengths regression equations

	Adjusted R^2	SE	Regression Equation
HGS_D	0.777	5.99	$-41.1 + 16.21\ \text{Gender} + 0.129\ \text{Age} + 0.366\ \text{Heigh} + 0.282\ \text{BMI}$
HGS_{ND}	0.739	6.18	$-36.64 + 15.272\ \text{Gender} + 0.03\ \text{Age} + 0.334\ \text{Heigh} + 0.30\ \text{BMI}$
Tip $pinch_D$	0.691	0.67	$3.86 + 1.962\ \text{Gender} - 0.003\ \text{Age} + 0.003\ \text{Height} + 0.018\ \text{BMI}$
Tip $pinch_{ND}$	0.616	0.71	$3.879 + 1.755\ \text{Gender} - 0.003\ \text{Age} + 0.001\ \text{Height} + 0.025\ \text{BMI}$
Key $pinch_D$	0.831	1.07	$3.609 + 4.523\ \text{Gender} - 0.001\ \text{Age} + 0.013\ \text{Height} + 0.04\ \text{BMI}$
Key $pinch_{ND}$	0.817	0.98	$3.648 + 3.938\ \text{Gender} - 0.002\ \text{Age} + 0.012\ \text{Height} + 0.02\text{BMI}$
Palmar $pinch_D$	0.507	1.12	$2.368 + 1.934\ \text{Gender} + 0.007\ \text{Age} + 0.02\ \text{Height} + 0.029\ \text{BMI}$
Palmar $pinch_{ND}$	0.465	1.19	$3.826 + 2.048\ \text{Gender} + 0.004\ \text{Age} + 0.012\ \text{Height} + 0.007\text{BMI}$

HGS: predicted handgrip strength; D: Dominant; ND: Non- Dominant; R^2: the amount of variance accounted for by the model; Age (years); Height (cm); Gender: male=1 and female=0.

DISCUSSION

As expected, this study was able to determine four easy measurable cofactors for hand strengths among Iranian young population.

In line with many previous studies [21,22], our results showed that gender was the most important variable affecting hand strength which was 44% in the case of grip strength, 29% for tip, 41% for key and 26% for palmar pinches; males being always stronger. Being naturally related to hand size, grip strength is associated with more number of contractile units, faster muscle contraction and greater muscle bulk [23].

The dominant hand is generally stronger in power grip strength than the non-dominant hand [23,24]. Our study showed that this difference was 10.2% for male and 9.5% for female. Following the "10% rule", the dominant hand possesses a 10% stronger grip force than non-dominant hand [25]. Two explanations could account for this result. First, the muscles of the dominant hand are more usually used forcefully in many daily activities than the other hand, and hence

dominant muscles get bigger and thus stronger. Second, being used more predominantly in everyday activities would result in larger forearm circumference; the hand dimension that is already known to be correlated with grip strength [12,26].

Concerning pinch strength values, they were also greater in dominant hand compared to the non-dominant one. Surprisingly, tip and palmar pinch strength differences between the two hands were higher for females than males (4.36 % for the tip and 2.1 % for palmar). This may be explained by frequent use of this type of pinches in more precise activities which are predominantly accomplished by females such as sewing, chopping and writing [27]. These activities often require the use of a more agile dominant hand as the main actuator, which can increase the strength difference between hands. The higher mean value of dominant hand for pinch strength compared to the other hand is reported by some researchers [28]. However, this trend was reversely observed for key pinch strength; meaning that the difference between the key pinch strength values of two hands is lesser among females than males. Therefore, it can be said that like grip strength, there was a significant difference between the dominant and non-dominant pinch strengths of male and female. However, adjusting for age and methodology, it seems that pinch force is likely to be weaker in Iranian youth compared to other populations. For example, Swiss youth aged between 18 to 30 years were found to have a higher mean pinch strength than Iranian youth of the same age range (approximately 9% for male and 12% for female) [9].

In accordance with previous studies, age had an inverse correlation with hand strength [29–31]. However, these correlations were relatively weak (-0.13 to -0.27) compared to those previously reported. In fact, our limited age range of sample could explain this disparity, since the effect of age is much remarkable in studies with a rather vast age range. Abe et al (2016) showed that the thickness of anterior forearm muscle increases with age; which results in the age-related decline in HGS. However, this effect seems to be accelerated after the seventh decade because of muscle loss [32].

Physiological reasons may explain the high correlation between grip and pinch strengths with height but not weight. Taller people have a larger muscle mass enabling them to implement greater force during gripping and pinching, probably because of the fact that height is closely correlated to muscle volume. In contrast, weight is known as a reflection of fat rather than muscle tissue [33]. In other words, obese people have a higher fat to muscle ratio, which makes them unable to generate as much strength as taller people.

Many other body dimensions especially those of upper extremities have already been found to be related with hand strengths. HGS increases with hand length, palm width, palm length, waist circumference, forearm circumference and forearm length in males and females [12,13,34,35]. However, palm width is the best predictor of HGS in both genders, probably because strong massive muscle, as well as big hand skeleton, lead to grip manual equipment properly [13,29,36]. In some recent studies carried out on Iranian adults, a significant positive correlation was observed between HGS with forearm circumference, hand length and palm width [26,37]. Concerning wrist circumference, despite the contradictory results obtained from some researches [16,24], it seems that HGS increases with wrist circumference in Iranians.

Some previous researchers have formulated prediction models for hand grip and/or pinch strengths in different national and ethnic groups [9,35,38].

The main advantage of this study was to propose simple regression models for predicting values of hand strengths for Iranian youth-based only on four simple and ready-to-measure individual factors. The present study has some limitations that should be discussed. First, the data may not be transferable to countries or populations with different socioeconomic conditions nor to the other age ranges of Iranian people. Second, other contributing factors like nutritional status and ethnicity were not be considered into account in the present study. Further studies would be recommended in order to establish required prediction models in the national or sub-national levels.

CONCLUSION

Grip and pinch strengths of young adults could be easily predicted using a few readily available human parameters (i.e., age, gender, height and BMI). In other words, applying proposed equations, the values of HGS and PSs could be estimated without the need for measuring any of the hand anthropometric dimensions. Findings could be of importance not only in clinical and design settings but also in job selection.

ETHICAL ISSUES

The study was approved by the ethical committee of Shahid Beheshti University of Medical Sciences, Tehran, Iran IR.SBMU.REC. 1396.83).

CONFLICT OF INTEREST

The authors declare no conflicts of interest concerning this article.

AUTHORS' CONTRIBUTIONS

- Study concept and design: Sajjad Rostamzadeh, Mahnaz Saremi

- Acquisition of data: Sajjad Rostamzadeh, Parvin Yazdanparast
- Analysis and interpretation of data: Sajjad Rostamzadeh, Hashem Vahabzadeh-Monshi
- Drafting of the manuscript: Sajjad Rostamzadeh, Hashem Vahabzadeh-Monshi
- Critical revision of the manuscript for important intellectual content: Mahnaz Saremi

FINDING/ SUPPORTS

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