

Investigation of grip and pinch strengths in Iranian adults and their correlated anthropometric and demographic factors

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Abstract.

BACKGROUND: Grip and pinch strength measurement is important for objective evaluation of the function of the upper extremities in upper limbs injuries treatment and also for ergonomists as a way of optimizing the requirements of hand tool design.

OBJECTIVE: The present study was conducted to investigate the correlation of anthropometric and demographic factors with hand strength as well as to develop regression models for grip and three types of pinch strengths including Tip, Key and Palmar in Iranian adult population.

METHODS: The study population consisted of 1008 Iranian adults aged 20 to 107 years. Participants were selected using a stratified random sampling method from crowded places of the cities with the highest number of Persian ethnic group. Strength measurements were undertaken according to recommendations by the American Society of Hand Therapists (ASHT).

RESULTS: This study found a positive and significant correlation between all measured strengths and anthropometric factors. The regression equations of grip and pinch strengths were developed for dominant and non-dominant hands.

CONCLUSION: The results of this study provided more information about correlated factors of grip and pinch strengths. The regression equations developed in this research are applicable to clinical treatment and ergonomics programs.

Keywords: Regression models, anthropometric measurements, grip strength, pinch strength

1. Introduction

Grip strength is used as an index to objectively evaluate the function of the upper extremities in hand injuries treatment procedures [1]. Furthermore, it predicts post-surgical complications and losses [2], general inabilities and aging consequences such as illness risk and mortality increase [3, 4]. Additionally, grip strength testing is used to make decisions for

returning those who suffer from local hand injuries back to work and to estimate the amount of bone mineral density [3, 5]. Other usages include evaluation of other diseases [6] such as rheumatoid arthritis, chronic fatigue syndrome, developing disability, muscular dystrophy and heart attack [7]. Grip strength is of importance to ergonomists as a way of optimizing the requirements of workstations and tools design [8]. Measurement of pinch strength is also used for the same applications [9].

At present, in order to accomplish the mentioned evaluation and treatment purposes, hand strength is compared with normative data of grip and pinch

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strengths [10]. In the previous studies, however, the correlation of factors such as age, gender, posture, anthropometric factors, fat percentage, body mass index, socio-economic situation, occupation, life style and racial affiliation on grip strength were taken into account [11, 12]. Accordingly, by analyzing demographic and anthropometric factors that impact on hand strength, researchers have attempted to propose models for easier and more accurate estimations of grip [11, 12] and pinch strengths [13, 14] in healthy people. It is useful to develop and present models to evaluate the hand strength based on normal data using parameters that can be readily measured [15]. Noting the correlation of anthropometric dimensions on hand strength for developing regression equations can help to estimate deviation from normative data values of grip strength [16].

Based on previous studies [17, 18], the anthropometric factors depend on populations and are different for various ethnic populations. Even for a population of the same ethnic group, some differences in hand dimensions are observed. Additionally, the relationship between grip and pinch strength with correlated variables is different in various studies [19]. Furthermore, previous studies have only applied simple correlated variables which are easily measured. It is worth noting that when estimation accuracy is of importance, these simple variables may not have the required efficiency.

Given the above, the present study was conducted to investigate the influence of anthropometric and demographic factors on grip and pinch strengths and develop regression models for grip strength and three types of pinch strengths; Tip, Key and Palmar pinch, in Iranian adult population.

2. Materials and methods

2.1. Participants

This study was investigated among Persian ethnic group that forms the majority group in Iran. Participants were selected using a stratified random sampling method from the adult Iranian population. In the first step, big cities with the highest percentage of Fars ethnic population were selected including Mashhad, Isfahan, Shiraz, Kerman and Yazd. Within each city between 20 and 30 crowded locations were selected in a way to cover all geographical parts of these cities. In each location, a station was set up with a big notice board. Random samples of pedestrians

were invited to participate, however they were well informed about the main objectives of the study in advance. In total 1110 subjects were approached and 1008 agreed to participate in this study (response rate: 91%). People with musculoskeletal, neurological, cardiovascular and metabolic disorders or history of any diseases that would impact on hand strength were excluded from the study. The data were collected from May to November 2012 when temperatures were moderate. A notice board containing experiment explanations was prepared and installed in the sampling places to inform participants about the aim and procedure of the study. Additionally, the purpose, methods and the duration of the experiments were described to the individuals and their oral agreement to participate in the study was obtained.

2.2. Measurement procedures

Four occupational hygienists partook as the examiners and received appropriate training prior to the commencement of the study. Before the measurements, each sample was briefly interviewed concerning their eligibility to enter to the study and completed a demographic data form (i.e., ethnicity, age, gender, dominant hand, city, physical demand levels (including their work and regular sport activities)). In this study, the level of Physical demand including the participants' job and sport activities, similar to the levels in the study of Crosby and Wehbe, were classified in 6 groups [20]. According to Dictionary of Occupational Titles (DOT), physical activity is classified in five levels, but in the present study, similar to the study conducted by Werle et al. [16], it has been preferred to categorize people such as retired individuals in "beyond sedentary" level.

Strength tests were undertaken according to recommendations of American Society of Hand Therapists (ASHT) [22]. Based on ASHT, the body postures of the participants during the strength tests were determined as sitting, arms attached to the torso not rotating, the elbow flexed at 90 degrees, the forearm in neutral position, the wrist in 0–15 degrees of extension and 0–15 degrees of ulnar deviation. Three grip strengths (for both hands) were measured in this position with a 1-minute rest between each task (to avoid muscle fatigue) using Jamar Hydraulic Dynamometer (Sammons Preston Rolyan). The mean of three successive trials of strength measurements was then used for statistical analysis. Moreover, in order to standardize the participants' grip span, the handle of the Dynamometer as recommended by

ASHT was adjusted to the second position (provided the strongest grip [8]) for all participants and the distance between the two Dynamometer handles was 4.76 cm. Thereafter, based on the method applied by Mathiowetz et al. and the recommendations of ASHT, all participants were tested for tip, key and palmar pinches two successive times for each hand with a 1-minute rest between each task (to avoid muscle fatigue) using a Seahan Pinch Gauge. The maximum strength was recorded as the result of each type of pinch strength [10, 22].

Anthropometric dimensions including height, weight, hand length, hand width, mid-arm circumference, forearm circumference and hand span (for both hands) were measured. The height in centimeters (cm), without shoes, was measured using a portable stadiometer. Weight in kilograms (kg) was measured, without shoes and in light clothing, using a Seca 813 scale. Hand length (the straight distance between the crease of the wrist and the tip of the middle finger) and hand width (across the knuckles of the four fingers) were both measured in millimeters using a caliper. Mid-arm circumference was measured using a measuring tape being placed gently but firmly around the arm (the point halfway between the acromion and the olecranon process of the ulnar bone). Forearm circumference was taken five centimeters from the elbow crease using a Seca 201 measuring tape, and hand span (tip of the thumb to the tip of the small finger with the hand opened as wide as possible) was measured by ruler. In this research, body mass index (weight [kg]/height² [cm]) was also calculated to evaluate its influence on grip strength. The instruments for measuring strength were calibrated by the manufacturers and the equipment was purposefully purchased for the present study. Meanwhile, the calibrations were checked regularly throughout the study.

2.3. Statistical analysis

In this study, the relationship between grip and pinch strengths and anthropometric and demographic parameters was analyzed with 95% confidence interval. Accordingly, so as to investigate the relationship between grip strengths and anthropometric dimensions and also the relationship of strengths with age and BMI, Pearson Correlation Test was used. The influence of physical demand levels on grip strengths was evaluated by one-way ANOVA. In order to examine the differences between the genders for grip strength, the independent-samples *t*-test

was applied. Furthermore, to analyze the strength difference between dominant and non-dominant hands, the paired-samples *t*-test was performed. Finally, the modeling of grip and pinch strengths was carried out based on independent variables including age, gender, level of physical activity and anthropometric dimensions (i.e. hand length, hand width, mid-arm circumference, forearm circumference, hand span, height and weight) via stepwise multivariate linear regression analysis.

3. Results

3.1. Participant characteristics

The study population consisted of 1008 healthy Iranian participants (526 males and 482 females) age ranged from 20 to 107 years, living in five cities of Iran. An overwhelming majority of the participants were right-handed (93.4%). Table 1 presents the demographic and anthropometric characteristics of the participants. Normative data for grip and pinch strengths are presented in Table 2. For better interpretation, the parameters relevant to dominant hand were regarded as the basis for analysis.

3.2. Association between demographic factors and grip and pinch strengths

The results indicated that all hand strengths measured in females were significantly lower than those of the males ($p < 0.0001$). Accordingly, the grip strength of the dominant and non-dominant hands in females was 40 percent (17.7 kg) and 41.7 percent (17.6 kg) less than that of males, respectively. Tip, key and Palmar pinch strengths of the dominant hand in females were found to be 34.3 percent (3 kg), 32.5 percent (3.4 kg) and 34.5 percent (3.5 kg) less than those of the males' dominant hand, respectively. Whereas, the non-dominant hand of females' tip, key and Palmar pinch strengths were respectively 33.9 percent (2.9 kg), 33.2 percent (3.4 kg) and 35.4 percent (3.6 kg) less than those of males. Table 3 presents Pearson's correlation coefficients between the strengths of dominant hand and demographic and anthropometric variables. The results demonstrated that there was an inverse and significant correlation between age and all measured strengths in dominant and non-dominant hands in both genders ($p < 0.0001$).

Table 1
Demographic and anthropometric characteristics of the participants

Variables		Males	Females	Total
Age (year)	M (SD)	49.4 (18.1)	48.0 (17.0)	48.7 (17.6)
	Min-Max	20–107	20–91	20–107
Height (cm)	M (SD)	170.1 (7.2)	157.3 (6.5)	163.9 (6.9)
	Min-Max	145–197	136–179	136–197
Weight (kg)	M (SD)	76.2 (13.0)	68.3 (12.1)	72.4 (13.2)
	Min-Max	41.3–124.6	37.7–131.3	37.7–131.3
BMI	M (SD)	26.3 (4.2)	27.6 (4.6)	26.9 (4.4)
	Min-Max	14.5–45.8	17.3–53.4	14.5–53.4
Hand Length (mm)	R hand. M (SD)	193.2 (9.2)	175.8 (9.0)	184.9 (12.6)
	L hand. M (SD)	192.8 (8.9)	175.0 (9.0)	184.3 (12.6)
Hand Width (mm)	R hand. M (SD)	89.9 (4.4)	79.5 (4.5)	84.9 (6.8)
	L hand. M (SD)	88.9 (4.4)	78.4 (4.2)	83.9 (6.8)
Mid-arm Circumference (mm)	R hand. M (SD)	279.4 (30.5)	278.8 (32.6)	279.1 (31.5)
	L hand. M (SD)	276.3 (30.7)	274.9 (34.8)	275.6 (32.7)
Forearm Circumference (mm)	R hand. M (SD)	265.8 (22.2)	238.4 (22.8)	252.7 (26.3)
	L hand. M (SD)	261.6 (22.0)	234.7 (22.2)	248.7 (25.9)
Hand Span (mm)	R hand. M (SD)	225.4 (13.1)	201.1 (13.3)	213.8 (17.9)
	L hand. M (SD)	224.1 (14.0)	199.9 (13.0)	212.4 (18.2)
Hand Dominance	Right. <i>n</i> (%)	495 (94.1)	447 (92.7)	942 (93.4)
	Left. <i>n</i> (%)	31 (5.9)	35 (7.3)	66 (6.6)
Physical Demand Levels (PDL)	Beyond sedentary (%)	101 (19.2)	43 (8.9)	144 (12.2)
	Sedentary. <i>n</i> (%)	129 (24.5)	359 (74.5)	488 (48.7)
	Light. <i>n</i> (%)	111 (21.1)	60 (12.5)	171 (17.5)
	Medium. <i>n</i> (%)	51 (9.7)	4 (0.8)	55 (5.7)
	Heavy. <i>n</i> (%)	62 (11.8)	3 (0.6)	65 (6.5)
	Very heavy. <i>n</i> (%)	72 (13.7)	13 (2.7)	85 (9.4)
City	Mashhad. <i>n</i> (%)	107 (20.4)	93 (19.3)	200 (19.9)
	Isfahan. <i>n</i> (%)	96 (18.2)	100 (20.7)	196 (19.4)
	Shiraz. <i>n</i> (%)	117 (22.2)	99 (20.5)	216 (21.5)
	Kerman. <i>n</i> (%)	107 (20.4)	94 (19.5)	201 (19.9)
	Yazd. <i>n</i> (%)	99 (18.8)	96 (20.0)	195 (19.3)
	Total	<i>n</i> (%)	526 (100)	482 (100)

Table 2
Normative data of grip and pinch strengths in Iranian adults

Strength	Hand ^a	Males (<i>n</i> = 526)			Females (<i>n</i> = 482)		
		Mean	SD	Min- Max	Mean	SD	Min- Max
Grip (kg)	D	44.1	10.8	14.8–77.7	26.5	6.1	8.7–50.0
	ND	42.2	9.9	14.1–71.0	24.6	5.6	7.3–43.7
Tip Pinch (kg)	D	8.8	1.9	3.0–17.5	5.8	1.1	1.4–10.2
	ND	8.4	1.7	2.2–16.5	5.6	0.9	2.5–9.2
Key Pinch (kg)	D	10.7	1.7	5.1–16.8	7.2	1.2	2.6–14.0
	ND	10.3	1.7	4.7–17.7	6.9	1.1	3.8–14.0
Palmar Pinch (kg)	D	10.3	2.7	4.2–22.0	6.7	1.4	5.1–12.2
	ND	10.2	2.6	4.0–21.0	6.6	1.3	2.7–12.5

^aD, Dominant hand; ND, Non-Dominant hand.

3.3. Association between anthropometric factors and grip and pinch strength

There was a positive and significant correlation between all measured strengths and anthropometric dimensions of hand span, hand length, hand width, mid-arm circumference, forearm circumference, height and weight. This means that as the values of anthropometric factors increase, partici-

pants' hand strength increases as well (Table 3). The grip strength in both genders had the highest correlation with height, hand span, forearm circumference and hand length dimensions. While tip and key pinch strengths in males had the highest correlation with forearm circumference and mid-arm circumference, in females they correlated with height and forearm circumference. Analysis also revealed that there was a positive and significant correlation between

Table 3
Pearson's correlation coefficients between the strengths of dominant hand and demographic and anthropometric variables: Females, Up the diameter; Males, Down the diameter

Variables	Age	Grip Strength	Tip Pinch	Key Pinch	Palmar Pinch	Hand Span	Hand Length	Hand Width	Mid arm Circum	Forearm Circum	Height	Weight	BMI
Age	1												
Grip Strength	-0.68***	1											
Tip Pinch	-0.33***	0.48***	1										
Key Pinch	-0.40***	0.63***	0.66***	1									
Palmar Pinch	-0.56***	0.69***	0.57***	0.63***	1								
Hand Span	-0.25***	0.47***	0.29**	0.32***	0.28**	1							
Hand Length	-0.13**	0.39***	0.18***	0.28***	0.23**	0.55***	1						
Hand Width	-0.07	0.33***	0.36***	0.40***	0.19***	0.50***	0.54***	1					
Mid arm Circum	-0.25***	0.32***	0.47***	0.44***	0.28**	0.24***	0.09*	0.35**	1				
Forearm Circum	-0.30***	0.42***	0.47***	0.58***	0.33***	0.34***	0.22***	0.49***	0.85***	1			
Height	-0.47***	0.57***	0.27**	0.37***	0.40**	0.49***	0.58***	0.34**	0.22**	0.30**	1		
Weight	-0.13**	0.29***	0.36***	0.42***	0.21***	0.33***	0.32***	0.46***	0.74***	0.78***	0.37***	1	
BMI	0.09*	0.01	0.25***	0.26***	0.02	0.09*	0.04	0.30***	0.68***	0.68***	-0.21***	0.87***	1

*0.0001 < P-value < 0.05. **0.0001 < P-value < 0.001. ***P-value < 0.0001.

Body Mass Index (BMI) and tip and key pinch strengths.

3.4. Regression equations development

In the present study, in order to increase the power of the effective anthropometric and demographic variables, the analyses were conducted based on the dominant and non-dominant hands, and the relevant equations were developed (Table 4). In these equations, body mass index (BMI) was excluded from regression calculations for its manipulative correlation on weight and height dimensions. In grip and pinch strength equations, regardless of hand dominance, gender and age were the most powerful correlated factors; hand span and hand length were also the best correlated of grip strength among anthropometric factors. Weight and mid-arm circumference, however, were the weakest correlated factors and consequently excluded from the equations for both hands (Table 5). For pinch strength, contrary to grip strength, hand length and hand span were the weakest correlated factor and were excluded; nevertheless, in tip and key pinch strengths, hand width and forearm circumference were found to be the best correlated anthropometric dimensions. Physical demand levels, weight, hand length and hand span were also excluded from the equations for pinch strengths due to their low power. In regression models for Palmar pinch strength, forearm circumference and height were considered to be the best correlated anthropometric dimensions (in both dominant and non-dominant hands). In the equations for palmar pinch strength, hand span and mid-arm circumference were the weakest correlated factors. These two dimensions, as well as physical demand levels, hand length, hand width, mid arm circumference and weight, were excluded from the equations for dominant and non-dominant hands due to their weak effects.

4. Discussion

In this study, the impacts of demographic and anthropometric factors on grip and pinch strengths of healthy Iranian adults were examined and, regression equations were developed. Compared with previous studies [11–13, 23], more parameters were applied in the present research. The integrated association of job and sport activities on hand strength was investigated in this study. In the present study, the power of anthro-

Table 4
Regression Equations of grip and pinch strengths in Iranian adults

Strength	Hand ^a	Adjusted R ²	Regression Equation
Grip (kg)	D	0.78	-31-8.46 gender-0.26 age + 0.10HS + 0.11H L + 0.06 FC + 0.13Height + 0.17HW + 0.37 PDL
	ND	0.80	-28-8.61 gender-0.24 age + 0.10HS + 0.09H L + 0.06 FC + 0.10Height + 0.77H W + 0.49 PDL
Tip Pinch (kg)	D	0.61	1.8-2.13 gender-0.02age + 0.07 HW + 0.01 MAC + 0.01 FC
	ND	0.66	-1.14-1.62 gender-0.02 age + 0.06 HW + 0.02 FC + 0.01 Height
Key Pinch (kg)	D	0.75	0.1-1.91 gender-0.03 age + 0.06 HW-0.01MAC + 0.03 FC + 0.02 Height
	ND	0.75	1.27-1.84 gender-0.03 age + 0.07 HW-0.01MAC + 0.03 FC
Palmar Pinch (kg)	D	0.59	2.09-2.37 gender-0.06 age + 0.04 HW + 0.01 FC + 0.03 Height
	ND	0.63	2.6-2.47 gender-0.06 age + 0.04 HW + 0.01 FC + 0.03 Height

^aD, Dominant hand; ND, Non-Dominant hand. Gender = 1,male; 2,female; age:year; HS = HandSpan in mm; HL = Hand Length in mm; FC = Forearm Circumference in mm; MAC = Mid-arm Circumference in mm; HW = Hand Width in mm; Height in cm; weight in kg; PDL = Physical Demand Levels in six groups [1-6].

ometric dimensions in grip strength equations was higher than those for pinch strengths (Table 4). Angst et al. also found the power of co-factors combined, to be higher for grip than key pinch strength [5].

The results derived from examining the influence of gender and age on the grip strength of Iranian adults were similar to those reported in previous studies [5, 9, 10, 24, 25]. Therefore, the strength of males was more than that of females. Moreover, irrespective to gender, grip and pinch strengths declined as age increased. Bivariate analysis revealed a highly significant inverse correlation between all strength measured and age (Table 3). Multivariate regression analysis indicated that gender and age had the greatest impact on grip strengths in such a way that these two variables could be regarded as the best correlated factors of strength levels (Table 5). Previous studies also reported gender as the most important parameter in estimating hand strength [1, 5, 12-14].

In this study, there was no significant difference between physical demand levels and measured strengths for both genders. The findings reported by Ugurlu and Ozdogan, and Angst et al. were similar to the findings of the present study [5, 14]. They stated that close scores of strength tests among light and medium occupational groups raises doubts about the generalization of this classification [21]. Werle et al., however, observed a significant difference in grip strengths among all occupational groups in their study [16]. Assessing the association of occupational activity on grip strength in German adults, Gunther et al. concluded that grip strength was not dependent on work type but natural style of life together with fitness [8].

Bivariate analysis showed a positive and significant correlation between all measured strengths and anthropometric factors (Table 3). Grip and Palmar pinch strengths had the highest correlation with

height in both genders. The height dimension had a positive correlation with tip and key pinch strengths only in females. Correlation coefficients of height with grip strength of males and females were 0.57 and 0.44, respectively. In comparison, this correlation was respectively 0.39 and 0.42 for German males and females [26]. The height of participants in Ugurlu and Ozdogan study had a higher correlation with pinch strengths compared to their weight [14]. In the present study, the correlation coefficient between weight and grip strength was 0.29 for males and 0.32 for females; correlation coefficient between weight and grip strength was 0.25 for German males and 0.09 for German females [26]. These findings are consistent with the findings of Puh and Angst et al. [5, 9]. Height was also found to estimate hand strength in multivariate regression analysis (Table 5). Weight was the weakest correlated factor of grip and pinch strengths and was excluded from the regression equations. Weight had no correlation in the study by Angst et al. either [5].

In this study, hand length and hand span had a positive significant correlation with grip strength in males and females. In the studies by Wu et al. [8] and Nicolay and Walker [24], hand length had a strong correlation with grip strength. Hand span and hand length were the best correlated factors of grip strength in multivariate analysis, while for pinch strengths, hand length and hand span were the weakest correlated factors and were excluded from the equations. However, the correlation between pinch strength and these factors were significant (Table 3).

Bivariate tests showed that hand width had a positive and significant association with grip strength for both sexes. Multivariate regression analysis indicated that hand width was an effective factor on grip strength. Nicolay and Walker reported hand width to be the best anthropometric dimension to estimate grip strength [24]. In the present study, this factor was a

Table 5
Stepwise multiple regression analysis results of normative grip and pinch strengths in Iranian adults (dominant hand; n = 1008)

Linear effect of variables	Grip strength			Tip pinch strength			Key pinch strength			Palmar pinch strength		
	Regression coefficients	Standardized coefficients	p-values									
Gender												
Male	-8.600	-0.340	<0.0001	-2.030	0.50	<0.0001	-1.920	-0.42	<0.0001	-2.310	-0.40	<0.0001
Female	-0.260	-0.37	<0.0001	-0.020	-0.18	<0.0001	-0.030	-0.23	<0.0001	-0.060	0.35	<0.0001
Age	0.370	0.04	0.008	-0.030	-0.02	0.355	-0.002	-0.001	0.940	0.070	0.03	0.108
PDL	0.110	0.11	<0.0001	0.0001	-0.002	0.950	0.005	0.03	0.393	0.010	0.07	0.080
HL	0.170	0.09	0.003	0.060	0.20	<0.0001	0.060	0.17	<0.0001	0.030	0.08	0.066
HW	0.004	0.01	0.709	0.009	0.13	<0.0001	-0.006	-0.08	0.008	0.005	0.06	0.137
MAC	0.050	0.10	0.002	0.008	0.10	0.031	0.030	0.34	<0.0001	0.010	0.12	0.010
FC	0.100	0.14	<0.0001	0.002	0.01	0.695	-0.004	-0.03	0.270	0.002	0.01	0.701
HS	0.130	0.10	<0.0001	0.010	0.061	0.072	0.020	0.08	0.003	0.030	0.10	0.004
Height	0.003	0.003	0.903	0.007	0.04	0.229	-0.004	0.02	0.393	-0.010	-0.07	0.050
Weight												

Gender = 1, male; 2, female; age = year; HS = HandSpan in mm; HL = Hand Length in mm; FC = Forearm Circumference in mm; MAC = Mid-arm Circumference in mm; HW = Hand Width in mm; Height in cm; weight in kg; PDL = Physical Demand Level in six groups [1-6].

strong correlated factor of tip and key pinch strengths as compared with other anthropometric dimensions studied. Bivariate tests demonstrated that this dimension had a fair correlation with tip and key pinch strengths.

Forearm circumference had a higher correlation with grip strength in males than in females. Gunther et al. observed a lower correlation coefficient in German males and females [26], while Nicolay and Walker found a higher correlation than that of the present study [24]. The correlation between forearm circumference and pinch strength was also stronger in males than females. In multivariate analysis, despite the fact that forearm circumference existed in the equations of all strengths (Table 4), it had more association on pinch than grip strength (Table 5). Forearm circumference was also introduced by Jurimae et al. as one of the correlated factors for grip strength, with 43.3 percent of power in the regression model [27].

Mid-arm circumference had a positive correlation with grip strength among both genders. Nayak and Queiroga reported a positive significant correlation between grip strength and mid arm circumference only in older English males [28]. Furthermore, mid-arm circumference had a stronger correlation with tip, key and Palmar pinch strengths in males. For females, nonetheless, there was only a significant correlation between mid arm circumference and Tip and Key pinch strengths and there was no significant correlation with mid-arm circumference and Palmar pinch strength (Table 3). Multivariate analysis showed that mid-arm circumference was the weakest correlated factor of grip and Palmar pinch strengths, and was consequently excluded from the regression equation. In contrast, this factor was an effective one in regression model of grip strength in older English individuals [28], as well as in regression models of tip and key pinch strengths among Iranian adults (Present study).

In the present study, the relation between grip strength and BMI was not significant, irrespective to gender. This is in line with the results of Anjum et al. [26] and Klum et al. However, Adedoyin et al. found a positive significant correlation only in females [17]. In the present study, there was a positive significant correlation between BMI and tip and key pinch strengths in males, while there was no significant correlation between BMI and Palmar pinch strength in males and all strengths in females.

The developed regression models of this study can be easily programmed and applied to determine readily the normal grip and pinch strengths of individuals. The inability to generalize the developed grip strength

equations to other populations with different ethnic groups, cultures, and socioeconomic situations was one of the limitations of this study. On the other hand, these equations are only valid for the reference populations of databases with normative data of grip strength and are not applicable for those participants with disability. The findings of this study are applicable for estimating the appropriateness of workers' strength with the required strength to work with hand tools. Working with tools which require more strength than the strength of the workers may lead to loss of control of that tool and hence, may result in injuries. For instance, inappropriateness of the elderly hand strength while working with shaver or women's strength while working with drill in an assembly section of the factory are problems that could be tackled with a simple estimation of individuals' strength and with the change in the design and selection of hand tools to minimize the static hand strength and grip strength. This would further help reduce muscle fatigue and impairments in upper extremities.

5. Conclusion

The results of this study provided more information about factors that impact on grip and pinch strengths. Moreover, regression equations were proposed for grip and pinch strengths based on the dominant and non-dominant hand. The regression equations developed in this research are applicable to clinical treatment, physiological studies and medical evidence, and can also be used to compare people with normative data readily.

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