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Effects of Elbow Flexion on the Hand-Grip Strength

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Abstract

The objective of this study was to explore the effects of elbow flexion on the hand-grip strength. The data were collected by trained, senior and graduate students as a required mini-project in an ergonomics course. A sample of 125 female and 222 male adults, ages 18 to 47 (22.5±3.35), body heights of 173.0±10.47cm and body weights of 73.6±16.48 kg, mostly from college student population, were tested using standardized data collection form, positioning and instructions. In this study, the grip strengths of 347 subjects were measured and recorded over a multiple number of years. Pair-wise comparisons using the Student's T-Test showed that the hand-grip strength at the elbow in the fully extended position was significantly higher than when the elbow flexed. The test also showed significantly higher grip strength in 90° flexed position than in 30°, 60° or 120° flexion. No significant differences were found in the grip strength among the 30°, 60° or 120° elbow flexed positions. Comparison of the average hand-grip strength of dominant-hand and non-dominant hand of the subjects showed a significant difference. The female subjects found to have about 41% lower grip strength than the male counterparts.

Keywords: Grip Strength; Elbow Flexion; Dominant and Non-dominant Hand; Gender Effect

Introduction

The hand is the most important work tool for the human. The grip is the action of grasping an object by hand and holding it firmly. The hand grip strength is the ability in forceful flexion of all finger joints with the maximum voluntary force that the subject is able to exert. Grip strength is used as an objective index of the functional integrity of the upper extremity [1]. Manjula, et al. [2] have performed a review of literature on grip strength. Some researchers have reported strong correlations between grip strength and various anthropometric factors, such as weight, height body surface area and hand length [3-6]. Khan, Ansari, and Agrawal [7] reported declining hand-grip strength is associated with increase in the body mass index (BMI). Sartorio, et al. [8] reported increase in the grip strength with age advancement in children, and boys showed greater hand-grip strength than the girls. Smrithi, et al. [9] reported positive correlation between hand-grip strength and weigh and BMI only in females and between hand-grip strength and weigh, height and BMI of males, but negative correlation between hand-grip strength and the weight in overweight male subjects. Mathiowetz, Rennells, and Donahoe [10] reported that grip-strength was higher with the elbow positioned in 90° of flexion as compared with when the elbow was positioned in full extension. Interestingly, the grip strength has been reported to be higher in dominant hand for the right-handed individuals, but no such significant differences could be detected for the left-handed subjects [11].

Objectives

The primary objective of this study was to explore the effects of elbow flexion on the hand-grip strength.
In addition, the study sought to investigate the correlation between HGS and the physical characteristics (i.e., gender, weight, height and handedness).

Methods

Subjects

The study is based on a sample of 347 normal, healthy participants (222 males and 125 females) of ages 22.6±3.5 years. The subjects were volunteer college students whom were recruited by senior and graduate students performing a mini-project, as a required laboratory activity in an ergonomics course. The data were compiled from the student mini-projects over a multiple number of years. A standardized data collection form was provided to each experimenter to record each subject's physical characteristics (i.e., gender, age, weight, height, and handedness), and the hand grip strength data. The physical characteristics of the subjects are summarized in Table 1.

Subjects	Sample Size	Right-Handed	Left-Handed	Weight (kg) Mean±SD	Height (cm) Mean ± SD	Age (years) Mean ± SD
Female	125	116	9	62.0±10.48	164.2±8.11	22.2±3.3
Male	222	197	25	80.2±15.63	178.0±8.16	22.8±3.43
All	347	313	34	73.6±16.48	173.0±10.47	22.5±3.35

Table 1: Physical Characteristics of the participants (subjects).

Equipment and Methodology

The students (observers) were trained in measuring the subject's grip strength. They were provided a standardized data collection form for recording each subject's physical characteristics and their observed experimental data. Each observer collected and recorded the right- and left-hand grip strength data on two subjects using the standardized data collection form and attached to his/her lab report. The grip strength of both right and left hands was measured using a Lafayette Instrument hand-grip dynamometer (Model 78010 measuring up to 100 kg for male subjects and Model 78011 measuring up to 50 kg for female subjects) (Figure 1a) at standing position with shoulder adducted and holding the upper arm vertical on the side but not touching the body, while the elbow flexed at the desired flexed position. The elbow flexion level (angle between the lower and upper arms) was approximated using a goniometer (Figure 1b). The subjects were asked to exert his/her maximum squeezing force on the hand dynamometer handle, and the results were recorded on the data collection form.

Figure 1: (a) a Lafayette Instrument hand grip dynamometer and (b) a goniometer.

The grip strength of both hands was measured in standing position, with the shoulder adducted and held vertical, while the elbow flexion varied at five different angles. As illustrated in Figure 2, the elbow was flexed by 120°, 90°, 60°, 30°, and 0° (elbow in full extension).

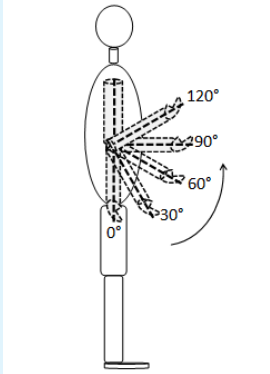

Figure 2: Elbow flexion levels.

The subjects were asked to apply their maximum force on the dynamometer handle in each trial. The observed values were recorded in kilograms. The orders of the measurements on each subject for the hands (left and right), and the elbow positions were predetermined for each subject on a random basis (by lottery-style drawings). Each observer was instructed to alternate the experiments between the two subjects. This along with the hand alternation provided at least 2 minutes for the hand-fatigue recovery. Each pair of measured data was treated as paired-observation, and the Student's t test was used to perform statistical analyses for pair-wise comparisons of the grip strength at the five elbow flexion levels (angles).

Results

All data forms were carefully reviewed, and those with incomplete information were deemed not useful and discarded. The mean and standard deviation (designated as Std Dev) of the grip strength values (in kg force) at various elbow flexion levels were computed for both female and male, as well as all subjects are presented in Table 2.

Grip Strength of Dominant Hand							Grip Strength of Non-dominant Hand					
Flexion:	120°	90°	60°	30°	0°	**Ave**	120°	90°	60°	30°	0°	**Ave**
Female (n = 125)												
Mean	26.5	27.1	26.2	26	28.2	**26.8**	24	24.7	23.8	23.9	25.4	**24.4**
Std Dev	7.07	6.67	7.21	6.83	6.73	**6.54**	6.72	6.74	6.58	6.53	6.5	**6.34**
Male (n = 222)												
Mean	44.5	46.1	45.1	45	47.2	**45.6**	40.4	42.4	41.1	41.2	43.4	**41.7**
Std Dev	9.57	9.88	9.55	9.16	9.75	**8.97**	9.57	9.45	8.95	8.73	9.77	**8.73**
All (n = 437)												
Mean	38	39.3	38.3	38.2	40.4	**38.8**	34.5	36.1	34.9	35	36.9	**35.5**
Std Dev	12.29	12.73	12.62	12.41	12.67	**12.18**	11.71	12.07	11.66	11.52	12.26	**11.51**

Table 2: The mean and standard deviation of the grip strength (in kg force) at various elbow flexion levels for the female, male and all subjects.

The elbow positions associated with the highest measured grip strength values were tallied. As shown in Table 3 for the dominant hand and Table 4 for the non-dominant hand, about a 50% of subjects (both female and male) achieved their greatest grip strength with the elbow in a fully extended position (i.e., in a 0° flexion). The results also revealed that about 27% of the subjects had their highest grip strength with the elbow in the 90° flexed position. Some subject had their greatest grip strengths at a multiple elbow positions. This explains why the percentages add up to more than 100%. As can be seen in Table5, the same pattern was found when the grip strength in both hands of each subjects were averaged.

Elbow flexion	**Female subjects (n = 125)**		**Male subjects (n = 222)**		**All subjects (n = 347)**	
	Number	% of subjects	Number	% of subjects	Number	% of subjects
120°	20	16	27	12	47	14
90°	**27**	**22**	**67**	**30**	**94**	**27**
60°	12	10	21	10	33	10
30°	12	10	17	8	29	8
0°	**65**	**52**	**101**	**46**	**166**	**48**

Table 3: The number and percentage of subjects having the highest grip strengthen their dominant hands at a specific elbow flexion level.

Elbow flexion	Female subjects (n = 125)		Male subjects (n = 222)		All subjects (n = 347)	
	Number	% of subjects	Number	% of subjects	Number	% of subjects
120°	18	14	33	15	51	15
90°	**40**	**32**	**55**	**25**	**95**	**27**
60°	9	7	28	13	37	11
30°	16	13	23	10	39	11
0°	**61**	**49**	**106**	**48**	**167**	**48**

Table 4: The number and percentage of subjects having the highest grip strength in their non-dominant hands at a specific elbow flexion level.

Elbow flexion	Number of subjects	Percentage of subjects
120°	47	14
90°	88	25
60°	25	7
30°	24	7
0°	179	52

Table 5: The number and percentage of subjects having the highest averaged grip strength in both hands at a specific elbow flexion level.

A pair-wise comparison, using the Student's T-Test, was used to statistically analyze the differences in the hand-grip strengths at the five elbow positions. The results of the comparisons are summarized in Table 6 for the dominant hand, Table 7 for the non-dominant hand, and Table 8 for both hands averaged grip strength achieved at the 120°, 90°, 60°, 30° and 0° elbow flexion levels. The comparison test results showed the same patterns of consistent differences in the grip strengths in the dominant, non-dominant and the average for both hands for each pair of elbow positions.

Elbow Flexion	90°	60°	30°	0°
120°	**$DHG_{90°} - DHG_{120°}$** (0.768, 1.765) p-value = 0.000	$DHG_{60°} - DHG_{120°}$ (-0.202, 0.801) p-value = 0.240	$DHG_{30°} - DHG_{120°}$ (-0.334, 0.749) p-value = 0.452	**$DHG_{0°} - DHG_{120°}$** (1.761, 2.982) p-value = 0.000
90°		**$DHG_{90°} - DHG_{60°}$** (0.530, 1.403) p-value = 0.000	**$DHG_{90°} - DHG_{30°}$** (0.575, 1.543) p-value = 0.000	**$DHG_{0°} - DHG_{90°}$** (0.523, 1.688) p-value = 0.000
60°			$DHG_{60°} - DHG_{30°}$ (- 0.266, 0.450) p-value = 0.613	**$DHG_{0°} - DHG_{60°}$** (1.545, 2.599) p-value = 0.000
30°				**$DHG_{0°} - DHG_{30°}$** (1.715, 2.613) p-value = 0.000

Table 6: A pair-wise comparison of the dominant hand grip strength at various elbow flexions.
Note: DHG90° (for example) designates the mean dominant hand grip strength in the 90° elbow flexion. Values in the parentheses are the 95% confidence interval between means of grip strength in the pair of compared elbow flexions.

Elbow Flexion	90°	60°	30°	0°
120°	**$NHG_{90°} - NHG_{120°}$** (1.116, 2.024) p-value = 0.000	$NHG_{60°} - NHG_{120°}$ (-0.039, 0.850) p-value = 0.074	$NHG_{30°} = NHG_{120°}$ (-0.035, 0.952) p-value = 0.068	**$NHG_{0°} - NHG_{120°}$** (1.807, 3.014) p-value = 0.000
90°		**$NHG_{90°} - NHG_{60°}$** (0.769, 1.560) p-value = 0.000	**$NHG_{90°} - NHG_{30°}$** (0.677, 1.546) p-value = 0.000	**$NHG_{0°} - NHG_{90°}$** (0.298, 1.384) p-value = 0.002
60°			$NHG_{60°} - NHG_{30°}$ (-0.390, 0.284) p-value = 0.757	**$NHG_{0°} - NHG_{60°}$** (1.509, 2.502) p-value =.000
30°				**$NHG_{0°} - NHG_{30°}$** (1.502, 2.402) p-value = 0.000

Table 7: Pair-wise comparison of the non-dominant hand grip strength at various elbow flexions.
Note: NHG90°(for example) designates the mean non-dominant hand grip strength in the 90° elbow flexion. Values in the parentheses are the 95% confidence interval between means of grip strength in the pair of compared elbow flexions.

Elbow Flexion	90°	60°	30°	0°
120°	**$BHG_{90°} - BHG_{120°}$** (1.009, 1.827) p-value = 0.000	$BHG_{60°} - BHG_{120°}$ (-0.040, 0.746) p-value = 0.079	$BHG_{30°} - BHG_{120°}$ (-0.102, 0.768) p-value = 0.133	**$BHG_{0°} - BHG_{120°}$** (1.865, 2.927) p-value = 0.000
90°		**$BHG_{90°} - BHG_{60°}$** (0.730, 1.400) p-value = 0.000	**$BHG_{90°} - BHG_{30°}$** (0.696, 1.473) p-value = 0.000	**$BHG_{0°}$ - $BHG_{90°}$** (0.482, 1.464) p-value = 0.000
60°			$BH_{60°} - BH_{30°}$ (-0.249, 0.288) p-value = 0.886	**$BHG_{0°} - BHG_{60°}$** (1.604, 2.474) p-value =.000
30°				**$BHG_{0°} > BHG_{30°}$** (1.674, 2.443) p-value = 0.000

Table 8: Pairwise comparison of both-hands averaged grip strength at various elbow flexions.
Note: BHG90° (for example) designates the mean both-hand averaged grip strength in the 90° elbow flexion. Values in the parentheses are the 95% confidence interval between means of grip strength in the pair of compared elbow flexions

Based on the results, as presented in Tables 6-8, the effects of the elbow flexion levels are grouped and presented in Table 9.

Factor	n	Mean	Grouping		
BH at 120°	347	38.0	A		
DH at 60°	347	38.3	A		
DH at 30°	347	38.2	A		
DH at 90°	347	39.3		B	
DH at 0°	347	40.4			C

Table 9: Grouping Information as was determined by the pair wise comparisons.
Note: Means that do not share a grouping letter are significantly different.

As shown in Table 10, the pair-wise comparison indicated that there is a significant difference between the grip strength obtained by dominant and non-dominant hands.

Paired T for DHGA - NHGA				
	N	Mean	StDev	SE Mean
DHGA	347	38.815	12.176	0.654
NHGA	347	35.47	11.509	0.618
Difference	347	3.345	4.032	0.216
95% CI for mean difference: (2.919, 3.771)				
T-Test of mean difference = 0 (vs ≠ 0): T-Value = 15.45 P-Value = 0.000				

Table 10: A pair-wise comparisons of the effects of the dominant and non-dominant hands on the grip strength.
Note: DHGA and NHGA designate the average grip strength in the dominant and non-dominant hands, respectively.

The average grip strength in both hands of the female and male subjects was compared using the Student's two-sample T-Test. The test revealed a significant difference between the two genders regarding their grip strength (Table 11). On an average basis, the females had about 41% lower grip strength than the male subjects.

	N	Mean	St.Dev	SE Mean
MBHGA	222	43.65	8.54	0.57
FBHGA	125	25.59	6.33	0.57
Difference = μ (MBHGA) - μ (FBHGA) Estimate for difference: 18.057 95% CI for difference: (16.472, 19.641) T-Test of difference = 0 (vs ≠): T-Value = 22.42 P-Value = 0.000 DF = 319				

Table 11: Two-sample T-test for MBHGA vs FBHGA.
Note: MBHGA and FBHGA designate the average grip strength of both hands for the male and females subjects, respectively.

Conclusion

The results of this study revealed that the greatest hand grip strength is attained when the elbow is held in the fully extended position (no flexion). This is probably due to the fact that the muscles are not loaded for holding an object away from the body, which increases torque in the hand-arm joint that must be counter-acted by the muscles for maintaining the state of equilibrium. However, holding the elbow in an extended position and hanging the arm on the side of the body may not be practical for performing most types of work and daily activities. As the results of study revealed, performing the grip exertion task in the 90° flexed elbow position is the next desirable elbow posture, in which the grip strength was found to be statistically significantly higher than the strength obtained in any other elbow flexed positions.

The results of this study also showed that, on an average, the grip strength of the dominant hand was found to be significantly higher than that of the non-dominant hand. However, no significant difference was found for the dominant and non-dominant hands regarding at which elbow position the highest grip strength is achieved. This study showed that the grip strength of the female subjects was significantly lower than that obtained by the male subjects. On an average, the female group had about 41% lower grip strength than the male subjects.

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