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Grip Strength Survey Based on Hand Tool Usage

Erman ÇAKIT*[1]

[1]Aksaray University, Engineering Faculty, Industrial Engineering Department, 68100, Aksaray

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Abstract: Hand grip strength is broadly used for performing tasks involving equipment in production and processing activities. Most professionals in this field rely on grip strength to perform their tasks. There were three main aims of this study: i) determining various hand grip strength measurements for the group of hand tool users, ii) investigating the effects of height, weight, age, hand dominance, body mass index, previous Cumulative Trauma Disorder (CTD) diagnosis, and hand tool usage experience on hand grip strength, and iii) comparing the obtained results with existing data for other populations. The study groups comprised 71 healthy male facility workers. The values of subjects' ages was observed between 26 and 74 years. The data were statistically analyzed to assess the normality of data and the percentile values of grip strength. The results of this study demonstrate that there were no significance differences noted between dominant and non-dominant hands. However, there were highly significant differences between the CTD group and the other group. Hand grip strength for the dominant hand was positively correlated to height, weight, and body mass index, and negatively correlated to age and tool usage experience. Hand dominance, height, weight, body mass index, age and tool usage experience should be considered when establishing normal values for grip strength.

El Aleti Kullanımına Göre Kavrama Kuvvetinin İncelenmesi

Anahtar Kelimeler
Kavrama kuvveti,
El aleti kullanımı,
Kümülatif travma bozukluğu

Özet: El kavrama kuvveti, üretim süreçlerinde belirli işleri tamamlamak için kullanılan el aletlerinde önemli yere sahiptir. Bu çalışmada, i) el aletlerini kullanan kişiler arasında kavrama kuvveti farklılığının belirlenmesi, ii) boy uzunluğu, vücut ağırlığı, yaş, sağ-sol el kullanımı, vücut kütle indeksi, el aleti kullanımı deneyimi ve kümülatif travma bozukluklarının (KTB) kavrama kuvveti üzerindeki etkilerinin incelenmesi ve iii) literatürdeki diğer popülasyonların kavrama kuvveti ile karşılaştırılması amaçlanmıştır. Çalışmaya yaşları 26 ile 74 arasında değişen ve sağlık açısından problemi olmayan 71 çalışan katılmıştır. İstatiksel analizler ile elde edilen sonuçlara göre dominant el ile diğer el arasında kavrama kuvveti açısından anlamlı istatiksel farklılık görülmemiştir. Geçmişte KTB rahatsızlığı geçiren grup ile geçirmeyen grup arasında ise önemli derecede istatiksel farklılık görülmüştür. Kavrama kuvvetinin; boy uzunluğu, vücut ağırlığı, ve vücut kütle indeksi ile arasında pozitif korelasyon ilişkisi; yaş ve el aleti kullanım süresi ile negatif korelasyon ilişkisi bulunmuştur. Kavrama kuvveti için normal değerler oluşturulurken; dominant elin kullanımı, boy uzunluğu, vücut ağırlığı, vücut kütle, yaş ve el aleti kullanım süresi göz önünde bulundurulmalıdır.

1. Introduction

Hand grip strength is defined as a measurement of the strength of different muscles in the hand and the forearm [1]. It is measured in either kilograms or Newtons by squeezing a hand grip strength dynamometer with one's maximum strength [2]. Because gripping is important for many daily functions, grip strength is frequently used in clinical practice as a representation of long-term body strength and health [3,4,5]. Hand grip strength is broadly used for performing tasks involving equipment in production and processing activities [6]. Most professionals in this field rely on grip strength to perform their tasks. Facility workers, especially working in small companies, may be more

*Corresponding author: ermancakit@aksaray.edu.tr

likely to use equipment and hand tools that are old and cheap, most of them not ergonomically designed [7]. The use of poor tools might be a potential factor that increases the risk of Cumulative Trauma Disorder (CTD).

In the USA, hand and finger injuries constitute 35% of the total work-related injuries [8]. In order to get information about the capacity of workers, the assessment of grip strength is very important. The obtained information can be considered to design tools, equipment, and workstations [9].

There are various factors which affect hand grip strength such as gender, weight, height, age, and hand dominance[10]. There is a non-linear relationship between grip strength and age [11]. According to gender differences, male participants have greater grip strength than female participants [12]. The dominant hand is almost 10% stronger than the non-dominant hand [13]. In addition, there is a positive relationship between grip strength, weight and height [14].

Several authors have evaluated the grip strength of various populations. For instance, Fernandez and Uppugonduri [15] have compiled data on hand grip strength from South Indian male workers (n=128) in the electronic industry. Chau et al. [16] have compiled grip strength data from French males (n=55) and females (n=45). Kamarul et al. [17] have compiled grip strength data from Malaysian males (n=212). Mandahawi et al. [18] have compiled grip strength data from Jordanian males (n=115) and females (n=120); the subjects were mainly carpenters, vehicle drivers, electrical technician, and others. Recently, Cakit et al. [19] have compiled grip strength data from Turkish male (n=92) and female (n=73) students studying at dentistry faculty.

There were three main aims of this study: i) determining various hand grip strength measurements for the group of hand tool users, ii) investigating the effects of height, weight, age, hand dominance, CTD, and hand tool usage on hand grip strength, and iii) comparing the obtained results with existing data for other populations.

2. Material and Method

2.1. Sample size

The minimum required sample size was predicted applying the equation used in "General requirements for establishing anthropometric databases" [20]:

$$n \geq \left(3.006x\frac{CV}{\alpha}\right)\ CV = \frac{s}{\bar{x}}x100 \qquad (1)$$

(n: sample size, CV: coefficient of variation, α: the percentage value of relative accuracy, $\bar{x}$: the mean value of the population and s: the standard deviation fort he corresponding population).

Based on the inital pilot study of 15 participants, A relative accuracy was assumed as 5%, and using the mean (46,4 kg) and standard deviation (6,45kg) values were calculated and a relative accuracy was assumed as 5%. The minimum required sample size was calculated as 70 from the equation above. Thus, seventy-one US-based healthy male facility workers were randomly selected for this study.

2.2. Participants

Seventy-one US-based healthy male facility workers participated in the study. The values of subjects' ages was observed between 26 and 74 years. The average values and standard deviations of age, height and weight of the subjects were 47.44± 16.34 years, 170.73±10.29 cm, and 80.04± 16.58 kg, respectively. Of the 71 participants, only one was left-handed, the remaining 70 were right-handed. The demographic data of participants are summarized in Table 1. Some of the tools that participants have used mostly are screw drivers, pliers, drill, electric testing, etc. (Figure 1). The hand tool experience was changed between 6 and 55 years and some participants had CTD before.

Figure 1. Some hand tools used frequently by participants

Hand grip strength measurement was taken for both hands. At the beginning of the study, the subjects were informed of the objectives of the study, and those who agreed to voluntarily participate in the study signed a Consent to Participate form. This study was approved by the Institutional Review Board for Research with Human Subjects at University of Central Florida. A hand injury or any related disability was not observed at the time of the study.

Table 1. Subject demographics

Facility workers	(n=71)
Gender	All male
Hand dominance	70 right-handed, 1 left-handed
Mean age, year (Min-Max)	47.44 (26-74)
Mean body weight, kg (Min-Max)	80.04 (60-100)
Mean body height, cm (Min-Max)	170.73 (160-185.4)
Body Mass Index, kg/m2 (Min-Max)	27.17 (23.4-33.1)

2.3. Apparatus and measurements

The Jamar dynamometer has been used to measure grip strength of both the right and left hands; it is a hydraulic instrument that measures in pounds (lbs) and kilograms (kg), up to 200 lbs or 90 kg, respectively (Figure 2). Maximal voluntary contraction (MVC) is recorded when the manometer needle stops at each particpant's optimal grip point, which remains in place until it is manually reset to zero.

Figure 2. Jamar dynamometer used in experiment

The American Society of Hand Therapists (ASHT) recommends standardised positioning: subject seated, shoulders adducted and neutrally rotated, elbow flexed at 90 degrees, forearm in neutral, and wrist between 0 and 30 degrees of extension [21]. Several studies have reported no significant difference in grip strength with subjects either sitting or standing [22, 23, 24]. For this purpose, in our study, standardised positionining described by ASHT was considered as stated above (Figure 3-a and 3-b).

Figure 3. Typical subject positioning (left), Front view (right)

As shown in Figure 3.a, there is no support for the arm, since the dynamometer is positioned vertically [25]. The span is adjustable with five different grip distances (2.5, 3.8, 5.1, 6.4 and 7.6 cm apart) according to a comfort scale. It has been found that maximal grip strength is usually calculated when the scale is in the second or third position [26,27,28]. In the current study, maximum grip strength values were obtained in the second position in centimeters (3.8cm).

The popular approach for assessing maximum grip strength is to calculate the average value of three trials [29]. Participants performed three maximum attempts with each hand, while the average value was recorded in kilograms. In addition, participants' body mass index (BMI) was determined as well, according to weight and height factors.

2.4. Statistical analysis

To perform the normality of data and the important percentile values of grip strength, all data were statistically analyzed using IBM SPSS® version 20. The mean, standard deviation (SD), and percentile values were obtained in order to summarize the descriptive statistics. T-tests were used to compare dominant hand versus non-dominant hand, CTD group versus other group, and American versus other populations for existing hand grip strength measurements in previous research. The levels of statistical significance were declared at p value as 5 % or 1%.

3. Results and Discussion

Important percentile values (first, 25th, 50th, 75th, and 99th) of grip strength data for the dominant and opposite hands were calculated to represent the extreme values (Table 2). Hand tool designers might be interested in the extreme values of grip strength (first and 99th percentiles) since they influence fit and comfort.

Table 2. Percentiles value for American male facility workers

Grip strength (kg)	1st	25th	50th	75th	99th
Dominant Hand	34.00	37.88	44.67	58.74	66.66
Non-dominant Hand	31.00	33.00	42.00	58.68	63.33

The mean and standard deviation for each hand in CTD situations is shown in Table 3. The percentage difference between dominant and non-dominant hands and the significance test results for the differences are represented in Table 4. The results of this study demonstrate that there were no significance differences noted between dominant and non-dominant hands. However, there were highly significant differences between the CTD group and the other group. The results suggest that individuals with CTD lost some grip ability on hand tools. The last objective of this study was to compare US-based grip strength data with some of the international data.

Several studies have been carried out on hand grip strength in different countries. Grip strength was used to compare with South Indian (n=128 male) [15], French (n=55 male) [16], Malaysian (n=212 male) [17], Jordanian (n=115 male) [18], Turkish (n=92 male) [19] (Table 5). Based on the results of the T-tests for the significance between American and other populations, there were significant differences between U.S. males and males from other countries, excluding the nations of Jordan, Malaysia, and Turkey (Table 6). Based on the comparison of the results, grip strength is significantly different in distinctive populations. According to the results obtained, the grip strengths of American males were significantly higher than South Indian males and significantly lower than French males. Table 7 depicts the correlations among the variables.

Table 3. The grip strength(kg) mean and standard deviation for both hands and CTD diagnose.

Dominant Hand		Non Dominant Hand		CTD Group (n=35)(DH)		Other Group (n=36)(DH)	
Mean	SD	Mean	SD	Mean	SD	Mean	SD
48	11.64	44.85	12.89	38.6	4.9	55.52	9.7

DH: Dominant Hand

Table 4. Comparison of grip strength between dominant and opposite hands, CTD-Other group

	Dominant vs. Non-dominant Hand		CTD vs. Other group	
	t	%Difference	t	%Difference
Grip strength (kg)	0.83	6.56	4.96	43.83

* Statistically significant (p<0.05); **statistically significant (p<0.01) %Difference for opposite hands = 100 x (mean for Dominant – mean for Opposite hand) / mean of Dominant %Difference for CTD = 100 x (mean for CTD group – mean for other group) / mean of CTD group

Table 5. Summary data of grip strength of American male facility workers and other populations (n=71)

American		French		Jordanian		Malaysian		South Indian		**Turkish**	
Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
46.48	12.95	55.3	9.4	43.05	11.6	41.2	12	32.05	3.43	43.21	6.42

Table 6. Comparison of grip strength between American male facility workers and other nationalities

American vs. French		American vs. Jordanian		American vs. Malaysian		American vs. South Indian		American vs. Turkish	
t	%Diff	t	%Diff	t	%Diff	t	%Diff	t	%Diff
3.28**	18.97	1.22	7.38	1.91	11.36	10.67**	31.04	1.69	7.03

* Statistically significant (p<0.05); **statistically significant (p<0.01) %Difference = 100 x (mean for American – mean for comparison nationality) / mean of American

Table 7. Correlation between dominant hand grip strength and other parameters

Age	Height	Weight	Body Mass Index (BMI)	Tool usage experience (years)
-0.67*	0.72*	0.57	0.28	-0.48

* Statistically significant (p<0.05)

This study supported the results obtained from the study of Amosun et al. [30] that a positive relationship between grip strength, weight and height was found. As shown in Table 7, hand grip strength for the dominant hand was positively correlated to height, weight and body mass index (p<0.05 for height); negatively correlated to age and tool usage experience (p<0.05 for age).

4. Discussion and Conclusion

In conclusion, there were no significance differences found between dominant and non-dominant hands. However, there were highly significant differences between the CTD group and non-CTD group, and between U.S. males and males from other countries, excluding the nations of Jordan, Malaysia, and Turkey. The hand grip strengths of U.S. male workers appeared to be stronger than those of other populations aside from French males; the dominant hand had greater grip strength than the non-dominant hand. Such differences have practical implications for the design of hand tools. However, more data are needed to reliably establish these differences. Hand dominance, height, weight, body mass index, age and tool usage experience (for facility workers) should be considered when establishing normal values for grip strength. On the other hand, tools should be selected more carefully to minimize possible problems such as excessive vibration and force that might lead to a CTD diagnosis. Furthermore, tools should be balanced properly and designed based on hand anthropometry such as palm width, length, etc. Workers should be trained to use tools properly and how to report problems with tools.

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References

[1] Bassey, E.J., &Harries, U.J. (1991). Normal values for hand grip strength in 920 men and women aged over 65 years, and longitudinal changes over 4 years in 620 survivors. Clin. Sci. ; 84: 331-337.

[2] Bassey, E.J. (1990). Tests of muscle strength. In: Collins KJ, ed. Handbook of Methods for the Measurement of Work Performance, Physical Fitness and Energy Expenditure in Tropical Populations. London: International Union of Biological Sciences, Medical Research, 59-65.

[3] Massey-Westrop, N., Rankin, W., Ahern, M., Krishnan, J., &Hearn, T.C. (2004). Measuring grip strength in normal adults: reference ranges and a comparison of electronic and hydraulic instruments. Journal of Hand Surgery 29A, 514–519.

[4] Nicolay, C.W., &Walker, A.L. (2005). Grip Strength and Endurance: Influences of anthropometric Variation, Hand Dominance and Gender, International Journal of Industrial Ergonomics 35, 605-618.

[5] Rajendran, K., Thamburaj, S., Syed Abudaheer, K., & Thiruvevenkadam, I. A. (2016). Comparison of Hand Grip Strength in Different Positions of Shoulder with Elbow in 90º Flexion and 0º Extension Positions. International Journal of Health Sciences and Research (IJHSR), 6(2), 245-253.

[6] Çakıt, E., Durgun, B., & Cetik, O. (2015). A neural network approach for assessing the relationship between grip strength and hand anthropometry. Neural Network World, 25(6), 603.

[7] Çakıt, E., Durgun, B., & Cetik, O. (2016). Assessing the Relationship Between Hand Dimensions and Manual Dexterity Performance for Turkish Dental Students. In Advances in Physical Ergonomics and Human Factors (pp. 469-479). Springer International Publishing.

[8] Dubrowski, A., Carnahan, H. (2004). Grip force when grasping moving cylinders. International Journal of Industrial Ergonomics 34, 69–76.

[9] Mital, A., Kilbom, A., (1992). Design, selection and use of hand tools to alleviate trauma of the upper extremities- Part II, International Journal of Industrial Ergonomics, 10, 7-21, Elsevier Science Publication.

[10] Koley, S., & Atri, R. (2016). A Study on Handgrip Strength in Pregnant and Non-pregnant Women of North India. International Journal of Biomedical Research, 7(5), 236-239.

[11] Hinson, M., & Gench, B. E. (1989). The curvilinear relationship of grip strength to age. Occupational Therapy Journal of Research, 9, 53–60.

[12] Crosby, C. A., Wehbé, M. A., & Mawr, B. (1994). Hand strength: Normative values. Journal of Hand Surgery, 19A, 665–670.

[13] Robertson, L. D., Mullinax, C. M., Brodowicz, G. R., & Swafford, A. R. (1996). Muscular fatigue patterning in power grip assessment. Journal of Occupational Rehabilitation,6, 71–85.

[14] Petersen, P., Petrick, M., Connor, H., & Conklin, D. (1989). Grip strength and hand dominance: Challenging the 10% rule. American Journal of Occupational Therapy, 43, 444–447.

[15] Fernandez, J.E., Uppugondurı, K.G. (1992). Anthropometry of South Indian industrial workmen. Ergonomics, 35(11): 1393-1398.

[16] Chau, N., Remy, E., Pétry, D., Huguenin, P., Bourgkard, E., & André, J.M. (1998). Asymmetry correction equations for hand volume, grip and pinch strengths in healthy working people. European Journal of Epidemiology, 14(1), 71-77.

[17] Kamarul, T., Ahmad, T. S., & Loh, W. Y. C. (2006). Normal hand grip strength in the adult Malaysian population. Journal of Orthopaedic Surgery, 14(2), 172-71.

[18] Mandahawi, N., Imrhan, S., Al-Shobaki, S., & Sarder, B. (2008). Hand anthropometry survey for the Jordanian population. Industrial Journal of Industrial Ergonomics, 38(11-12), 966-976.

[19] Cakit, E., Durgun, B., Cetik, O. and Yoldas, O. (2014), A Survey of Hand Anthropometry and Biomechanical Measurements of Dentistry Students in Turkey. Hum. Factors Man., 24: 739–753. doi: 10.1002/hfm.20401.

[20] ISO 15535, 2006. General Requirements for Establishing Anthropometric Databases.

[21] Fess, E.E. (1992). Grip Strength, 2nd edition. Chicago: American Society of Hand Therapists.

[22] Gilbertson, L., & Barber-Lomax, S. (1994). Power and pinch grip strength recorded using the hand-held Jamar dynamometer and B+L hydraulic pinch gauge: British normative data for adults. British Journal of Occupational Therapy, 57, 483–488.

[23] Butler, M. (1997). Grip strength: A comparative study. New Zealand Journal of Occupational Therapy, 48, 5–12.

[24] Desrosiers, J., Bravo, G., Hébert, R., & Dutil, E. (1995). Normative data for grip strength of elderly men and women. American Journal of Occupational Therapy, 49, 637–644.

[25] Mathiowetz, V. (1990b). Grip and pinch strength measurements. In L.R. Amundsen(Ed.). Muscle strength testing: Instrumented and non-instrumented systems (pp. 163-177). New York: Churchill Livingstone.

[26] Goldman, S., Cahalan, T. D., & An, K. N. (1991). The injured upper extremity and the Jamar five-handle position grip test. American Journal of Physical Medicine and Rehabilitation, 70, 306–308.

[27] Firrell, J. C., & Crain, G. M. (1996). Which setting of the dynamometer provides maximal grip strength? Journal of Hand Surgery, 21A, 397–401.

[28] Crosby, C. A., Wehbé, M. A., & Mawr, B. (1994). Hand strength: Normative values. Journal of Hand Surgery, 9A, 665–670.

[29] Mathiowetz, V., Weber, K., Volland, G., & Kashman, N. (1984). Reliability and validity of grip and pinch strength evaluations. Journal of Hand Surgery, 9A, 222-226.

[30] Amosun, S. L., Moyo, A., & Matara, C. (1995). Trends in hand grip strength in some adult male Zimbabweans. British Journal of Occupational Therapy, 58, 345–348.