



## Correlation between handgrip strength and hand-forearm anthropometry

Correlación entre la fuerza de la empuñadura y la antropometría mano-antebrazo

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### ABSTRACT

#### Keywords:

Anthropometry  
Forearm  
Grip strength  
Hand  
Pearson

The Pearson correlation coefficient ( $r$ ) between the grip strength and hand-forearm anthropometry was found to determine either existing or not a linear relation among them. Collecting data of the variables was obtained from ten young adults in both, right and left hand-forearm, it was taken into account some qualitative variables: to be right-handed, the gender with five (5) men and five (5) women, and it was established as a condition that the individual was healthy and did not have a previous career as an athlete. A direct linear relationship with hand anthropometry and the grip strength is concluded, even though as expected, there was a strong difference between the force exerted by a male and a female individual, being the first stronger. Respect to the forearm, an inverse relation was found between the maximum circumference of the forearm and the grip strength. Finally, the strongest relationships found were in the width and length of the palm, as well as in the circumference of the wrist. Results were validated comparing the results of this research against the results of specialized literature. Some considerations may be considered for future research. Grip strength can promote the risk of accidents and ergonomists should consider this factor appropriately for their design.

### RESUMEN

#### Palabras clave:

Antropometría  
Antebrazo  
Fuerza de agarre  
Mano  
Persona

El coeficiente de correlación de Pearson ( $r$ ) entre la fuerza de agarre y la antropometría del antebrazo manual supone una relación existente o no lineal entre ellos. La recopilación de datos de las variables se obtuvo de diez adultos jóvenes, tanto en el antebrazo derecho como en el izquierdo, se tuvieron en cuenta algunas variables cualitativas: ser diestro, el género con cinco (5) hombres y cinco (5) mujeres, y se establecieron como condiciones que el individuo estaba sano y no tenía una carrera previa como atleta. Se concluye una relación lineal directa con la antropometría de la mano y la fuerza de agarre, aunque como se esperaba, existía una gran diferencia entre la fuerza ejercida por un individuo masculino y femenino, siendo la primera más fuerte. Respecto al antebrazo, se encontró una relación inversa entre la circunferencia máxima del antebrazo y la fuerza de agarre. Finalmente, las relaciones más fuertes encontradas fueron en el ancho y largo de la palma, así como en la circunferencia de la muñeca. Los resultados se validaron comparando los resultados de esta investigación con los resultados de literaturas especializadas. Algunas consideraciones pueden ser consideradas para futuras investigaciones. La fuerza de agarre puede promover el riesgo de accidentes y los ergónomos deben considerar este factor de manera adecuada para su diseño.

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## Introduction

One of the most significant developments during the long period of early human evolution was man's achievement of upright posture since hands become available for activities other than locomotion. The tremendous value of the human hand as a functional part for grasping, manipulating, writing, as well as other activities, need not be emphasized [1]. Therefore, dimensions or sizes of the human hand are important for two primary reasons: protection and function. Thus, dimensional information on the hands is required for the effective design of handles of tools or implements to be grasped with the hands such as cutting tools [2], as well as handwear.

Anthropometry of the hand plays an essential role in different fields, like aeronautics [3] medicine or criminology where hand anthropometry is used to determine the sex of a deceased person. Determination of sex is often considered as one of the simplest tasks in forensic analysis but become increasingly important in cases of mass disasters, where there is a likelihood of recovering feet and hands separated from the body [4].

Despite the application of high technology at work, there are still physically demanding occupations in fields such as automotive industries, manual material handling jobs, postal, emergency and military services [5]. Hand-grip strength is identified as one limiting factor for manual lifting and carrying loads [6], [7], [8]. Manual lifting and carrying of loads are common types of exercise in everyday life at home and work. Studies of grip strength typically examine maximum force during a single repetition, but this type of exertion is relatively rare in the workplace, where tasks frequently involve repeated forceful, and dynamic grasping or prolonged static holding [6]. This study is of high relevance to industry: Grip strength and relative endurance may both contribute to the risk of work-related accidents and cumulative musculoskeletal injury. Because grip force and endurance are unrelated, ergonomists should consider which factor is most important and appropriate for their design and research goals. Measurements of the forearm and hand were found to be better predictors of grip strength than were height and weight [6] so

that anthropometry of hand-forearm. The ability to predict strength was most accurate for the single-repetition and then declined with increasing duration of the experiment [8]. This research study the hand-forearm anthropometry and the grip strength trying to find a correlation coefficient to attribute a linear relation as expected.

## Materials and methods

### Selection of participants

10 no-athletes young adults between 20 and 25 years old were selected for this study. This study included participants being right-handed, the gender selected with five (5) men and five (5) women. Also, it was established as a condition that the individuals were healthy at the time of collecting data and there were no previous musculoskeletal disorders. The participants were informed previously about the study and they were willing to participate according to an informed consent (Nijhawan et al.). [9]. For an optimal data collection, the procedure to be followed was carefully explained to the participants.

### Anthropometry data

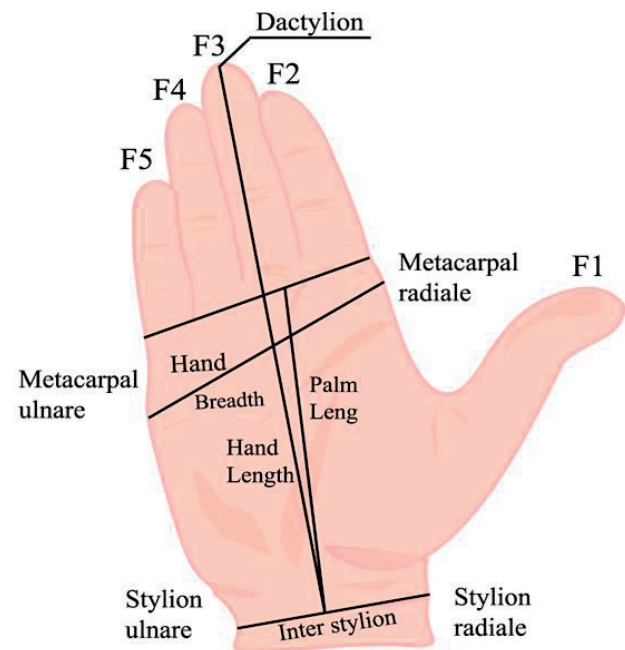


Figure 1. Measures and landmarks of the Hand.

Flexures (joint lines) are the major markings found in hand commonly crease the skin across the flexor

surfaces of the wrist, palm, and digits and are the sites of folding of the skin during movement. These flexures are useful landmarks for measurements from the hand [4]. Hand length - distance from the Interstylium (middle point of the line connecting the Stylium Radiale and the Stylium Ulnare) to the Dactylium (tip of the middle finger). The hand width - the distance between Metacarpal Radiale and the Metacarpal Ulnare. Palm length - the distance between the mid-point of the distal transverse crease of the wrist and the most proximal flexion crease of the middle finger. Finger lengths are measured as the distance between proximal flexion creases of the finger and the tip of that finger. Three other measurements were taken on each person's forearms. Forearm length was measured as the distance from the tip of the olecranon process to the styloid process of the ulna (Fig. 3). Forearm circumference was taken 5 cm from elbow crease, and circumference of the wrist was taken at the wrist fold, just distal to the ulnar styloid process [6]. These measures were taken with a Vernier caliper.

**Handgrip test**

For measuring grip strength, a Jamar hand dynamometer was used, the Jamar is small and portable but relatively heavy (1.5 lb) hydraulic dynamometer. The dial reads force in both kilograms and pounds, with markings at intervals of 2 kg or 5 lb and can determine a maximum force of 90 Kg, has five adjustable positions, as well as, it is the most widely cited in the literature and accepted as the gold standard by which other dynamometers are evaluated and it has the highest accuracy of the instruments tested in [10]. It requires 3–4 pounds of force to make the indicator needle move, which may be inappropriate when measuring grip strength in very weak patients and the reading error is reported to be greater at lower loadings. The calibration accuracy should be checked on new machines, and the manufacturers recommend annual or more frequent calibration if used on a daily basis [8]. At the time of measuring the grip strength, people had to have the hands dry and clean, since these physical conditions could affect the strength of grip, and they had to form a 90-degree angle between the arm and forearm. Data were taken from both hands.

**Results and Discussion**

After ordering the data collected between anthropometry of the hand and arm together with the forces, a total of 240 data were obtained. For the data analysis, descriptive statistics are used, through which averages and deviations were calculated to finally proceed to find a Pearson correlation coefficient to know if there is a relationship between the grip strength and the hand measurements. Likewise, the data were represented as discrete variables, also by inferential statistics [11], it is deduced that none of the individuals has exercise routines where it strengthens the hands and the forearm. The used formulas were:

Average Value ( $\bar{X}$ ):

$$\bar{X} = \frac{\sum_{i=1}^n x_i}{n} \tag{1}$$

Standard deviation ( $\sigma$ ):

$$\sigma = \sqrt{\frac{\sum_{i=1}^n (x_i - \bar{X})^2}{n}} \tag{2}$$

Analysis of covariance ( $\sigma_{xy}$ ):

$$\sigma_{xy} = \frac{\sum_{i=1}^n (x_i - \bar{X})(y_i - \bar{Y})}{n} \tag{3}$$

Pearson correlation coefficient (PCC)  $r$  is a measure of the linear correlation between two variables X and Y that has a value between +1 and -1, where 1 is a total positive linear correlation, 0 is no linear correlation, and -1 is a total negative linear correlation. It is widely used in the sciences [12].

$$r = \frac{\sigma_{xy}}{\sigma_x \sigma_y} ; \tag{4}$$

The degree of correlation and the hierarchies of the Pearson coefficient are presented in the following table.

**Table 1.** Degree of pearson correlation

Value pearson coefficient	Degree of pearson correlation
R = 0	No Correlation
R = 1	Perfect positive correlation
0 < R < 1	Positive correlation
R = -1	Perfect negative correlation
-1 < R < 0	Negative correlation

Source: [8].

**Table II.** Hierarchies of pearson coefficient

Pearson value	Hierarchy
$\pm 0.96 -- \pm 1.00$	Perfect
$\pm 0.85 -- \pm 0.95$	Strong
$\pm 0.70 -- \pm 0.84$	Significant
$\pm 0.50 -- \pm 0.69$	Moderate
$\pm 0.20 -- \pm 0.49$	Weak
$\pm 0.10 -- \pm 0.19$	Very weak
$\pm 0.09 -- \pm 0.00$	Null

Source: [8].

Hand, wrist, and forearm measurements were taken to the participants (see Table III). Regarding table IV, the average handgrip strength measured in Jamar hand dynamometer shows a clear difference

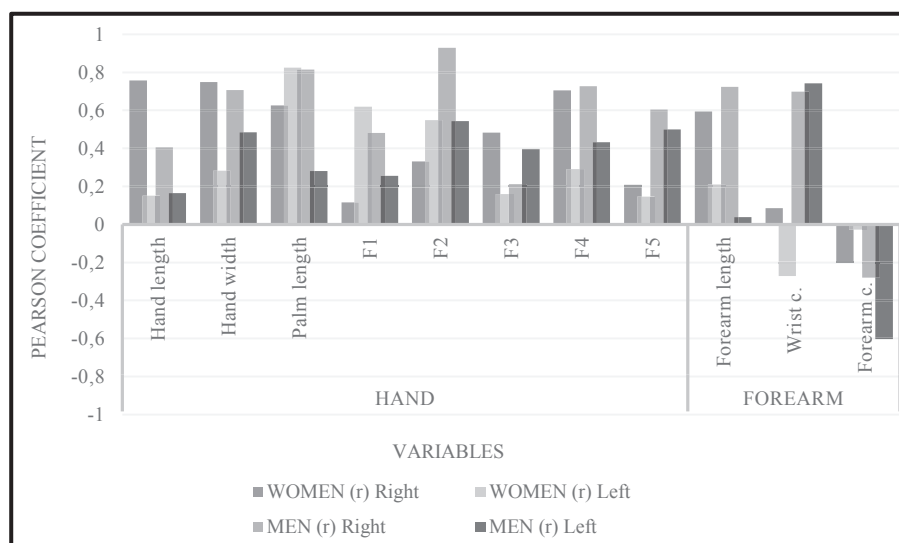
in gender as all men have a superior strength over women, although, measures on men have a higher standard deviation than women.

**Table III.** Average values of anthropometry data

	Average measure [cm]	Women		Men	
		Right	Left	Right	Left
HAND	Hand length	16.98	16.78	18.53	18.34
	Hand width	7.252	7	8.132	7.936
	Palm length	9.632	9.462	10.474	10.308
	F1	5.584	5.526	5.708	5.78
	F2	6.294	6.502	6.87	6.7
	F3	6.94	7.108	7.618	7.682
	F4	6.356	6.572	6.992	6.992
FOREARM	F5	5.208	5.252	5.788	5.778
	Forearm length	22.94	23.2	25.54	26.34
	Wrist circumference	4.96	4.91	5.362	5.226
	Forearm circumference	5.406	5.316	6.41	6.03

**Table IV.** Average values of grip strength and standard deviation

Gender	Right hand		Left hand	
	Average Handgrip Strength [Kg]	Standard Deviation	Average Handgrip Strength [Kg]	Standard Deviation
Women	19.62	3.885	18.18	3.407
Men	42.04	12.840	35.22	13.608



**Figure 2.** Pearson correlatio coefficient vs Anthropometry variables.

As seen in Figure 1 and table V, regarding men, it was found in both, right and left hands similar results concerning hierarchy (weak) in the thumb and the middle finger. Likewise, all the fingers and hand have a direct relationship with grip strength since no measurement marked a null correlation.

low in women (null and weak for right and left hand), as well as, Pearson coefficients are positive in the right hand and the left negative, thus, in women, this measure cannot be considered.

Table V. Anthropometry variables & pearson correlation coefficient

	Measure	Women ( <i>r</i> )		Men ( <i>r</i> )	
		Right	Left	Right	Left
HAND	Hand length	0.7574	0.1515	0.4049	0.1639
	Hand width	0.7493	0.2832	0.7071	0.4843
	Palm length	0.6251	0.8244	0.8145	0.2808
	F1	0.1157	0.6187	0.4803	0.2561
	F2	0.3312	0.5480	0.9286	0.5437
	F3	0.4831	0.1600	0.2121	0.3953
	F4	0.7055	0.2904	0.7276	0.4326
	F5	0.2085	0.1455	0.6040	0.4996
	Forearm length	0.5933	0.2103	0.7235	0.0377
FOREARM	Wrist circumference	0.0855	-0.2707	0.6979	0.7413
	Forearm circumference	-0.2031	-0.0278	-0.2795	-0.6035

There is a discrepancy between hands as the width of the hand, and the length of palm has an increase in Pearson coefficient (*r*) in the right hand disagreeing with the opposite hand in both genders.

Regarding the length of the hand, in both genders, it is noticed that the correlation is weak and very weak in men and women. Although, in the right hand of women there is a significant hierarchy, differing from the left hand that is very weak.

In the analysis between genders, there are coincidences in the hierarchy in the right hand of men and women in three measures, the two previously mentioned and the middle finger, while in the left hand there are similarities in the length and width of the hand and the fingers F2 and F4.

According to the measurements on the forearm, it should be noticed that in men there is a negative correlation in the maximum circumference of the forearm, which tells us that there is an inverse relationship between both measures, as one increases another decrease, something that would make us frown because it seems illogical. In women, a negative relationship was also found in this measure.

Although they are not coincident, there is a correlation in the circumference of the wrist in men with a hierarchy moderate and significant for right and left hand respectively. This correlation is very

In men, there is a clear discrepancy in the length of the forearm, because in the right hand it shows a significant relationship while on the left it is null. Between genders, a negative and weak relation was found in the measurement of the maximum circumference of the forearm.

## Conclusions

It could be inferred that the way in which force is applied varies between the hands. Because the test was applied to right-handed individuals, there is a tendency in which the correlation increases in the right hand in some measures.

It seems that the hierarchy of finger by finger cannot find something completely defined, it is advisable to take other measures in considerations such as the taken into account in [13] where it is advisable to consider all the possible measures concerning the hand in different positions.

The average maximum strength of the hand showed an expected result, a clear difference between men and women as the force exerted by a male is stronger than a female individual. It is found in [5] that 90% of women produced less strength than men. Even the results of female national elite athletes indicate that the level of strength attainable by extremely high training will rarely exceed 50% of untrained men. These results are related to the existence of an

appreciable difference due to the difference in body mass.

The results obtained by the fingers are not the same as those found in [9]. Since in this investigation it was found that the force exerted by the fingers they had the following order - Medium, Annular, Index and Pinky. - Instead, the results were randomized, without any clear trend.

Grip strength can contribute to the risk of work-related accidents and musculoskeletal injuries and the risk increase as age increase [14]. It is recommended to study the relationship between the risk of work-related accidents and relative endurance. Because of ergonomists must consider which factor is most important and appropriate for their design [15].

In summary, hand anthropometry has a direct linear relationship with the grip strength since no measurement was null in the results. As well as, the strongest relationships found were in the width and length of the palm, and the circumference of the wrist.

Future studies have to consider all possible measures of the hand anthropometry in all the relevant positions of the hand with the purpose of obtaining more accurate results. It is recommended to take into account standards to measure anthropometry [16] – [19] and to enlarge the number of variables in studies like the role of muscle loss [20] and the effect of elbow position [21]. Finally, the standard deviation of average grip strength that the Jamar hand dynamometer shows have to be considered for the analysis of data.

## References

- [1] R.M. White. “Comparative Anthropometry of the Hand”, Army Natick Research and Development Laboratories, 1981.
- [2] O. Rincón-Becerra y G. García-Acosta, “Definición de dimensiones antropométricas en la construcción de guantes a partir de requerimientos de diseño”, *Iconofacto*, vol. 11, no. 16, pp. 125-40, 2015.
- [3] S. Daniels-Gilbert and H.T.E. Hertzberg, “Applied Anthropometry of the Hand.” *American Journal of Physical Anthropology*, vol. 10, no. 2, pp. 209-216, 1952.
- [4] T. Kanchan and K. Krishan, “Anthropometry of hand in sex determination of dismembered remains - A review of literature,” *Journal of Forensic and Legal Medicine*, vol. 18, no. 1, pp. 14–17, 2011.
- [5] D. Leyk *et al.*, “Hand-Grip Strength of Young Men, Women and Highly Trained Female Athletes”, *European Journal of Applied Physiology*, vol. 99, no. 4, pp. 415–21, 2007.
- [6] C.W. Nicolay and A.L. Walker, “Grip strength and endurance: Influences of anthropometric variation, hand dominance, and gender,” *International Journal of Industrial Ergonomics*, vol. 35, no. 7, pp. 605–618, 2005.
- [7] J. Sallinen, S. Stenholm, T. Rantanen, M. Heliövaara, P. Sainio and S. Koskinen, “Hand grip strength cut points to screen older persons at risk for mobility limitation,” *Journal of the American Geriatrics Society*, vol. 58, no. 9, pp. 1721–1726, 2010.
- [8] H.C. Roberts *et al.*, “A review of the measurement of grip strength in clinical and epidemiological studies: Towards a standardised approach,” *Age Ageing*, vol. 40, no. 4, pp. 423–429, 2011.
- [9] A.W. Castellanos-Morantes y L.E. Méndez-Serrano, “Estudio de la Relación entre la Antropometría de la Mano y la Distribución de Fuerzas en el Agarre Máximo en Individuos no Atletas”, trabajo de fin de grado, Universidad Industrial de Santander, Bucaramanga, 2017.
- [10] V. Mathiowetz, K. Weber, G. Volland and N. Kashman, “Reliability and validity of grip and pinch strength evaluations”, *The Journal of Hand Surgery*, vol. 9, no. 2, pp. 222–226, 1984.
- [11] P. Bruce and A. Bruce, *Practical statistics for data scientists: 50 essential concepts* Beijing: O'Reilly, 2017.

- [12] P. Karl and G. Francis, "VII. Note on regression and inheritance in the case of two parents," *Proceedings of the Royal Society of London*, vol. 58, no. 347–352, pp. 240–242, 1895.
- [13] J.W. Garrett, "The Adult Human Hand: Some Anthropometric and Biomechanical Considerations," *Human Factors*, vol. 13, no. 2, pp. 117–131, 1971.
- [14] S. Giampaoli *et al.*, "Hand-grip strength predicts incident disability in non-disabled older men.," *Age Ageing*, vol. 28, no. 3, pp. 283–288, 1999.
- [15] Panero and M. Zelnik, *Human Dimension and Interior Space*. New York: Random House US, 2014.
- [16] Coordinación de promoción y prevención, "Protocolo De Evaluación De Medidas Antropométricas," Colombiana de Salud, 2014.
- [17] Instituto Nacional de Salud, "Medidas antropométricas, registro y estandarización," 1998.
- [18] Universidad de los Andes, "Protocolo para la toma y registro de medidas antropométricas" Nieer, 2009.
- [19] T. G. Lohmann, A. F. Roche, and R. Martorell, *Anthropometric Standardization Reference Manual*. Human Kinetics Books, Champaign, Ill., 1988.
- [20] D.A. Kallman, C.C. Plato and J.D. Tobin, "The Role of Muscle Loss in the Age-Related Decline of Grip Strength: Cross-sectional and Longitudinal Perspectives," *Journal of Gerontology*, vol. 45, no. 3, pp. 82–88, 1990.
- [21] V. Mathiowetz, C. Rennells, and L. Donahoe, "Effect of elbow position on grip and key pinch strength," *The Journal of Hand Surgery*, vol. 10, no. 5, pp. 694–697, 1985.