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Original Article

An Analysis of Hand Size and Grip Strength in a Working Population in Bogotá, Colombia

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Abstract

Background: Handgrip strength (HGS) has been extensively studied for its clinical and industrial significance, often linked to anthropometric measures like height, weight, and hand dimensions. In Colombia, research on these correlations exists but is fragmented and methodologically varied, limiting the ability to generalize findings. This lack of standardization highlights the need for a unified approach. This study aimed to address this gap by analyzing HGS in the Colombian context.

Methods: Overall, 678 subjects (48.9% female and 51.1% male) were enrolled in 2022. They were aged between 18 and 63 yr old, apparently healthy, and were from Bogota, Colombia. It was measured using a Jamar dynamometer. To determine the seven variables of the hand, the posture recommended by the ASHT was followed.

Results: Men had significantly higher HGS than women. The dominant hand represents 94.6% of females and 90.5% of males. However, dominance does not have a negative impact on gender when it is analyzed alone. The use of predictive models with cubic regressions permitted us to establish significant variables such as gender and hand width for the right hand and gender, age, hand thickness, and maximum palmar length for the left hand.

Conclusion: The predictive models, the HGS relationship and the dimensions of the hand are evidenced, but in future studies it will be necessary to include the arm, forearm, and wrist sections to the methodology.

Keywords: Handgrip strength; Hand anthropometry; Dynamometry

Introduction

Handgrip Strength HGS is a standard parameter used to determine hand function. The measurement is made with a conventional manual dynamometer, and it is characterized by being a simple and low-cost process (1). The results of this type of evaluation can be used in different clinical applications, such as determining the efficacy of surgical procedures (2–5), the diagnosis of mus-

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culoskeletal diseases (6–11), determination of states of malnutrition in people (12, 13) or even, association of poisoning by dangerous substances that can affect the nervous system (14).

The assessment of grip strength is also applied in the industrial area. Product designers make use of anthropometric variables and manual force (15, 16). Applicants to the police, fire services and armed forces require passing periodic grip strength tests (17). The characterization of force has allowed the development of standards that have been used to design taking into account the health, safety, comfort and productivity of workers and consumers (7, 18).

Several studies have attempted to correlate handgrip strength with anthropometric measures in individuals. The strength could be associated with the anthropometry of the hands (19). Grip strength is related to height, forearm diameter and middle finger length (20), however, hand strength is affected by height, weight, body mass index, and hand and forearm dimensions (21). The study conducted by Miyatake et al (22) included height, body weight, abdominal circumference, hip circumference, and percentage of body fat.

In Colombia, some peer-reviewed and non-refereed publications have been reported showing methodological designs aimed at determining the relationship between grip strength associating them with variables such as height, weight, age, gender, and manual dominance (6, 23–30). However, these studies are isolated and conducted in different regions of the country, employing varying methodologies and measuring instruments. This lack of standardization precludes generalizing the results to the Colombian population as a whole or to specific subpopulations.

As a result of the diversity of methodologies utilized in Colombian population studies, the objective of this study was to determine how handgrip strength (HGS) relates to gender, age, dominant hand (DH), body mass index (BMI), and hand anthropometric measurements (hand length, palmar length, hand breadth, maximum hand breadth, hand thickness, hand circumference, and maximum hand circumference).

This study addresses significant gaps in the literature by providing a comprehensive analysis of handgrip strength (HGS) in the Colombian population, using a standardized methodology.

Materials and Methods

Subject

This study was conducted in 2022 and consisted of 678 participants (48.9% females and 51.1% males), aged 18 to 63 yr, of Colombian descent, healthy, and without any history of musculoskeletal or psychological trauma. Each participant completed a comprehensive demographic survey, which included information such as gender, age, height (cm), weight (kg), and dominant hand. Additionally, participants were screened to confirm the absence of any diagnosed upper limb disorders or specific hand and arm training. Finally, anthropometric measurements were taken on the dominant hand, followed by an assessment of handgrip strength.

The data was collected by the Pontificia Universidad Javeriana (PUJ-Bogotá) and Universidad Santo Tomás (USTA-Bogotá), Colombia and all participants received informed consent approved by the Ethics Committee Number 12 of the Faculty of Engineering.

A non-probabilistic convenience sampling method was used to select participants based on their availability and willingness to participate. The sample size was determined pragmatically, considering the constraints of time and access to participants, rather than through probabilistic methods. Although a heterogeneity of 50%, a margin of error of 5%, and a 99% confidence level are commonly used to calculate sample sizes in probabilistic sampling, these parameters were not applied in this study. The use of convenience sampling, while facilitating participant recruitment, limits the ability to generalize the findings to the broader population due to the lack of random selection.

Hand Anthropometric Dimensions and Posture

The hand measurement techniques employed in this study were based on the guidelines provided in the NASA 1024 guide in the 1978 book called Anthropometric Source Book II (31), which has been used in other anthropometry and hand dynamometry studies (32–34). 1) Hand length (measured from the distal part of the wrist to the tip of the middle finger), 2) Palmar length (from the most distal crease of the wrist to the most proximal crease of the phalanx of the middle finger), 3) Width of the hand (measured at the level of the distal palmar crease), 4) Maximum width of the hand (measured between the head of the fifth lateral metacarpal to the head of the first lateral metacarpal), 5) Thickness of the hand (with the hand from a lateral projection, it is the distance that is understood between a line projected from the head of the second metacarpal by palmar to a line projected from the second metacarpal by dorsal), 6) Maximum circumference of the hand (measured by encircling the hand around the head of the first metacarpal passing through the eminence hypothenar) and 7) Hand circumference (measured as a perimeter passing through the fifth metacarpal head and ending at some point on the second metacarpal head. Figure 1 shows the previously described sizing procedure. All dimensions are in centimeters (cm).

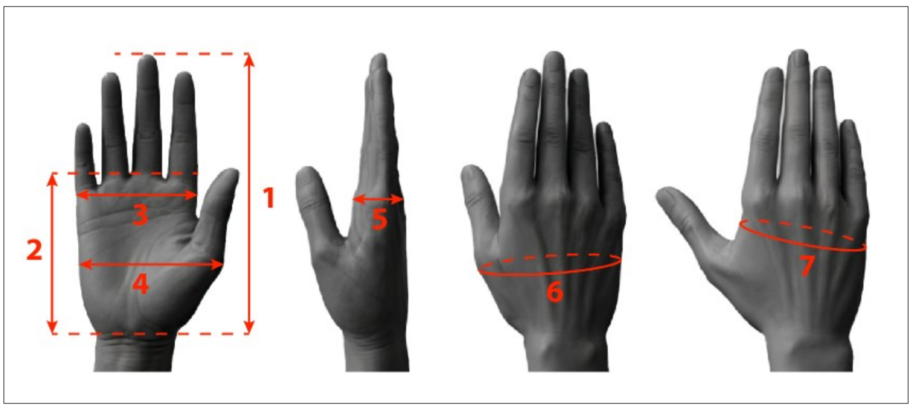

Fig. 1: Anthropometric Hand Sizing

Each participant adopted the posture for measuring handgrip strength (HGS) according to the guidelines set by the American Society of Hand Therapists (ASHT) and commonly used in previous studies. Each participant sat in a chair with lumbar support, with his or her knees bent at a 90-degree angle and their feet flat on the ground. In this exercise, the shoulders must remain neutral, with the arm parallel to the body and the elbow flexed 90 degrees. The purpose of this is to ensure that the forearm and wrist are in a neutral position and that the wrist supination does not exceed 30 degrees (35, 36).

The measurement of the HGS was carried out with a Jamar brand grip dynamometer, and it was duly calibrated under the ABNT-NBR-8197:2012 Standard. Using the dominant hand, each person measured three times for each hand, starting with the dominant hand for three seconds, alternating the force with the non-dominant hand for three seconds, and repeating the process until the three attempts had been completed in each hand. There was a 30 sec rest interval between each measurement (12), (13), and (28). Figure 2 shows the equipment used and illustrates how the grip is performed for each of the tests.

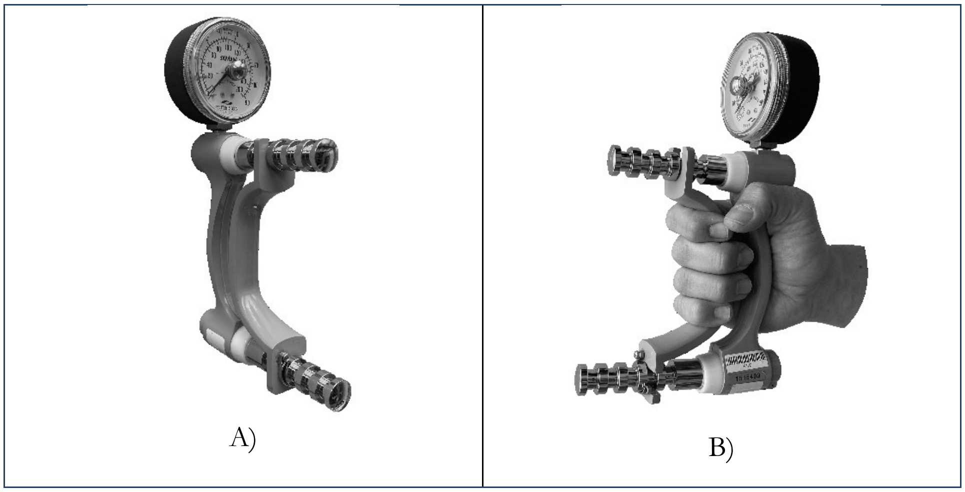

Fig. 2: A) Jamar Measurement Equipment. B) Grip Illustration.

An analysis of quantitative data was conducted by comparing the cases of dominant hand, gender, BMI, and age. Based on the HGS for each hand, predictive equations were calculated based on the other variables (scalars) using a cubic regression model (37).

Data analysis

The data analysis was conducted according to the methodology outlined by Gunther et al (37), with some modifications to fit the characteristics of the data. The analysis followed five stages: In stage (1), the distribution of the variables was tested using the Kolmogorov-Smirnov test and QQ plots. For stage (2), the relationship between HGS strength and gender was established using a student's t-test for independent samples. Subsequently, a univariate general linear model analysis was carried out for the case of gender and the dominant hand. In stage (3) the relationship of each of the HGS forces with respect to age was established through a linear regression. Stage (4) established the correlation of the HGS forces of each dominance by means of a student's t-test of related means and then determined the relationship of each of the HGS forces per dominant hand with each of the anthropometric variables. Finally, in stage (5) predictive equations were formulated for each of the tests, after a principal component analysis, using the varimax rotation algorithm. The selection of the variables for this stage was made based on the *P*-value and then separate models were established for each dominant hand (left and right). The data was processed with SPSS ver. 29.

Results

The dominance of the right hand was reported by 94.6% of female participants and 90.5% of male participants, while the rest of the population reported left-handed dominance. The HGS strength in both the right and left hand presented a normal distribution, the same happens with the independent variables of anthropometric measurements, age, weight and height.

Gender influence

Regarding the female gender, a range of HGS right hand was found between 10 kg to 46 kg, and 4 kg to 46.67 kg for HGS left hand. Strength was significantly higher in men (P=0.001), with a mean of 42.935 and DS=11.419 vs. women with a mean of 25.801 and DS=6.959.

For the male case, HGS values are reported for the right hand at 14 kg and 84 kg, and 10.67 kg at 82 kg for the left hand. Strength was significantly higher in men (P<.0), with a mean of 40.938 and DS= 11.936 vs. Women with a mean of 24.197 and DS= 6.768.

Influence of dominance and side

For both the right and left hands, the HGS failed to show significant results for the dominant hand or for the combination of gender and dominant hand. However, there were significant associations with gender, with a greater effect on the right hand than the left (Table 1).

Table 1: HGS right and left according to gender and dominance

Univariate Analysis of Variance	HGS Right Side		HGS Left Side	
	(P)	η2	(P)	η2
Corrected Model	<.001***	0.447	<.001***	0.416
Gender	<.001***	0.381	<.001***	0.321
Hand Dominance	0.380	0.028	0.152	0.053
Gender*Hand Dominance	0.603	0.004	0.360	0.012

*P<0.05, **P<0.01, ***P<0.001; tested using Two-way ANOVA

Age influence

The right HGS is related both for men R^2= 6.7% and for women R^2=5.4% and left HGS is equally related for men R^2= 7.1% and for women R^2= 5.3%. All the assumptions of the linear regression were fulfilled. The results met all the assumptions of collinearity, independence of observations, outliers, homoscedasticity, and normal distribution of errors (Fig. 3).

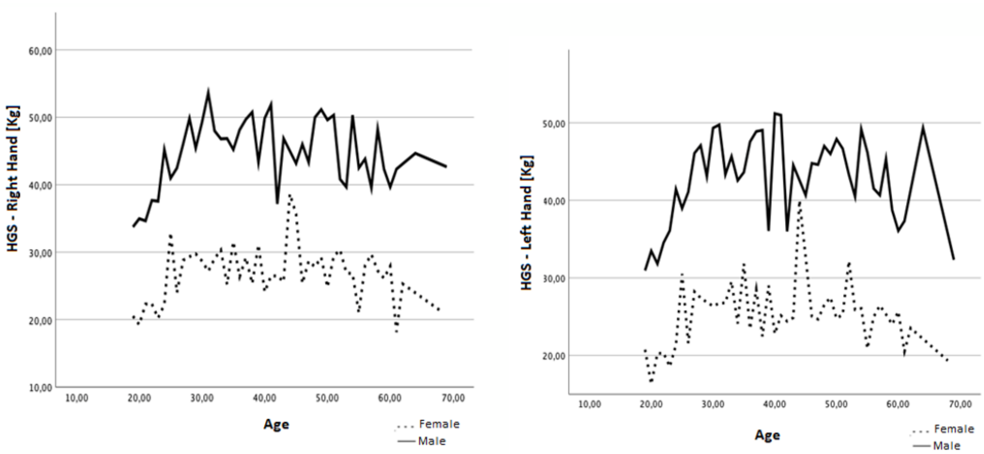

Fig. 3: Handgrip Strength stratified by right/left hand and age

Influence of anthropometric measurements

Initially, a significant relationship is reported between the HGS strength of the right and left hand, for each of the genders; for the female case HGS paired mean=1.604, DS=3.137 and T(332)=9.332 P<.001, and for the male HGS paired mean=1.997, DS=4.400 and t(346)=8.456 P<.001.

Based on weight, hand length, and hand width, the HGS indices show significant differences by gender, always being greater in the male gender (Table 2). Only the maximum palmar length is not correlated with the left HGS of males, while the other variables are significantly correlated with the left and right HGS of both genders. In both genders, palmar length and left HGS showed a low but significant negative correlation (Table 3).

Table 2: Handgrip strength per body weight and per hand size

Index	Hand	Gender	Mean	DS	2 Tailed Significance (*P*)
HGS/Weight	R	F	0.414	0.105	<.001***
		M	0.591	0.162	
	L	F	0.404	0.100	0.002***
		M	0.529	0.162	
HGS/hand length (kg/cm)	R	F	2.646	0.848	<.001***
		M	4.008	1.247	
	L	F	2.499	0.907	0.002***
		M	3.587	1.286	
HGS/hand breadth (kg/cm)	R	F	3.300	0.916	<.001***
		M	5.076	1.303	
	L	F	3.383	0.814	<.001***
		M	4.817	1.002	

*P<0.05, **P<0.01, ***P<0.001; tested using t Student

Table 3: Correlations between Handgrip Strength and Anthropometric Measures

Anthropometric measures	Male (n=334)				Female (n=330)			
	HGS Right		HGS Left		HGS Right		HGS Left	
Height	0.125**	0.030	0.094	0.605	0.129*	0.026	0.386	0.114
Weight	0.261**	<.001	0.202	0.259	0.421**	<.001	0.492*	0.058
BMI	0.210**	<.001	0.199	0.266	0.378**	<.001	0.498**	0.035
Right Hand Circumference	0.395**	<.001			0.220**	<.001		
Right Hand Maximum Circumference	0.544**	<.001			0.274**	<.001		
Right Hand Thickness	0.357**	<.001			0.154**	0.008		
Right Hand Breadth	0.324**	<.001			0.256**	<.001		
Right Hand maximum Breadth	0.340**	<.001			0.241**	<.001		
Right Hand Length	-0.170**	<.001			-0.295**	<.001		
Right Hand Maximum Length	0.137*	0.017			0.158**	0.006		
Left Hand Circumference			0.498*	0.011			0.396	0.115
Left Hand Maximum Circumference			0.548**	0.005			0.365	0.149
Left Hand thickness			0.711**	<.001			0.272	0.291
Left Hand Breadth			0.635**	<.001			0.527*	0.030
Left Hand Maximum Breadth			0.292	0.156			0.473	0.055
Left Hand Length			-0.429**	0.032			-0.223	0.390
Left Hand Maximum Length			0.252	0.224			0.315	0.218

Pearson´s Correlation coefficient (r), *P*-value (*P*) 2 tailed probability, (*); (**) significant

Regression Equations

The results of the Factor Analysis for each hand were used to identify the independent variables in the regression equations. Regarding the right hand, three factors were found to explain 68.83% of the variance. These factors report three items with the highest value: maximum right palmar length (factor 1), thickness of the right hand (factor 2) and age (factor 3). Regarding the left hand, two factors are presented that describe 67.544% of the variance. Factor one contains the item with the greatest value for the width of the left hand and factor two for age (Table 4). The following variables were introduced into the regression: gender, maximum right palmar length, thickness of the right hand, age, and width of the left hand.

Based on the factorial results, stepwise cubic regression was performed for each of the hands, since they presented the best fit. For the right hand, gender, hand thickness, age, palmar length2, age3 and age2 were considered. For the left hand, gender and hand width were included (Table 5).

Table 4: Rotated Component Matrix Revealing Anthropometric Lead Variables and Age

	Right Hand			Left Hand		
	1	2	3		1	2
Height	0.519	0.582	-0.314	Height	0.824	-0.430
Weight	0.363	0.617	0.459	Weight	0.729	0.462
BMI	0.058	0.327	0.777	BMI	0.488	0.675
Age	0.320	-0.133	0.792	Age	0.090	0.798
Right Hand Circumference	0.402	0.743	0.039	Left Hand Circumference	0.804	0.062
Right Hand Maximum Circumference	0.564	0.636	0.094	Left Hand Maximum Circumference	0.859	0.063
Right Hand Thickness	-0.124	0.780	0.107	Left Hand Thickness	0.707	0.159
Right Hand Breadth	0.702	0.283	0.287	Left Hand Breadth	0.874	0.107
Right Hand Maximum Breadth	0.730	0.081	0.313	Left Hand Maximum Breadth	0.652	0.070
Right Hand Length	0.670	-0.172	-0.424	Left Hand Length	0.276	-0.834
Right Hand maximum Palm length	0.782	0.359	-0.100	Left Hand maximum Palm length	0.852	-0.211

Extraction method: principal component analysis. Rotation method: varimax. Rotation converged in 5 iterations

Table 5: Handgrip Strength Regression Equations

Side	R^2 Adjusted	Regression Equation
Hand Right	0,621	y= -67.947 + 15.254 Gender + 3.151 Hand width + 4.491 Gender - 0.097 Age^2 + 0.001 Age^3+ 0.025 Maximum palmar $length^2$
Hand Left	0,586	y= 0.367+ 9.599 Gender + 0.349 Hand width

HGS Force: Gender (female 0, male 1), Age (years), hand thickness, hand width, and maximum palmar length (cm).

Discussion

The study of grip strength has been widely investigated in populations from various countries (1, 3, 7, 9, 13, 15, 22, 36, 37). However, studies on the Colombian population have been developed using different methodologies, which naturally impact the objectives and conclusions (6, 23–30), additionally they seek to characterize the population in terms of strength development. The study proposed here was carried out considering the use of a single methodology, the dominance of the hand, the anthropometric dimensioning of the dominant hand, and variables such as weight, height and age of the participants.

According to previous research, grip strength was significantly greater in men than in women (9, 30, 36). An association was found between hand dominance and gender, with the largest effect observed in the right hand, which is consistent with most participants reporting right-handed dominance. Additionally, the right hand has a greater impact on grip strength than the left hand (24, 25, 36)

Based on the analysis of the age variable, the highest values of grip strength (HGS) were found in both right and left hands of men between the ages of 30 and 40. The values declined after that decade, but peaks occurred in the 1950s and 1960s. Women between the ages of 35 and 40 had the highest values of HGS in both hands. On the other hand, both hands show a peak between 42 and 44 yr of age.

The study carried out by Rostamzadeh in which he proposes normative values of HGS mentions that men perform the highest HGS in the dominant hand in three age ranges: 25 to 29 yr, 35 to 39 yr and 50 to 54 yr, in women, peak HGS values are found in two age ranges: 25-29 yr and 40-44 yr and occur in the dominant hand (36). Similarly, Lopes et al (11) reported that the maximum HGS values for both men and women, in both their dominant and non-dominant hands, occur between 30 and 39 yr of age.

Typically, studies that investigate the relationship between hand grip strength (HGS) and anthropometry consider variables such as weight, height, Body Mass Index (BMI), and some studies also include hand length, hand width, and wrist diameter (7, 21, 37). Other studies have included measurements of the arm and forearm (19, 20). Based on the analysis of 7 anthropometric dimensions of the hand, it was possible to determine that, for men and women, there is no relationship between the HGS and the width of the hand and the maximum palmar length for the left hand. Moreover, the HGS does not correlate with the thickness, circumference, or maximum circumference of the left hand of women.

The principal component analysis revealed three dominant factors for the right hand and two for the left hand. The variables that showed correlation for both the right and left hand were age, hand circumference, hand thickness, and maximum palmar length. The only variable that did not exhibit any correlation with grip strength in both hands was palmar length. The use of the component extraction method was proposed by Günther et al. (37). Although it does not analyze the same number of hand anthropometric variables, it suggests that height, forearm length, and hand length are the strong variables correlate with HGS.

The correlations with the highest value were presented in the first factor on the left hand: height and weight have a high correlation with the HGS; however, as can be seen in Table 4, the BMI only correlates with one factor of the left hand and one of the right hands, and in Table 3, women have the greatest relationship with the BMI.

A cubic regression model was used to develop predictive models. Thus, the main variable for both hands was gender, followed by age, but only for the right hand. The use of this type of predictive model is rarely employed. Günther et al (37) proposes the same technique with gender, age, height and BMI as main variables. Conversely, Vaz et al. (5) do not consider hand dimensions, but instead establishes cubic equations with gender, forearm circumference, age and height, as predictors.

A model for the dominant and non-dominant hand using linear regression can also be found, for example, Fernandes et al. develop a model including variables such as height, weight, and sex (10). A model has been proposed with gender, hand length, and arm circumference as variables for the dominant hand and the non-dominant hand (11). On the other hand, Ramírez-Vélez et al. used cubic equations exclusively to predict the relationship between HGS and age (30).

Conclusion

The absence of significant correlations between HGS and some anthropometric dimensions considered in this study demonstrates the complexity of the factors influencing handgrip strength. Therefore, future studies include anthropometric dimensions of the forearm and arm.

Characterizing handgrip strength for a working population provides a database that helps understand the physical capabilities of that sector. Additionally, it allows for the creation of safe tools and devices, reducing the risk of injury and improving the activities performed by individuals.

Journalism Ethics considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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Conflict of interest

The authors declare no conflicts of interest.

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