Original Article

Assessment of Handgrip Strength in Healthy African Subjects: Establishing Age and Gender Stratified Reference Values

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ABSTRACT

Background: The handgrip strength assesses hand function in traumatic and non-traumatic upper extremity conditions. It is also a surrogate marker for other systemic diseases unrelated to the upper limb. Various reference values have been established in different world regions, with few studies in our population. **Aim:** To determine the average handgrip strength by gender and age categories among healthy subjects in Nigeria. **Materials and Methods:** It was a cross-sectional study assessing handgrip strength by age category (ten-year bin width), gender, and handedness in 210 healthy persons aged 10 to 79 in Nigeria. Its relationship with age, height, weight, mid-arm circumference, triceps skinfold thickness, and mid-arm muscle area was evaluated using multiple linear regression. **Results:** The mean handgrip strength in the dominant and non-dominant hands was 31.09 kg and 28.45 kg, respectively, $P < 0.001$. Males have higher values than females in all age categories. The grip strength peaked in the 30–39-year age group in both genders and declined afterward. Age exhibited a nonlinear pattern but had an overall negative relationship, while height was positively related to grip strength in both genders. In contrast, mid-arm circumference and mid-arm muscle area predicted handgrip strength only in males. Triceps skinfold thickness was excluded from the model because of multicollinearity with the mid-arm muscle area, while weight did not predict grip strength in either gender. **Conclusion:** The handgrip strength in this study is less than that in western literature. Hence, test interpretation should reference the values from this study.

Keywords: *Grip strength, hand, Nigeria, reference values*

Introduction

The hand, although small, is a crucial organ in the human body. It functions as a communication medium, gesturing and expressing various emotions such as fear, anxiety, and love.[1] It is also a sensory organ, able to decipher an object by feeling, an ability known as stereognosis.[2] Many daily functions require the coordinated use of the hand and wrist. From a simple crude activity, such as gripping a hammer, to a complex one, such as writing, the intricate mechanisms of the hand enable it to perform these functions seamlessly. The hand is so important that it constitutes a subspecialty in orthopedic practice.

The hand's importance means that impairment can be incapacitating for the patient. The loss of function can be due to pathologies within the hand, wrist, forearm, or arm or be caused by referred pain from the shoulder, neck, or mediastinum.[1] Also, neurologic disorders such as spinal cord dysfunction, cerebrovascular disease, neurodegenerative diseases, and peripheral nerve lesions can affect hand function.[3] Injuries of the hand or wrist, such as fractures or dislocations, tendon ruptures, carpal tunnel syndrome, De Quervain's tenosynovitis, and hand infections, can all result in disabilities.

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In treating these pathologies, the primary goal is to restore the function to its pre-morbid state, monitored by measuring hand function in such patients. Such assessments are vital in evaluating the treatment efficacy, comparing treatment methods, and guiding rehabilitation protocols.[4] Different tools measure hand and wrist functions.[4] Generic tools such as the Short Form-36 (SF-36) and the sickness impact profile[5,6] measure the impact of musculoskeletal problems on the patient's general well-being. More specific tools, such as the DASH questionnaire, the Brigham and Women's Hospital CTQ, the PRWE, and the HSS wrist scoring systems, subjectively assess hand and wrist outcomes.[4]

However, objective assessment of hand and wrist functions traditionally employs grip strength measurement with a dynamometer.[4] Due to its reliability and simplicity, it is frequently used to assess hand function after hand and wrist injuries.[7] Studies have been done in different regions of the world to determine the reference values of the grip strength in different populations.[8-10] Few studies have been done in Africa and Nigeria to establish reference guidelines.

Materials and Methods

A one-year cross-sectional comparative study was conducted in Enugu, Nigeria. Ethical approval with IRB/HEC number S.313/IV/and protocol number 2413 was obtained from the hospital's Ethics Committee. The sample consisted of consenting healthy persons aged between 10 and 79 and was divided into categories of ten-year difference. The exclusion criteria were any diagnosed limb musculoskeletal condition, demyelinating CNS diseases, diabetes mellitus, diagnosed mental disorders, and upper limb surgery. The sample size was calculated with the formula for "equal size comparative study with a quantitative outcome."[11]

$n = (Z\alpha/2 + Z\beta)^2 \times 2\sigma^2/d^2$,

where n = sample size for each group

$Z\alpha/2$ = standard normal variate, 1.96 at type 1 error of 5%

$Z\beta$ = 0.842 at 80% power

d = effect size, the minimum clinically significant difference

σ = standard deviation (from a previous study or pilot study).

Adedoyin *et al*. in 2009 showed a mean HGS in males in the dominant hand to be 35.2 kg with a standard deviation of 8.6.[12] Another study found the minimum deficit in HGS that causes a clinically significant effect is 6.5 kg.[13] Substituting these values into the above equation:

$$n = \frac{(1.96 + 0.842)^2 \times 2 \times (8.6)^2}{(6.5)^2}$$

n = 28 subjects per group.

Therefore, 30 subjects per age category, 15 males and 15 females were recruited for this study, giving a total sample size of 210 subjects. The authors used a stratified random sampling method to ensure a representative sample of different age categories. They selected the participants from four different strata: male secondary schools, female secondary schools, universities, and old people's homes. Simple random sampling was used to choose the schools and homes. Within each stratum, 30 participants were selected using a random selection method involving 420 folded papers with YES or NO written on them.

Participants were asked to pick from the bag, recruiting those who selected YES and excluding those who chose NO. The HGS was measured with a digital dynamometer (Camry 90 kg Digital Dynamometer), weight with a portable analog scale (Harrison, Germany), and height was measured with an architect's measuring tape (Yueshang, China). The MAC and TSF were measured with inelastic tape and a skin-measuring caliper (Creative Health Products, Michigan, USA), while a questionnaire was used to collect relevant biodata. The instruments were tested for accuracy and reliability before the commencement of the study.

The authors followed the procedure outlined by the American Society of Hand Therapists (ASHT). Participants were seated with their backs against the seat, feet together, and shoulders adducted and in neutral rotation. The elbow was flexed at 90°, and the wrist was dorsiflexed at 30°. Participants were instructed to squeeze the dynamometer as hard as possible, and the average of three measurements for each hand was recorded as their HGS value. Weight was measured without shoes and jewelry, and height was measured without footwear. The mid-arm circumference (MAC) was measured on the dominant limb, and the triceps skinfold thickness (TSF) was measured at the midpoint of the arm. The muscle area at mid-arm (MAMA) was calculated as MAC (cm)–TSF (cm) × 3.142.[14]

Results

Anthropometric characteristics of the study population

The mean age of the participants was 44.24 years (SD = 20.34). There was no significant

Table 1: Anthropometric characteristics of the study subjects, values are mean (SD)

Age category (yrs.)	10–19	20–29	30–39	40–49	50–59	60–69	70–79
Age (yrs.)	13.77 (3.04)	23.77 (3.04)	34.73 (2.41)	43.87 (2.43)	55.13 (2.61)	65.33 (2.45)	73.07 (2.82)
Height (m)	1.57 (0.09)	1.70 (0.09)	1.71 (0.08)	1.66 (0.08)	1.66 (0.09)	1.62 (0.10)	1.60 (0.08)
Weight (kg)	48.30 (13.31)	68.19 (10.58)	80.93 (14.12)	79.13 (14.43)	75.50 (18.92)	68.83 (15.96)	62.68 (14.18)
M.A.C. (cm)	23.65 (3.97)	28.85 (2.99)	33.17 (3.46)	33.90 (6.71)	31.45 (3.70)	30.80 (4.45)	29.03 (4.32)
T.S.F. (cm)	11.00 (6.77)	14.90 (9.17)	18.37 (10.19)	22.10 (13.63)	17.60 (11.31)	15.00 (8.34)	13.80 (8.39)
MAMA (cm)	39.75 (17.48)	43.80 (31.35)	46.50 (30.51)	37.08 (35.63)	43.52 (29.98)	49.64 (17.49)	47.86 (20.02)

Table 2: Handgrip strength by age categories in the dominant and non-dominant hands

Age group (yrs.)	Female				Male			
	Mean dominant HGS (kg)	SD	Mean non-dominant HGS (kg)	SD	Mean dominant HGS (kg)	SD	Mean non-dominant HGS (kg)	SD
10–19	23.85	7.02	22.27	7.74	23.88	9.09	20.97	7.88
20–29	36.70	10.84	32.68	11.96	41.45	6.82	34.73	4.80
30–39	32.38	8.76	28.88	6.96	52.12	15.37	48.76	15.91
40–49	32.00	8.83	30.57	8.09	36.16	10.91	33.30	8.85
50–59	22.80	5.80	22.89	4.48	34.58	10.05	31.77	7.66
60–69	25.40	6.98	23.22	7.53	30.19	9.42	27.88	8.63
70–79	18.80	5.83	18.10	5.24	25.03	6.37	22.40	8.30

Table 3: Regression table of the predictive factors of handgrip strength in males

	b+	Std. error	*P*	95% confidence interval for *B*	
				Lower bound	Upper bound
(Constant)	-63.160	22.369	0.006	-107.545	-18.774
Age (yrs.)	-0.186	0.046	0.000	-0.277	-0.094
Weight (kg)	-0.176	0.122	0.151	-0.418	0.065
Height (m)	29.655	14.892	0.049	0.105	59.205
MAC (cm)	2.063	0.418	0.000	1.233	2.893
MAMA (cm)	0.131	0.046	0.006	0.039	0.223

+ = Unstandardized coefficient

Table 4: Regression table of the predictive factors of handgrip strength in females

	b+	Std. error	*P*	95% confidence interval for *B*	
				Lower bound	Upper bound
(Constant)	-36.167	19.204	0.063	-74.272	1.939
Age (yrs.)	-0.203	0.044	0.000	-0.290	-0.116
Weight (kg)	0.118	0.089	0.186	-0.058	0.294
Height (m)	31.981	12.218	0.010	7.737	56.225
MAC (cm)	0.391	0.242	0.109	-0.089	0.871
MAMA (cm)	0.047	0.040	0.240	-0.032	0.126

+ = Unstandardized coefficient

difference in the mean age of males (44.54 years, SD = 20.86) and females (43.93 years, SD = 19.90), *P* = 0.829. The participants' mean weight was 69.08 kg (SD = 17.84). There was no statistically significant difference in the mean weight between males (69.94 kg, SD = 18.74) and females (68.22 kg, SD = 16.94), *P* = The subjects' weight increases with age, reaching a peak in the fourth decade, and gradually decreases. The subjects' mean height was 1.65 m (SD = 0.10). Males were significantly taller than females, 1.69 m vs. 1.60 m, $P < 0.001$. The participants' mid-arm circumference (MAC) was 30.12 cm (SD = 5.36). Females have a larger MAC (30.97 cm, SD = 5.91) than males (29.27 cm, SD = 4.62). This difference was statistically significant, *P* = 0.021.

Like the weight, the MAC increases with age until the fifth decade and decreases after that. The subjects' mean triceps skinfold (TSF) thickness was 16.11 cm (SD = 10.32). The TSF was thicker in females (22.18 cm, SD = 8.69) than in males (10.04 cm, SD = 8.00), $P < 0.001$. The TSF shows the same relationship with age as weight and MAC, increasing with age, reaching a peak in the fourth decade, and gradually decreasing. The participants' mean mid-arm muscle area (MAMA) was 44.02 cm (SD = 26.91). Males have a significantly larger MAMA (60.42 cm, SD = 21.23) than females demales (27.63 cm, SD = 21.48). Table 1 summarizes the anthropometric characteristics of the study participants in the different age categories.

Handgrip strength assessment in the subjects

Two hundred and seven subjects (98.57%) were right-hand dominant, while only three participants, 1.43%, were left-hand dominant. The mean handgrip strength was 2.64 kg higher in the dominant hand than in the non-dominant hand, which was significant, $P < 0.001$. The value was significantly higher in males than females, both in the dominant, $P < 0.001$, and the non-dominant hands, $P < 0.001$. Like the previous variables, the handgrip strength increased and peaked in the fourth decade and gradually reduced thereafter. Analysis of variance (ANOVA) showed a significant difference in the grip strength among the age categories, F (6,203) = 17.05, $P < 0.001$. Tamhane's post hoc test indicates that the grip strength in the second decade is significantly less than in the third, fourth, and fifth decades.

In contrast, there was no significant difference in the grip strength between the second, sixth, seventh, and eighth decades of life. Table 2 shows the values by age categories in dominant and non-dominant hands stratified by gender.

Grip strength predictive factors

Multiple linear regression was conducted separately for males and females to analyze the factors that predict handgrip strength in the participants. The model was statistically significant, $P < 0.001$, with an R^2 of 0.51 for males and 0.41 for females. These values suggest that the model explains 51% and 41% of the variation in handgrip strength in males and females. The model predictors included age, weight, height, MAC, TSF, and MAMA, with age, height, MAC, and MAMA being significant. Table 3 is the regression table for males, while Table 4 presents the regression coefficients for females.

TSF was excluded from the model as it shows multicollinearity with MAMA, with a correlation coefficient of -0.90. Age is negatively related to grip strength. Each yearly increase in age results in a 0.2 kg loss of grip strength in both genders. By contrast, each one-meter increase in height results in a 30 kg and 32 kg increase in grip strength in males and females, respectively. MAC and MAMA are also positively correlated with grip strength only in males, with a 1 cm increase improving grip strength by 2 kg and 0.13 kg, respectively. Hence, the formula to predict an individual's handgrip strength, based on the tables above, is given for males:

Grip strength (kg) = -63.160 + age (-0.186) + height (29.655) + MAC (2.063) + MAMA (0.131)

And, for females:

Grip strength (kg) = -36.167 + age (-0.203) + height (31.981) + MAC (0.391) + MAMA (0.047)

Discussion

Handgrip strength assessment is helpful in hand disorders and systemic disease that bears no direct anatomic relationship to the hand due to its ease of administration, reliability, and non-invasiveness.[15-20] However, studies showed that its values vary according to the subject's age, race, gender, and other anthropometric features.[8-10,17,21] Hence, test interpretation should consider these parameters. Many studies have established reference ranges for their population, with few studies conducted in our environment informing this research.

Most anthropometric parameters show a similar relationship with participants' age categories in this study. They rise from the second decade to the fourth or fifth decade and then decline, and this pattern was observed for weight, height, MAC, and TSF. Females have a higher MAC and TSF but a lower MAMA. The reason is that females have more subcutaneous fat than males,[22] which caused the former two parameters to be higher. By contrast, males generally have larger muscle mass, reflected in the higher MAMA values.

In this study, the mean handgrip strength in the dominant hand was 31.09 kg and 28.45 kg in the non-dominant hand, a difference of 2.64 kg. Although this difference was statistically significant, it did not reach clinical significance. Kim *et al*.[13] have shown that it takes a deficit of 6.5 kg for a decrease to be clinically noticeable. It is expected that the dominant hand will have a higher grip strength than the non-dominant hand since it is frequently used. Wolff's law states that increased muscle-bone stress will lead to stress adaption, resulting in increased mechanical strength.[22] This difference was seen in both genders in this study, with males having higher values.

This gender difference is expected as males engage in more physical labor and have more androgens than females, positively influencing musculoskeletal development. Other studies demonstrated a similar trend in grip strength between the sides and gender. Michael *et al*.[23] showed that the mean values of the grip strength in Nigerian subjects' right and left hands were 32 kg and 30.7 kg in males and 20.4 kg and 18.7 kg in females, respectively.

These values are not far from those in this study, although they did not indicate the handedness of the study population. However, considering that less than 2% of the study sample in the index work were left-hand dominant, one would assume that the right hand was the dominant hand in such studies. They also used the Jamar manual dynamometer in contrast to the electronic one used in this study, which may explain the differences in the values since the sample size and the study population are similar to the index study.

Lam *et al*.[9] also showed a similar trend in the Malaysian population. They consistently demonstrated higher grip strength in the dominant hand and in males across all age groups. It is difficult to directly compare as they recruited only patients older than 60 and categorized them in a five-year age bracket compared to the ten-year group in the index study. However, averaging their figures gave males a mean grip strength of 35 kg and 28 kg in the seventh and eighth decades, respectively. Males within the same age group in the index study had a mean grip strength of 30 kg and 25 kg, which is not much different. The same calculation for the females in the same age brackets gave a mean grip strength of 24 kg and 18 kg for the seventh and eighth decades, respectively. These values closely parallel the values in this study, with 25 kg and 18.8 kg in corresponding categories, respectively. They also used the Jamar dynamometer, which could explain some observed differences.

Rostamzadeh *et al*.[24] studied the grip strength in more than 2000 school children aged 7 to 18 years in Iran. They found an average male grip strength of 25.6 kg and a female grip strength of 17.8 kg, close to the male value in the index study's 10- to 19-year-old age group. The values for males and females were 23.88 kg and 23.85 kg, respectively. The female value was higher in the index work compared to Rostamzadeh's work. One reason for this difference between the girls may be the device used. They used the Jamar mechanical dynamometer, while the index study used the electronic one. Studies have shown that a greater force is required to actuate the mechanical dynamometer than the electronic one.[25] Young girls may not generate as much force as their male counterparts, making the mechanical dynamometer less sensitive than the electronic one. The authors also demonstrated that the dominant hand was stronger than the non-dominant hand in both genders, which agreed with this study's finding.

The grip strength showed a quadratic relationship with age rather than a linear one. It increases and reaches a peak in the fourth decade (30–39 yrs.) in males and the third decade (20–29 yrs.) in females in this work and then steadily declines.

This decrease is likely due to an age-related decline in activity and hormone levels. The mean annual grip strength loss in males in this study was 0.68 kg per year. In this study, males show the fastest rate of change in the fifth decade as they lose an average of 1.6 kg of grip strength per year. In contrast, females experienced the highest rate of change in the sixth decade, losing an average of 0.92 kg of grip strength per year in this study, with an average yearly loss of 0.34 kg per year. The rate of change was calculated by dividing the difference in grip strength from each age category to the next by 10, which is the bin width of the age group. The yearly average loss was obtained by averaging the result from the previous calculation over the number of affected age categories. This finding differs from a Russian study that found that males experienced the fastest decline in grip strength in the 70- to 75-year-old group at a 1 kg/year rate.[14] However, the mean yearly loss in females was similar to that in a Danish study of 0.34 kg per year.[26]

Michael *et al*.[23] found that grip strength peaked in the 30–39-year Nigerian subjects in both genders, similar to this study. In contrast, Adedoyin[12] found it peaked in 20–29 years in another Nigerian study. An Australian study[27] showed that the grip strength was maintained from 20 to 49 years before gradually decreasing in males. Females showed a peak grip strength in the 30–39-year age group. However, the grip strength was higher in all the age groups for both genders in the subjects than their corresponding age mates in the index study. This finding of higher grip strength in western studies was supported by a Swiss study[28] which showed an average male grip strength in the 50 s and female grip strength in the 30 s, well above values in this study. Similar findings were seen in studies done in the USA and Canada.[29,30] This difference could be due to better socioeconomic variables in western countries, which translates to better nutrition and overall well-being.

A multiple linear regression model was built with the subjects' age, height, weight, MAC, TSF, and MAMA as predictors in analyzing the factors influencing handgrip strength. However, TSF was excluded from the model due to multicollinearity with MAMA. Age significantly predicted handgrip strength, with a one-year increase in age associated with a 0.2 kg decline in grip strength. However, it must be noted that the relationship between age and grip strength is not linear. However, considering the overall gain and loss over the years, there is a net loss in grip strength as one ages from 10 to 79 years. Several studies support the decrease in grip strength with advancing age.[12,31,32] The reasons for decreasing grip strength with increasing age are multiple, including reduced physical activity, decreasing hormonal level with associated age-related sarcopenia, and immobility caused by comorbid conditions in old age.

The weight did not predict grip strength in this study. The reason weight is not a good predictor of grip strength could be that being overweight is likely due to fat accumulation in most people. Adipose tissue secretes cytokines (adipokines) which have been correlated with lower muscle mass and strength.[33,34] This finding agrees with Michael *et al*.,[23] who did not find a significant association between weight and grip strength among Nigerian adults. It is also similar to Fallahi and colleagues,[35] who examined grip strength in athletes and non-athletes. However, it disagrees with Adedoyin,[12] who found that weight positively correlates with grip strength only in males. This analysis was not conducted as there is insufficient evidence to suggest that weight would act differently in males and females in its relationship with grip strength.

In contrast to weight, height significantly predicted grip strength, with a 1 cm increase predicting a 0.30 kg and 0.32 kg gain in grip strength in males and females. This finding was similar to Frederiksen *et al*.,[26] who found that a unit height increase results in a 0.36 kg gain in grip strength. Also, Ong[36] found a statistically significant association between height and grip strength. However, Fallahi[35] and Michael[23] did not find a significant association between grip strength and height. Growth, which depends on several factors, including genetics, nutrition, and testosterone, would correlate with a higher muscle mass and bone density, translating to a higher grip strength among taller individuals. An individual's muscle cross-sectional area is correlated with the body surface area or the square of the body height.[37] But this relationship should be explored since the results are still conflicting.

The MAC is an indirect measure of the nutritional status of an individual. In this work, a 1 cm increase in the MAC improves the grip strength by 2.0 kg only in males. The bulk of the arm comprises the biceps, brachialis, and triceps muscles with the overlying subcutaneous tissue and skin. Women tend to have more subcutaneous fat, while men tend to have more muscle, which could explain why MAC is not correlated with grip strength in women. Ong *et al*.[36] showed a positive relationship between the MAC and the grip strength in Singapore. By contrast, a Russian study[14] failed to demonstrate any significant relationship between MAC and grip strength. Hence, conflicting results may be found depending on the proportion of gender. The Russian study had more women than men (74% vs. 27%) and did not detect a significant relationship between MAC and grip strength.

By contrast, the Singapore study[36] had a more balanced proportion of women and men (54% vs. 46%) and detected a significant relationship between MAC and grip strength. In addition, the latter study had a larger sample size than the former, 2043 vs. 909. Hence, it has more power to detect a relationship if one truly exists. The index study used an equal proportion of males and females, thereby canceling out the confounding effect of gender on the relationship between MAC and grip strength.

The MAMA is directly related to lean muscle mass and is expected to vary proportionately with the HGS. In this study, a one-centimeter increase in MAMA raises the grip strength by 0.13 kg in males. MAMA did not predict grip strength in women, probably because women tend to have less muscle than men. This finding agrees with Rukadikar *et al*.,[38] who found a strong positive correlation between handgrip strength and MAMA in male cricket players. In contrast, Turusheya and colleagues[14] found no relationship between MAMA and grip strength, similar to this study's finding.

Conclusion

This study showed that the average grip strength in our population is lower than those published in the western literature and that males have a higher grip strength than females. Also, age and height predict grip strength in both genders, while MAC and MAMA predict it only in males.

Recommendation

The reference values in this work should be used to assess our population's handgrip strength.

Limitation

The researcher did not encounter any limitations in the conduct of this work.

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Conflicts of interest

There are no conflicts of interest.

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