THE RELATIONSHIP AMONG ISOMETRIC GRIP STRENGTH RECOVERY AND ANTHROPOMETRIC PARAMETERS

Syed Misbah Uddin[1*], Chowdury M. L. Rahman[2]

[1]*Department of Industrial and Production Engineering, ShahJalal University of Science and Technology, Sylhet-3114, Bangladesh.*E-mail:misbah-ipe@sust.edu*

[2]*Department of Industrial and Production Engineering, ShahJalal University of Science and Technology, Sylhet-3114, Bangladesh*

Abstract

Grip strength has a specific role in ergonomics especially for hand tool using. In ergonomics a hand tool must be designed such a way that provide a better fit for the user, hence it reduces the risk of potential injuries associated with the use of hand tool. Grip strength decreases in repetitive hand activities, and that it will recover after an adequate rest period. This paper presents the relationship between isometric grip strength and recovery in addition to the influence of potential anthropometric factors on grip strength. 20 male and 20 female subject's age range from 20 to 51 years were selected in order to evaluate dominant hand grip strengths. Factors assessed for potential association with grip strength were; demographics such as age and gender; body constructs such as height and weight; upper extremity such as the linear dimensions of elbow to wrist length, hand length and hand breadth. Linear regression analysis was performed in order to identify influencing factors independently associated with grip strength. Pearson product correlation was performed to identify the nature of relationship between isometric grip strength and anthropometric parameters. Through descriptive statistics based on greatest mean grip strength, optimal handle position has been found in position-3 (3.5 cm) for male and position-2 (3.0 cm) for female. Mean grip strength of male has been found greater than female. Grip strengths of male and female in dominant hands are found to decrease with aging, and are significantly different between male and female. Z-test indicates that there are no significant differences on the rate of recovery at each point in time between groups. Linear regression analysis indicates that weight and hand breadth in male; age and weight in female have a significant effect on grip strength.

***Keywords:** Grip strength, Grip Analyzer, Correlation, Z-test, Regression and ANOVA.*

---***---

1. INTRODUCTION

The ability to grip is one of the most important functions of the hand, and grip strength can be used to reflect overall muscular strength [1]. Grip strength has been used as a measure of function in various health-related conditions. Hand grip strength is an easily obtainable measure of physical health and muscle function. Reliable and valid evaluation of hand strength is very important in determining the effectiveness of various surgical or treatment procedure. Grip strength has been found to be associated with numerous factors such as demographics (age, gender), body construct (height, weight, bone mineral density [BMD], hand size, upper arm circumference, hand dominance), socioeconomic variables (occupation, social status, lifestyle) and physical and psychosocial variables. Recovery is the time required for repair of damage strength to the body. The loss of muscular strength of hand is caused by forceful grip strength. The more forceful grip strength required more recovery time to regenerate the muscular strength. Furthermore, grip strengths significantly differ between ethnicities [2]. Grip strength can be used to compare the patient's response to work and subsequent recovery. This will be helpful in determining when return to work should occur. This would be reasonable to expect a similar ranking in terms of work duration and work accomplished. It can be used as a measure of fatigue.

Reliable and valid evaluation of hand strength can provide an objective index of general upper body strength [3]. The grip strength is the result of forceful flexion of all finger joints with the maximum voluntary force that the subject is able to exert under normal conditions. Hand grip strength is an easily obtainable measure of physical health and muscle function. Grip strength decrease in repetitive hand activities, and that it will recover after an "adequate" rest period. In particular, occupational ergonomists have tried to use strength data in redesigning work tasks requiring physical exertion, in order to reduce or eliminate the exposure of workers. It is also able to predict a decline in function in old age [4].

Grip strength has been widely used in evaluating the integrated performances of muscles in orthopedics and ergonomics. Further potential benefit lies in the predictive value of a demonstrated relationship between grip strength and anthropometric measures of the upper extremity. Grip strength may also play a role in injury prevention and rehabilitation.

2. BACKGROUND OF THE STUDY

Since the late 19th Century, assessment of isometric grip strength has been an interest of numerous fields, involving physical educators, anthropologists, and physician as well as occupational therapists [5]. Many of these have sought overt data, such as loss or gain of grip strength, or have wished to compare different populations. Interest in relationships of various human factors and human performance to grip strength has characterized past research [6]. Although numerous dynamometers have been developed, researchers have turned toward the use of models with adjustable handle settings, allowing for adjustment of the instrument to the size of the human hand or for assessing strength at various spans of grip [7, 8]. The value of earlier studies was limited by the lack of standardized anthropometric technique, the lack of grip strength assessment protocols which are consistent with current practice, and the use of a wide variety of dynamometers, many of which are not in common use in occupational therapy clinics. Such information is certainly useful to the occupational therapist as part of grip strength evaluation, but also offers an increased understanding of the dynamics of human grasp as it relates to body dimensions and the size of the object grasped. The ability to generate power of an individual depends on the force that he or she can apply to produce work. The more work can be performed, if more power is generated. Grip strength can be used to reflect overall muscular power as a measure of work capacity of an individual [9]. This study examines the relationship between grip strength and recovery and this study also examines the relationship of several anthropometric variables to isometric grip strength. Findings which demonstrate that greatest strength values are obtained at a specific handle position and that position is significantly different than the other two handle positions.

3. METHODOLOGY

This part contains a description of the subjects, equipment and measurement and data collection methods.

3.1 Description of Subjects

Forty healthy subjects (20 males and 20 females) were recruited to be volunteers for this study. Subjects were between the ages of 20 and 51 years old. Dominance of hand was determined by statement of the subject. Personal data were collected from each subject include age and hand dominance. Exclusion criteria were participating in a regular sport or physical activity, having any fractural injury in any part of the hand, having any operation in arm, wrist or hand, and suffering from pain in upper limb at present.

3.2 Equipment

1. The standard, adjustable-handle dynamometer (Digital Analyzer grip/pinch)
2. Grip transducer.
3. Standard comfortable chair.
4. Weight measuring instrument.
5. Measuring scale.

3.3 Measurement and Data Collection Procedures

Data collection procedures were divided into two sections. The first part contains grip strength measurement and second part is about anthropometric measurement.

3.3.1 Grip Strength Measurement

Each subject was informed detail about the study and questioned about exclusionary criteria to participate in the study. For predicting optimal handle position of dynamometer, grip strength was taken at three positions for each subject in three several days. Grip strength was assessed using a Digital Grip Analyzer. The analyzer consists of adjustable two flat padded bars which is shown in figure 1, mounted parallel to each other maximum 3.5 cm apart. When these are squeezed together the maximum force is indicated on a digital display unit shown in figure 2, which registers from 0 to 1999 Newton (that is, from light touch to heavy pressure). Isometric grip strength data of each subject was measured by a Digital Grip Analyzer. The dynamometer (digital analyzer) was designed to record accurately the pressure exerted on the bars irrespective of the point of grip along their length. For maximum isometric grip strength measurement, the subjects were seated with the hand resting comfortably in a standard height chair. A person's usually have strongest grip strength when their forearm is neutral and the elbow at 90° before their body. The dynamometer was placed with a marked point on one bar against the web of skin between the thumb and index finger. The digital display was then set to zero, thus discounting any resting pressure exerted by the people due to involuntary flexion of the fingers. The observer stood immediately in front of the subject. The grip transducer was then placed in the subject's right hand, with the observer lightly cupping the handle at the base of the instrument in his right hand and the observer lightly supporting digital analyzer front display with his left hand. The observer then ensured that the grip transducer was being held in such a position that the subject's wrist was nearly deviated between neutral and 15 degrees.

Fig-1: Squeezing the two flat padded bars

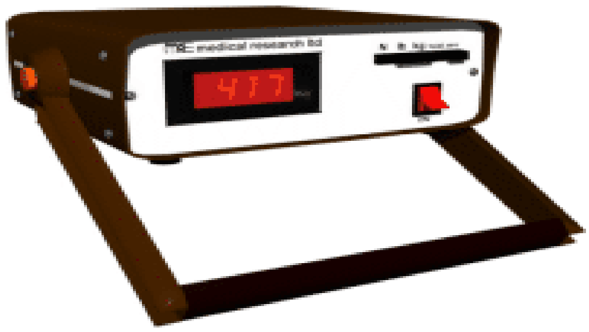

Fig-2: Digital Display Unit (Monitor)

The digital display is set to zero by pressing the zero button on the digital display unit for a minimum of 2 seconds. The Digital Display Unit cannot indicate negative values and so it is necessary to press the zero buttons even if the display already reads zero. Choosing the units we would like the force to be displayed as, on the Digital Display Unit, by pressing the appropriate button on the front panel. We preferred unit of force is in Newton. Each subject was told to squeeze the handles of this instrument as hard as possible and then release. The handles will not move as it squeeze, but the instrument will record the grip strength. The handle width can be adjusted so as to accommodate different hand sizes. A scale is attached to the handle so that a note of the handle width may be taken to ensure that any re-tests are comparable. For predicting the optimal positioning of the handle both male and female subjects, grip strength data was taken for each three position in three several days. Grip strength data were taken for the position of handle width at 2.5, 3.0 and 3.5 cm from each male and female subject. Grip strength data of three handle positions were analyzed by descriptive statistics. According to greatest mean value the handles of the digital analyzer were set at Position-2 (3.0 cm apart) for female and at Position-3 (3.5 cm apart) for male.

The person was told to squeeze the handle as hard as possible and then release after 3 sec. To get the maximum applied force, we activated the hold facility by ensuring that the hold button is pressed in (in = on, out = off). Readings are written down in collection sheet. Adequate recovery time (20 to 30 s) was given between the subsequent measurements to negate the fatigue factor [9]. This procedure was repeated three times with an inter task interval of 20-30 sec for each trial. At the beginning of isometric grip strength measurement, we recorded one data which was mentioned as pre - exercise strength of that person. In similar way grip strengths were measured after 1 min, 5 min, 10 min, and 20 min rest period.

3.3.2 Anthropometric Measurement:

The linear dimensions of elbow to wrist length, hand length and hand breadth were selected because of their relationship to the height of the subject. All anthropometric dimensions data for each subject was taken with the help of a measurement scale. All anthropometric dimensions were measured once and these measurements were used in data analysis. Anthropometric measurements were recorded in the data collection sheet.

4. ANALYSIS AND FINDINGS

Statistical analyses were done using statistical packages for the social sciences (SPSS) for windows version 17.0 and statistical significance was accepted for P values of < 0.05. Z-test (proportion test) was used to find whether differences exist between males and females subjects. Pearson product-moment correlation coefficient was used in the analysis of the associations of anthropometric variables. Due to the composite nature of many of the anthropometric measurements and the number of dimensions, linear regression analysis was used to be more appropriate in clarifying the nature of the relationships. The mean and standard deviation of age, height and weight of 20 male and 20 female subjects are shown in table 1.

Table-1: Anthropometric comparison of subjects across gender groups

Gender	Variables	Min	Max	Mean	Std. Dev.
Male	Age (years)	21	51	33.85	10.256
	Height (cm)	160	180	170.05	5.790
	Weight (kg)	47	82	65.15	8.229
Female	Age (years)	20	45	28.10	7.469
	Height (cm)	147	165	156.30	5.079
	Weight (kg)	46	64	55.65	4.464

4.1 Predicting Optimal Handle Position

Since grip strength varies significantly with the handle positions, there is a need to determine the optimal handle position for each individual. Optimal handle position is defined as the handle position of the digital analyzer at which highest mean of isometric grip strength is achieved. For this grip strengths were taken at three different handle positions such as 2.5, 3.0 and 3.5 cm apart for both the male and female that are shown in table 2. It was observed that maximum grip strength occurred at handle posion-3 (3.5 cm) for male and handle position-2 (3.0 cm) for female. So the optimal handle positions of the digital analyzer for male and female are 3.5 cm and 3.0 cm respectively. At the optimal handle position mean grip strength of male was 334.70 N with S.D of ± 85.273 and the mean grip strength of female was 164.70 N with S.D of ± 26.754. This result shows that grip strength of male is higher than that of female. This result is graphically shown in figure 3.

Table-2: Predicting optimal handle position

Gender		N	Grip strength (Newton)			
			Min	Max	Mean	Std. Dev.
Male	Position-1 (2.5cm)	20	135	501	305.20	74.525
	Position-2 (3.0 cm)		144	523	322.30	78.729
	Position-3 (3.5cm)		139	538	334.70	85.273
Female	Position-1 (2.5 cm)	20	114	195	160.35	25.707
	Position-2 (3.0 cm)		118	206	164.70	26.754
	Position-3 (3.5 cm)		109	210	154.85	27.446

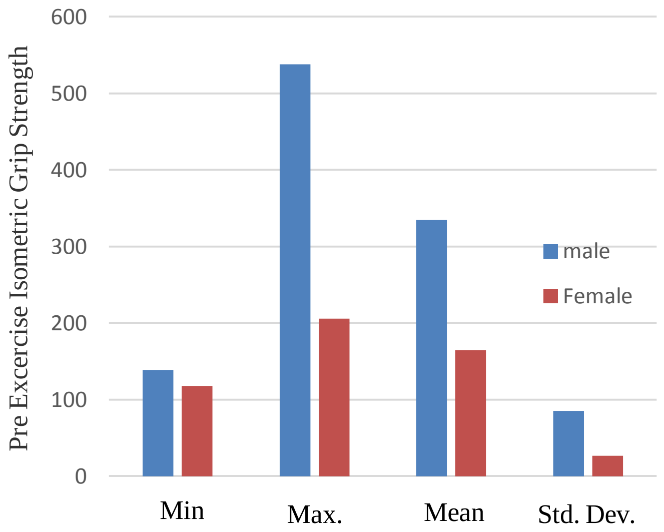

Fig-3: Comparison of pre exercise isometric grip strength between male and female.

4.2 Determination of Relationship between Isometric Grip Strength and Recovery

The relationship between isometric grip strength and recovery was analyzed by Z-test (proportion test) to identify any significance difference among groups. Z proportion test were performed after grouping the subjects in terms of the point in time when each subject returned to his or her initial isometric grip strength level. Those subjects who recovered within 5 min were placed in Group A, those who recovered within 10 min were placed in Group B, those who recovered within 20 min were placed in Group C, and those who required more than 20 min to recover were placed in Group D. In Group A there were 7 subjects (4 males and 3 females) recover within five minutes whose Z value was 0.416. In Group B there were 10 subjects (6 males and 4 females) recover within ten minutes whose Z value was 0.875. In the same way in Group C there were 12 subjects (5 males and 7 females) recover within 20 minutes whose Z value was 0.181.But in Group D there were 11 subjects (5 males and 6 females) did not recover fully within 20 minutes whose Z value was 0.126. All these data are recorded in table 3.

Table-3: Effect of recovery rate on time to recovery.

Group	Male (n1)	Female (n2)	% of Male (% p1)	% of Female (% p2)	Z value	P-value
A (<= 5 min.)	20	20	20	15	0.416	0.3387
B (<= 10 min.)	16	17	37.5	23.5	0.875	0.1907
C (<= 20 min.)	10	13	50	53.8	0.181	0.4282
D (> 20 min.)	5	6	50	46.2	0.126	0.4498

From the table it can be seen that, the P value of each Group is greater than 0.05. Based on P value it is concluded that, there were no significant differences among the groups in terms of the rate of recovery at each point in time. This result is depicted graphically in Figure 4.

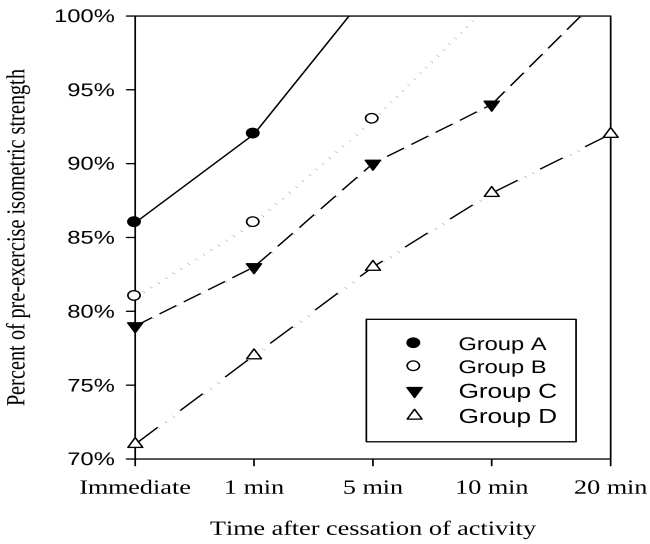

Fig-4: Relationship between post exercise isometric grip strength and recovery across groups based on Time to recover to pre exercise strength

In figure 4, time after cessation of activity are plotted in X axis and percent of pre-exercise isometric grip strength data are plotted in Y axis. Average post exercise isometric grip strength data for each group is plotted against cessation of activity. It is seen that the recovery rate of Group A was greatest among other groups followed by Group B & Group C. However group D did not recover fully within twenty minutes.

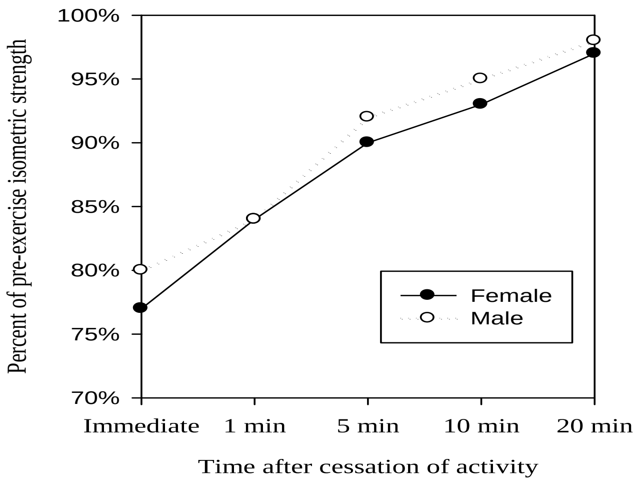

Fig-5: Comparison of gender groups in terms of post exercise isometric grip strength recovery as a percent of pre-exercise isometric strength

The figure 5 gives a graphical representation of comparison of gender groups in terms of post exercise isometric strength recovery as a percent of pre-exercise isometric strength. Time after cessation of activity are plotted in X axis and percent of pre-exercise isometric strength data are plotted in Y axis. Average percentage of post exercise isometric grip strength data of male and female are plotted at different time span. This graph shows, recovery rate increases with the rise of recovery time. From this graph it is also evident that recovery rate of male is greater than the recovery rate of female.

4.3 Determination of Influencing Anthropometric Factors

Pearson product-moment correlation coefficients and linear regression analysis were used to clarify the nature of the relationships between isometric grip strength and influencing anthropometric factors.

Table-4: Correlations of anthropometric factors and isometric grip strength for male.

Correlation coefficient of Male			
Anthropometric variables	Pearson Correlation	Sig. (2-tailed)	Sample size (N)
Age (years)	-.692**	.001	20
Height (cm)	.803**	.000	20
Weight (kg)	.611**	.004	20
Elbow to wrist length (cm)	.664**	.001	20
Hand length(cm)	.729**	.000	20
Hand breadth(cm)	0.235	.318	20
*. Correlation is significant at the 0.05 level (2-tailed).			
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 4 shows the relationships between anthropometric variables and isometric grip strength by Pearson product-moment correlation coefficients for male. From the table it is seen that age is negatively correlated with the grip strength and its value is -0.692 (p = .001), which means grip strength decreases with the increase of age. Height is strongly related with the grip strength. The strength of relationship of weight, elbow to wrist length hand length with the grip strength is moderate whereas hand breadth is poorly correlated to isometric grip strength.

Table-5: Correlations of anthropometric factors and isometric grip strength for female.

Anthropometric variables	Pearson Correlation	Sig. (2-tailed)	Sample size (N)
Age (years)	-0.669**	.001	20
Height (cm)	0.239	.310	20
Weight (kg)	0.551*	.012	20
Elbow to wrist length	0.697**	.001	20
Hand length(cm)	0.023	.922	20
Hand breadth(cm)	0.584**	.007	20
*. Correlation is significant at the 0.05 level (2-tailed).			
**. Correlation is significant at the 0.01 level (2-tailed).			

Table 5 shows the relationships between anthropometric variables and isometric grip strength by Pearson product - moment correlation coefficients for female. The correlation coefficients are high for age, weight, elbow to wrist length and hand breadth. The correlation coefficient between age and isometric grip strength is negative like before. Height and hand length are poorly correlated to isometric grip strength whereas weight, elbow to wrist length and hand breadth are moderately correlated with the grip strength

Linear regression model was used to measure the influencing factors for pre- exercise isometric grip strength. Table 6 shows the degree of dependency of pre- exercise isometric grip strength on the independent variables such as age (years), height (cm), weight (kg), elbow to wrist length (cm), hand length (cm), hand breadth (cm). Multiple correlation R value of 0.915 means the degree of linear relationship between the dependent variable and independent variables is strong. The R2 value of 0.838 means 83.8% variation of pre-exercise isometric grip strength is explained by explanatory variables. Here R2 value is adjusted by 76.3% taken into account degree of freedom in order to overcome the short coming of R2 value. Durbin-Watson test is used to measure auto correlation. Here Durbin-Watson value is 3.015 implies that data set are free from auto correlation.

Table-6: The degree of dependency of pre- exercise isometric grip strength on the anthropometric variables for male

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
0.915	0.838	0.763	41.556	3.015
Predictors: (Constant), Hand breadth (cm), Weight (kg), Elbow to wrist length (cm), Age (years), Hand length (cm), Height (cm)				
Dependent Variable: Pre-exercise isometric strength (Newton)				

The estimated value for the independent variables measured the impact (positive or negative) of the variables on dependent variables. Table 7 shows the estimated value for the parameter weight of 2.811 means that if one unit of weight is increased, the average of grip strength will be increased by 2.811 units, when all other variables are remain constant. The value of t is 1.914 which is significant at the 10% level of significance ($p<0.1$). The estimated value for the parameter age is -1.666 means that if one unit of age is increased, the average of grip strength will be decreased by 1.666 units; when all other variables are remain constant. The value of t is -1.376 which is not significant ($p>0.1$). So, only two parameters weight and hand breadth have a significant effect on isometric grip strength (as $p<0.1$ for the both).

Table-7: Impact of the anthropometric variables on pre-exercise isometric grip strength for male

Variables	Coefficients	Std. Error	t	Sig
(Constant)	-1234.84	493.386	-2.503	0.026
Age (years)	-1.666	1.211	-1.376	0.192
Height (cm)	3.615	5.503	0.657	0.523
Weight (kg)	2.811	1.468	1.914	0.078
Elbow to wrist length	16.672	17.714	0.941	0.364
Hand length (cm)	7.906	14.839	0.533	0.603
Hand breadth(cm)	29.153	14.633	1.992	0.068

The linear regression model summary for female is given in Table 8. From the table it is seen that multiple correlation R value is 0.842 which indicates the strong linear relationship between the dependent variable and independent variables. Since R2 = 0.709, it can be stated that approximately 70.9% of the variation in the value of pre- exercise isometric grip strength is accounted for by a linear relationship with anthropometric parameters. Here R2 value is adjusted by 57.4% and Durbin-Watson value is 1.745.

Table-8: Model summary of dependency of pre- exercise isometric grip strength on the anthropometric variables for female

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
0.842	0.709	0.574	17.452	1.745
Predictors: (Constant), Hand breadth (cm), Weight (kg), Elbow to wrist length (cm), Age (years), Hand length (cm), Height (cm)				
Dependent Variable: Pre-exercise isometric strength (Newton)				

The estimated value of parameters for female is also presented in Table 9. It shows that parameter age and weight have a significant effect on isometric grip strength (as $p < 0.1$ for the both).

Table-9: Impact of the anthropometric variables on pre-exercise isometric grip strength for female

Variables	Coefficients	Std. Error	t	Sig
(Constant)	28.492	270.470	0.105	0.918
Age (years)	-1.565	0.872	-1.795	0.096
Height (cm)	-62.977	98.665	-.638	0.534
Weight (kg)	2.519	1.071	2.350	0.035
Elbow to wrist length	5.692	9.243	0.616	0.549
Hand length (cm)	-1.580	7.652	-0.206	0.840
Hand breadth(cm)	4.786	8.245	0.580	0.572

Analysis of variance (ANOVA) was used to test the linearity of regression. From table 10 it is observed that the model is significant since F significant (F6,13= 5.276, p = 0.006) which indicates that the linear regression model is justified and it adequately represents the experimental data.

Table-10: Result of ANOVA for pre- exercise isometric grip strength and the anthropometric variables for female.

Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	9640.733	6	1606.789	5.276	0.006
Residual	3959.467	13	304.574		
Predictors: (Constant), Hand breadth (cm), Weight (kg), Elbow to wrist length (cm), Age (years), Hand length (cm), Height (cm).					
Dependent Variable: Pre-exercise isometric grip strength (Newton)					

5. CONCLUSION

Specific adjustment of the handle for male and female are necessary. In Digital Analyzer, greatest isometric grip strength of female is obtained in handle position two (3 cm) and for male in handle position three (3.5 cm). So the assessment of the maximum isometric grip strength were carried out with the Digital Analyzer in handle position two for female and in handle position three for male. This study found mean grip strength of male is greater than female. Grip strengths of male and female in dominant hands are observed to decrease with aging, and are significantly different between male and female. It also found that two anthropometric variables weight and hand breadth in case of male; age and weight for female have an adequate influence on isometric grip strength. The rest of the variables have little or no effect on isometric grip strength. There were a considerable gender differences for initial isometric grip strength and post-exercise isometric grip strength. However, there were no significant differences found between males and females in terms of the rate of recovery at each point in time. The information that is gathered during this study may lead to a consistent method of measuring the grip strength and increase the value of measurements that are taken. It may also increase the understanding of how grip strength is related to the anthropometric variables.

REFERENCES

[1]. Rantanen T, Era P, Heikkinen E. “Maximal isometric strength and mobility among 75-year-old men and women”. Age Ageing 1994; 23:132-7.
[2]. JE Lee, “Evaluation of Factors Influencing Grip Strength in Elderly Koreans” 19.2.103 - 2012
[3]. De,S., Sengupta; P., Maity; P., Pal A., and Dhara P.C.in 2011“Effect of Body Posture on Hand Grip Strength in Adult Bangalee Population”.
[4]. Rantanen, T., Guralnik, J.M., Foley, D. 1999. “Midlife hand grip strength as a predictor of old age disability”. The J. Am Med. Asso. 281: 558–560.

[5]. Montpetit, R. R., Montoye, H. J., & Laeding, L. (1967). "Grip strength of school children", Saginaw, Michigan: 1899 and 1964.Research Quarterly, 28, 231-240.
[6]. Malina, R. M. (1975). "Anthropometric correlates of strength and motor performance". Exercise and Sport Sciences Reviews, 3,249-274.
[7]. Bowers, L. E. (1961). "Investigation of the relationship of hand size and lower arm girths to hand grip strength as measured by selected hand dynamometer". Research Quarterly, 32, 308-314.
[8]. Heyward, V., McKeown, B., & Geeseman, R. (1975). "Comparison of the Stoelting hand grip dynamometer and linear voltage differential transformer for measuring maximal grip strength". Research Quarterly, 46, 262-266.
[9]. Lynne D. Wolf, Leonard N. Matheson, Dorian D. Ford & Anita L. Kwak "Relationships among Grip Strength, Work Capacity, and Recovery". Journal of Occupational Rehabilitation, Vol. 6, No. L 1996.

BIOGRAPHIES

Syed Misbah Uddin* is an Assistant Professor of the Department of Industrial and Production Engineering, ShahJalal University of Science and Technology (SUST), Bangladesh. He received his M. A. Sc. in Industrial System Engineering from University of Regina, SK, Canada.

Chowdury M. L. Rahman is an Assistant Professor in the Department of Industrial and Production Engineering of ShahJalal University of Science and Technology (SUST), Bangladesh. He received his B.Sc. Engg. degree in 'Industrial and Production Engineering' from ShahJalal University of Science and Technology, Sylhet, Bangladesh. He completed the course work of M.Sc. program in 'Mechanical and Manufacturing Engineering' from University of Calgary, AB, Canada. His research interests are in the areas of Ergonomics, Production/Operations Management, Operations Research, Logistics and Supply Chain Management.