

Normative Gripping Strength data and its Distribution among Middle Eastern Teenage and Young Adults

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Abstract— Reliable and valid evaluation of hand strength is important in many applications especially in hand tools design. There are many factors that determine the gripping strength of a certain population. It is expected that the gripping strength increases with age. The objective of this study is to present normative gripping strength data of young Middle Eastern adults and investigate the gripping strength distribution according to their age. Subjects in the study were 400 healthy male and female volunteers aged 9 to 18 years. Tukey's pairwise comparison test was used to find the significant changes in gripping strength as age increases. The result shows a profile of gripping strength discontinuity in the age domain. Each profile is considered as a target group that can be analyzed separately. The gripping strength for each group is tabulated in anthropometric tables showing the extreme values. It is believed there is currently no gripping strength data available for the population under study and the output of this study is expected to be utilized by product designers and healthcare professionals.

Keywords— Gripping strength; Middle Eastern; young adult; Tukey's test

I. INTRODUCTION

Gripping strength is considered one of the major factors to measure the upper extremity strength [1]. It has been clinically used to estimate adults' strength [2]. Physicians and physiotherapists use it to determine the effectiveness of treatment strategies to hand lesions and in treatment evaluation as seen in [3]. Hand tools designers use it to optimally design tools' handles as seen in [4]. It has been used in so many applications such as ergonomics, physiotherapy and sports [5]. Gripping strength is affected by some factor such as hand and forearm size, gender, age, grip position, and grip span [6-8]. Anthropometric dimensions such as stature, sitting hip breadth, wrist circumference, hand circumference and heel ankle circumference are found to be highly correlated with gripping strength [9].

Available Consolidated normative data is based on studies conducted on limited population in the United States and some European countries as seen in [10]. However, data derived from western population cannot be applied to other population. Study revealed that western mean grip strength can be as much as 1.5 times stronger than Malaysian population [11]. Moreover, Wua, Liangc, Wuc and Huangd [12] found that there is a significance gripping strength difference between western population and Taiwanese adults and suggested that using specific regional gripping strength norms rather than consolidated global would be more accurate in assessing an individual's upper limb by healthcare professionals. Hence, a recommendation that measurements need to be taken in different populations has risen [8].

An important part of the population presented by children and young adults has not given enough attention so far. Limited studies are performed on children covering specifically some medical situations as seen in [8,14,15]. Gripping strength increases with age from early childhood through puberty and begins to decline by the age of 45 years [13]. However, grip behavior along all ages has not been investigated to reveal what happens in between.

The purpose of this study is to measure gripping strength for children living in the Middle East. It also intends to determine the age cutoff point by which a change in gripping strength value is noticeable. Current research studied the gripping strength either by individual ages or by defining a range of ages subjectively. This research intended to determine the classes of ages that are similar in their gripping strength. Statistical analysis techniques were used to define these classes. The procedure is done for dominant and non-dominant hands for both genders.

II. METHODOLOGY

A. Participants

Participant of the study were Middle Eastern students recruited from elementary, mid and high schools studying at international schools in Madinah, Saudi Arabia. Subjects were randomly selected from multiple sections of grades (3- 12). For each grade, twenty students from each gender participated in the study. The total number of subjects is 400 with 200 males and 200 females. Ages of participants were obtained from the students records and entered to the nearest year. All participants were healthy and do not suffer from any joints or wrists problems. Only two male students were left handed and the rest of boys and girls were right handed.

B. Procedure

Data collection was scheduled throughout the academic semester to avoid classes interruption. A full description of the test procedure and the objectives of the study were demonstrated to the subjects before data collection. A pilot run for each age group was carried out to familiarize the subjects with the test procedure and equipment. Dominant hand was determined by asking the subjects which hand they use for writing. To eliminate the effect of device familiarity, the subject is asked to start with the right or the left hand randomly. Subjects perform the gripping while standing with shoulder abducted and naturally rotated, elbow flexed to 90 degrees and forearm with supination position as shown in Fig. 1. They were asked to exert their maximum gripping force for each hand. Each subject performed 3 completely randomized observations for each hand making a total of 2400 observations (400X6). Observations were collected giving participants enough time to rest by alternating with other subjects. To reduce the effect of other factors such as body anthropometrics, random observations were collected. For each observation, the age is selected randomly then a subject is randomly selected within the age.



Fig. 1. A subject performing the test

C. Experimental Design

Analysis of variance (ANOVA) using the Minitab software was used to analyze the gripping strength. A full factorial design (10 X 2 X 2 X 3) for the independent variables included ten levels of the age factor (9-18), two levels of the gender factor (male and female), two levels of hand dominance (dominate, none-dominant) and three replicates for each factor level combinations. The maximum value of the three replicates was recorded for each subject. The mean gripping strength and standard deviation in kilograms for each age and gender is summarized in TABLE I and II. The gripping strength was regrouped as it will be explained in section III using Tukey's pairwise comparison test. The significant level of 0.05 was used for all the hypothesis testing procedures.

TABLE I. MEAN AND STANDARD DEVIATION OF GRIPPING STRENGTH FOR MALE POPULATION

		Age									
		9	10	11	12	13	14	15	16	17	18
Mean	Dominant Hand	10.8	11.5	15.75	16.45	21.55	26.8	33.7	39.9	42.2	44.5
	Non Dominant Hand	10.4	10.9	13.6	16.6	19.5	23.4	27.7	36.7	37.6	37.8
StDev	Dominant Hand	2.09	1.40	2.95	3.12	3.98	6.05	4.27	6.58	7.28	4.83
	Non Dominant Hand	2.19	1.92	3.28	2.81	4.39	5.28	4.24	6.71	7.01	5.02

TABLE II. MEAN AND STANDARD DEVIATION OF GRIPPING STRENGTH FOR FEMALE POPULATION

		Age									
		9	10	11	12	13	14	15	16	17	18
Mean	Dominant Hand	8.6	8.9	11.9	14.7	18.1	21.3	21.3	24.5	26.6	27.3
	Non Dominant Hand	6.1	6.0	8.6	12.0	15.5	18.6	17.0	18.5	19.5	20.6
StDev	Dominant Hand	0.50	3.27	1.72	1.81	3.68	3.14	2.56	4.67	1.78	1.82
	Non Dominant Hand	0.74	1.68	1.84	1.20	3.61	5.14	3.24	5.87	1.38	3.88

III. RESULTS AND DISCUSSION

As shown in Fig. 2, the sample gripping strength average increases with age. However, the population means might not necessary behaves in the same manner since some of the differences in gripping strength means between consecutive ages are probably insignificant. Tukey’s pairwise comparison testing is conducted to detect any significant changes in the gripping strength means as age increases. The ANOVA general linear model is used to find the factors effects on the gripping strength and the results are shown in TABLE III .

Examining TABLE III, all factors and their two-way interactions are significant and affect the gripping strength. Since the gender and dominant factors are significant, the mean gripping strength of their levels are not equal. Based on samples’averages, males score higher gripping strength than their female counterparts and kids score higher using their dominant hand. For the age factor, ANOVA output indicates that there are differences of mean gripping strength among the age groups and and based on samples averages, older kids have higher gripping strength. T-test and Tukey’s pairwise testing procedures are used to examine if the mean gripping strength differences among each factor individually and as they interact with other factors are significant at the population level in contrast with samples averages.

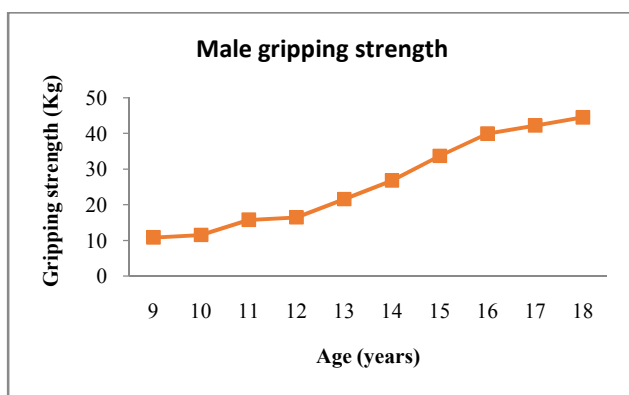


Fig. 2. Gripping strength with respect to age for male subjects

TABLE III. ANOVA OUTPUT

General Linear Model: gripping versus age, gender, dominance					
Analysis of Variance					
Source	DF	Ad SS	Ad MS	F-Value	P-Value
age	9	55894.9	6210.5	342.32	0.000
gender	1	16386.0	16386.0	903.18	0.000
dominance	1	2567.7	2567.7	141.53	0.000
age*gender	9	7511.5	834.6	46.00	0.000
age*dominance	9	755.7	84.0	4.63	0.000
gender*dominance	1	100.3	100.3	5.53	0.019
age*gender*dominance	9	95.4	10.6	0.58	0.811
Error	760	13788.2	18.1		
Total	799	97099.7			

A. T-test

The T-test is used to test the differences between factors having two levels. The following two tests are conducted to determine the mean gripping strength differences between the levels of gender and levels of dominance factor.

$$H_0: \mu_m = \mu_f$$

$$H_a: \mu_m > \mu_f$$

$$H_0: \mu_d = \mu_{ND}$$

$$H_a: \mu_d > \mu_{ND}$$

Where μ_m , μ_f , μ_d , μ_{ND} are the means gripping strength of male, female, dominance and none dominance hand respectively. According to the T-test results shown in TABLE IV, the null hypothesis are rejected and it is concluded that population's mean gripping of the male subjects is greater than the population's mean gripping strength of females subjects. The same conclusion can be drawn for the dominance factor as the population's dominant hand mean gripping strength is greater than the none dominants hand.

TABLE IV. OUTPUT FOR THE MEAN GRIPPING STRENGTH T-TEST OF THE GENDER FACTOR

Two-Sample T-Test and CI: male-gripping, female-gripping				
Two-sample T for male-gripping vs female-gripping				
	N	Mean	Step	SE Mean
male-gripping	400	24.9	12.4	0.62
female-gripping	400	16.01	7.12	0.36
Difference = μ (male-gripping) - μ (female-gripping)				
Estimate for difference: 8.868				
95% lower bound for difference: 7.693				
T-Test of difference = 0 (vs >): T-Value = 12.43 P-Value = 0.000 DF = 637				

B. Data Grouping

Traditionally, gripping strength data are presented by dividing the age domain under study into predefined age groups as seen in [11, 16]. This grouping routine might lead to incorrect representation especially when the data are presented by gripping strength sample average that might be smoothed out as a result of combining unrelated data within the group. In this research, the gripping strength data are combined into age groups where each group consists of ages that have statistically equivalent mean gripping strength. The grouping is accomplished for both genders across the two levels of the hand dominance factor using Tukey’s comparison test. Tukey’s method is preferred over other methods as it is simple, reliable, and it performs the test on the total number of groups simultaneously [17]. Four distinct populations can be formed which include (male, dominant), (male, non-dominant), (female, dominant) and (female, none-dominant).

The grouping starts for each population by testing the mean difference of age 9 gripping strength and age 10 using Tukey’s pairwise comparison test. If the difference is statistically insignificant, then age 10 joins age 9. Age 11 is then tested in the same manner. A disjoint is found when the mean gripping strength of a subsequent age has a mean gripping strength differ significantly from age 9 where this age forms a new group. The grouping procedure continues to cover all the ages in the study. For example, group GI of the (male, dominant) population is formed by age 9, 10 and 11 as a result of the tests that compare age 9 mean gripping strength with ages 10 and 11. The P values of these tests are greater than $\alpha(0.05)$. Since age 12 cannot join Group I, Group II is formed starting at age 12. TABLE V summarizes the grouping output based on Minitab Tukey’s comparison test of the entire (male, dominant) population. The final grouping for all the populations is summarized in TABLE VI.

TABLE V. MINITAB TUKEY’S COMPARISON OUTPUT FOR THE (MALE, DOMINANT) POPULATION

Ages differences	Differences of Means	SE of the Difference	T_value	P	Groups
Age 10-Age 9	0.7	1.35	0.52	1.00	GI(Age 9-11)
Age 11-Age 9	4.95	1.35	3.28	0.101	
Age 12-Age 9	5.65	.35	4.19	0.016*	
Age 13-Age 12	5.1	1.35	3.70	0.07	GII(Age 12-13)
Age 14-Age 12	10.35	1.35	7.6	0.00*	
Age15-Age 14	-5.78	1.35	-4.29	0.01*	GIII (Age 14)
Age 16-Age 15	6.25	1.35	4.64	0.002*	GIV(Age 15)
Age 17-Age 16	1,4	1.35	1.04	1.00	GV(Age 16-18)
Age 18-Age 16	4.6	1.35	3.42	0.213	

* Significant changes in the difference of means gripping strength; $p < \alpha = 0.05$

TABLE VI. FINAL GROUPING FOR ALL AGES

Population	Ages included in groups				
	GI	GII	GIII	GIV	GV
Male, Dominant	9,10,11	12,13	14	15	16,17,18
Male, none-dominant	9,10,11	12,13	14,15	16,17,18	-
Female, Dominant	9,10,11	12,13	14,15,16	17,18	-
Female, none-dominant	9,10,11	12,13,14,15	16,17,18	-	-

The gripping Strength data for all ages in each group are joined for all populations. For example, the collected gripping strength data for ages 9, 10 and 11 are joined to represent group GI data in the (male, Dominant) population. The 5th and 95th

percentile for each group within each population are given in TABLE VII. The data appear differently than a typical anthropometric table. The group columns in TABLE VII has disjoint age groups rather than age groups with fixed ranges. User can utilize these tables for different application considering each group as a separate population.

TABLE VII. GRIPPING STRENGTH ANTHROPOMETRIC TABLE

Population	GI		GII		GIII		GIV		GV	
	5 th	95 th	5 th	95 th	5 th	95 th	5 th	95 th	5 th	95 th
Male, Dominant	7.5	17.8	11.8	26.2	16.9	36.7	26.7	40.7	31.7	52.8
Male, None-Dominant	6.97	16.39	11.84	24.57	16.58	42.16	27.71	47.72	-	-
Female, Dominant	5.84	13.91	11.37	22.12	14.35	27.85	24.27	30.59	-	-
Female, None-Dominant	3.89	3.89	7.67	21.02	12.31	25.96	-	-	-	-

IV. CONCLUSION

This work was triggered by the rare gripping strength data on Middle Eastern populations. The normative gripping strength of 10 Middle Eastern age groups between 9 to 18 years old is investigated. The data in this study are presented differently compared with data presented in previous work. While previous work grouped gripping strength data in a predefined age range, this work group it naturally by finding the cutoff ages between age groups where gripping strength is statistically different. The age domain was analyzed to identify gripping strength discontinuity for each gender and hand dominance combinations. Using Tukey's pairwise comparison, distinctive groups that have different mean gripping strength are found. The data are tabulated in a modified anthropometric table showing the gripping strength extremes for different age groups. This work is limited to age, gender and hand dominance in determining the gripping strength distribution. The methodology can be generalized to study the gripping strength based on the characterization of gripping strength with different age domains and gender considering other factors such as hand geometry, weight, gripping position and physical fitness.

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Ali Mohamed holds his PhD degree from University of Windsor, Canada. He has tremendous experience in industrial engineering applications in both academia and industry. He is familiar with all industrial engineering practices in the auto industry particularly with the big three and their suppliers. Dr. Mohamed has a teaching and research experience in Canadian universities/colleges as well as overseas. Dr Mohamed is currently passing over his learning experience to small and middle size industries in collaboration with international agencies and training companies.