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ORIGINAL ARTICLE

Reference values and determinants for handgrip strength in healthy subjects☆

Michele Berçôt Budziareck*, **Rodrigo Roig Pureza Duarte**, **Maria Cristina G. Barbosa-Silva**

Programa de Pós-graduação em Saúde e Comportamento, Universidade Católica de Pelotas, Pelotas, RS, Brazil

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Summary
Background & objectives: To determine reference values and associated factors for handgrip strength among healthy adults.
Methods: Three hundred well nourished (SGA category A) subjects were studied, aged 18—90 years. Handgrip strength (HS) was determined using a hand dynamometer. Adductor pollicis muscle (APM) thickness and other anthropometric variables were also measured. Results were analyzed according to gender and age group. We carried out multiple linear regression in order to identify significant determinants of handgrip strength.
Results: HS is significantly associated with gender and decreases after age 60 years ($p < 0.001$). Different reference values for each gender and age category are presented, for both dominant (DHS) and non-dominant hands (NDHS). APM showed a strong correlation with HS ($R^2 = 0.71$ and 0.70, for DHS and NDHS, respectively). This association remained significant after adjustment for other variables such as gender, age and body mass index.
Conclusion: Reference values are needed to allow the use of HS as a muscular function assessment tool. Values should be stratified by gender and age group. The combined use of HS and APM may be useful as a method for nutritional assessment.

Introduction

In the last 20 years, a number of scientific publications from around the world point to hospital malnutrition as a direct cause for higher morbidity (slower wound healing; higher hospital infection rates; longer stay, especially among

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* Corresponding author. Programa de Pós-graduação em Saúde e Comportamento, Universidade Católica de Pelotas, R. Santos Dumont, 504A, 96020-380 Pelotas, RS, Brazil. Tel.: +55 53 3225 1243.
E-mail address: michelebercot@yahoo.com.br (M.B. Budziareck).

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intensive care patients; higher readmission rates) and mortality.[1] The obvious impact of such a scenario include avoidable deaths, additional costs for the social security system, and the social onus related to loss of working days.[2] Other variable in this equation is increased expenditure for the healthcare system.

A wide variety of methods are available for nutritional evaluation. Notwithstanding, none of these can currently be considered as a ''gold-standard'' for diagnosing hospital malnutrition.[3] Available methods include anthropometry, the creatinine height index, albumin, pre-albumin, immunocompetence evaluation, cholesterol, and the prognostic nutritional index, among others.[4] However, none of these methods provides a functional evaluation of malnutrition. SGA is a well accepted method of nutritional assessment that addresses functional status as a complement of its medical history, but it was not developed to be used to evaluate responsiveness, and so, its rating are not expected to show any modification after nutritional interventions in short periods of time.[5]

There is evidence that muscular function is altered and muscular strength diminished, in the presence of malnutrition.[6,7] According to Jeejeebhoy,[4] malnutrition-related muscular function alterations appear before changes in anthropometric and laboratory parameters. Nevertheless, methods for evaluating muscular strength during nutritional evaluation are still scarce.[8]

The earliest nutritional alterations occur within muscle cells, and have an effect on muscle cell function. Measuring muscular strength may therefore provide a sensitive method for nutritional evaluation.[9] Muscular loss is inevitable during malnutrition, and if untreated, may become progressive.[10] Therefore, in addition to their ability to detect early alterations related to malnutrition, muscular function tests could also prove useful for evaluating nutritional recovery, underscoring the importance of such evaluation in this context.

Recent studies have demonstrated the validity of using hand dynamometers as a method for nutritional evaluation, given that this is a simple, fast, useful, inexpensive, and efficacious test for muscular function.[11–14] Knowledge of reference values in a healthy population would allow a functional muscle evaluation not only in hospital and research settings, but also in population-based studies, since this is a simple and low-cost assessment method.

The two other papers with reference values had 108 subjects[9] and 496 subjects,[13] but they don't have similar distribution among the age categories and used different tools for the assessment of handgrip strength. The aim of the present study was to determine reference values for handgrip strength (HS) in a more homogeneous sample of healthy adults, as well as to study the influence on this parameter of variables such as gender, age, professional activity, and adductor pollicis muscle (APM) thickness.

Methods

Selection lasted from April to September 2006. The study had a cross-sectional design, and was carried out at the *Hospital Universitário São Francisco de Paula* (HUSFP) and at the *Centro de Extensão em Atenção à Terceira Idade* (CETRES), a communal center for older people. We also collected data at a local city square, due to the difficulty in recruiting male volunteers over 60 years of age in the two previous locations.

Subject recruitment procedures differed between each location. At HUSFP, we obtained an ordered list of the entire hospital staff and selected the necessary number of participants under 60 years old (200) using a random selection process (random list generated by Stata). At CETRES, we selected 11 of the 23 ongoing workshops, and, within each of these workshops, participants were randomly selected until the necessary number of subjects was obtained (50). Finally, at the local city square, after subjects agreed to participate, each volunteer was randomly assigned to participate or not in the study, so as to avoid selection bias. After the selection process, we invited to participate in the study three hundred healthy volunteers (150 men and 150 women) aged 18–90 years.

Following the selection process, volunteers were invited to participate in the study. Those who agreed to participate were informed about the study's methods and objectives. After accepting to participate, all subjects signed a term of informed consent. As inclusion criteria, all patients should be healthy as assessed by Subjective Global Assessment (SGA A). We excluded from this study subjects under the age of 18 years and those unable to perform the strength measurements.

Nutritional evaluation of subjects was carried out using subjective global assessment (SGA).[15] This method was performed by dieticians previously trained in the technique, since it depends on the evaluator's observational abilities. HS was measured using a Jamar® hydraulic hand dynamometer (Asimow Engineering Co., Los Angeles, CA), and APM thickness was measured using a Lange® skinfold caliper.

Initially, we administered a questionnaire to obtain additional information, including age, weight, height, and occupation, the latter considering two distinct professional groups, one in which manual physical effort is inherent to professional activity, and one in which it is not. Sports activities, dominant hand, and presence of injuries and/or fractures in any of the hands were also considered as relevant data, given that these may influence the final results. HS and APM were also measured at this time. The economic classification criterion by the Brazilian Market Research Association (*Associação Nacional de Empresas de Pesquisa* — ANEP was used. The criterion is based on the ownership of consumer goods, presence of domestic servants and on the schooling of the household head and group the individuals into one of five classes, from A (richest) through E (poorest).

HS and APM evaluation was carried out with the subject in a standardized position. For HS evaluation, subjects were seated, with their elbows flexed at 90° and supported at the time of the measurement.[16] We collected three measurements from each hand, and used the mean value in all analyses.[13] During HS measurement, we asked the subject to grip the dynamometer with maximum strength, and to hold the grip for three seconds. For APM evaluation, subjects were seated with both hands resting on the homolateral knee, and elbows flexed at approximately 90°, over the lower limb. The APM was pinched by the skinfold caliper at the vortex of an imaginary angle formed by the

Table 1 General and anthropometrical characteristics of the subjects (all sample and by gender)

Variables	All $n = 300$[a]	Male $n = 150$[a]	Female $n = 150$[a]
	Mean ± SD	Mean ± SD	Mean ± SD
Age (years)	44.9 ± 18.5	45.3 ± 18.1	44.5 ± 19
Height (cm)	1.67 ± 0.1	1.73 ± 0.07*	1.61 ± 0.08*
Weight (kg)	72.9 ± 13.8	80.3 ± 12.4*	65.5 ± 11.0*
BMI body mass index (kg/m^2)	26.1 ± 4	26.7 ± 3.8*	25.4 ± 4.1*
HS dominant hand (kg)[b]	30.4 ± 11.7	38.9 ± 10.0*	22 ± 5.7*
HS non-dominant hand (kg)[b]	27.9 ± 11.7	36.4 ± 10*	19.5 ± 5.6*
APM dominant hand (mm)[c]	22.9 ± 5	26.1 ± 4.4*	19.8 ± 3.3*
APM non-dominant hand (mm)[c]	21.9 ± 5	25.1 ± 4.4*	18.7 ± 3.1*

*$p < 0.05$ t test between genders.
[a] n: number.
[b] HS — handgrip strength.
[c] APM: adductor pollicis muscle.

extensions of thumb and index finger. The mean of three measurements was considered as the measure of thickness of the adductor pollicis.[17]

Normal distribution of variables was determined using the Shapiro Wilk and Skewness and Kurtosis (SK) tests. Linear trend tests were performed to evaluate the distribution of HS measurements in the different age groups. Both paired and unpaired tests were used, according to the type of variable. Data were presented as stratified into 3 age groups and according to gender. We used the Kruskall—Wallis test to compare HS between different age groups, and the Wilcoxon test for comparison between genders. Despite the non-normal distribution of HS found in the present study, other studies in the literature present the results of mean and standard deviation for this measure.[13] We will thus use as measures of central distribution both the mean and standard deviation and median and 5th and 95th percentiles, considering the 5th percentile as the minimum reference value.

We tested the correlation between HS and age, weight, height, body mass index (BMI), and APM. Multiple linear regression analysis was used to adjust for the effects of other variables and to identify those independently associated with HS. All analyses were carried out using STATA software, version 9.2 (StataCorp, Texas, USA). The 5% significance level was adopted for all analyses.

The present study was approved by the Research Ethics Committee of the *Santa Casa de Misericórdia de Pelotas*.

Results

General and anthropometric data referent to all 300 volunteers is presented in Table 1. Mean age was 44.9 ± 18.5 years, with no statistical difference between men and women. All anthropometric variables studied were significantly greater in men. All subjects were considered well nourished according to SGA.

A little over half the subjects (56.3%) came from social classes C, D, and E, and 42.7% of subjects lived with a partner.

The large majority of subjects were right-handed (91%). We present HS values grouped into dominant hand — HSD (right-hand in right-handed subjects and left hand in left-handed subjects) and non-dominant hand — HSND (left-hand in right-handed subjects and right hand in left-handed subjects). Two ambidextrous subjects were excluded from this analysis.

A total of 110 (36.7%) subjects were employed in professions that required manual physical effort, such as mechanic, welder, and/or persons working with general tasks (launderer, cleaner). All volunteers were performing their professional tasks normally at the time of evaluation. There was no significant difference in HSD and HSND between manual and non-manual workers ($p > 0.05$). The leisure-related activity was also evaluated and no volunteer presented regular physical activity, so this variable was not considered in the analysis.

Table 2 Handgrip strength of dominant hand according to gender and age

Age	Handgrip strength (dominant — kg)			
	Male ($n = 150$)		Female ($n = 150$)	
	Mean ± SD	Median (P5—P95)	Mean ± SD	Median (P5—P95)
18—30 years ($n = 100$)	43.4 ± 8.35	43*,** (30[a]; 57)	22.8 ± 4.87	23*,** (16[a]; 30)
31—59 years ($n = 100$)	41.9 ± 9.21	42*,** (27[a]; 55)	24.0 ± 5.93	23*,** (16[a]; 35)
≥60 years ($n = 100$)	31.3 ± 7.95	31*,** (18[a]; 44)	19.1 ± 5.18	18.5*,** (11[a]; 29)

The 5th percentile value in each group should be considered as cut-off value for healthy subjects.
*$p < 0.05$ linear trend among age groups in the same gender (Kruskall—Wallis test).
**$p < 0.05$ differences between gender in the same age group (Wilcoxon test).
[a] Cut-off values for healthy subjects.

Table 3 Handgrip strength of non-dominant hand according to gender and age

Age	Handgrip strength (non-dominant − kg)			
	Male ($n = 150$)		Female ($n = 150$)	
	Mean ± SD	Median (P5–P95)	Mean ± SD	Median (P5–P95)
18–30 years ($n = 100$)	40.4 ± 8.17	39.5*,** (30[a]; 54)	20.7 ± 5.05	21.5*,** (13[a]; 29)
31–59 years ($n = 100$)	39.4 ± 9.57	39*,** (26[a]; 61)	20.9 ± 6.01	21*,** (10[a]; 29)
≥60 years ($n = 100$)	29.2 ± 8.00	29*,** (18[a]; 45)	16.8 ± 4.80	16.5*,** (10[a]; 27)

*$p < 0.05$ linear trend among age groups in the same gender (Kruskall–Wallis test).
**$p < 0.05$ differences between gender in the same age group (Wilcoxon test).
[a] Cut-off values for healthy subjects.

Tables 2 and 3 present the results of measurements of HSD and HSND, distributed according to age group and gender. HSD was significantly greater than HSND ($p < 0.05$) in all age groups in both genders. Men had significantly greater HS than women in all age groups. The linear trend test showed that HSD and HSND decreased significantly as age increased ($p < 0.001$), as seen in Figure 1. Suggested minimum reference values for HSD and HSND are those presented as the 5th percentile in Tables 2 and 3, stratified by gender and age group.

The correlation between HS and variables such as age, weight, height, BMI, and APM were also evaluated, and are presented in Table 4. There was a positive correlation between both HSD and HSND and APM ($R^2 = 0.71$ and 0.70, respectively); height ($R^2 = 0.62$ for both); weight ($R^2 = 0.55$ and 0.54, respectively), and body mass index ($R^2 = 0.20$ and 0.18, respectively), and a negative correlation with age ($R^2 = -0.29$ and -0.28, respectively). All these correlations were significant ($p < 0.001$). We did not evaluate the correlation between HS and nutritional status, given that the entire sample was considered as nourished according to SGA.

The result of multiple linear regression is presented in Table 5. Gender was the most important determinant of HSD and HSND: women showed a deficit of 11.47 and 11.48 kg, respectively, in relation to men in the same age group ($p < 0.001$). Age was also a determinant of HSD and HSND, with a reduction of 1.90 and 1.57 kg, respectively, for each decade after age 21 ($p < 0.001$). Even after adjustment for gender and age, APM remained significantly associated with HSD and HSND, with 0.85 and 0.82 kg increases in strength for each additional millimeter of muscle ($p < 0.001$). After adjustment for all biological variables, subjects whose professional activities were associated with less manual effort showed a decrease in HS of 2.06 kg for the dominant hand only ($p = 0.03$). The above variables (gender, age, APM, and occupation involving manual effort, for HSD only) explained almost 70% of HS variability (Figure 2).

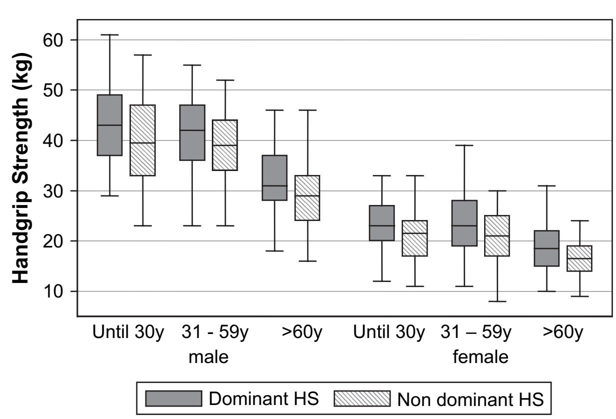

Figure 1 Handgrip Strength on dominant and non-dominant hand according to gender and age ($p < 0.05$ for differences between genders and linear trend among age groups).

Discussion

HS behaved similarly to other anthropometric variables with respect to gender and age, like weight and height: values were significantly higher in men, and fell progressively with ageing (Tables 2 and 3). This decrease was more pronounced in the population above 60 years old, in both genders. A comparison of the present findings with those of other studies shows the expected results, i.e., that age and gender influence muscular strength.[7,9,13,18,19] Such influence justifies the need for different reference values for each gender and age group.

As expected, HS was significantly greater in the dominant hand. This is in agreement with the findings of Hornby and coworkers.[6] The stronger correlation with APM ($R^2 = 0.71$ for HSD and $R^2 = 0.70$ for HSND, both with com $p < 0.001$) than with age and other anthropometric variables suggests that HS may be considered as a fast and simple test for muscular function, which can be used in clinical settings. However, no studies of such use were found in the literature, and further validation is required.

Table 4 Pearson's correlation values from handgrip strength (dominant and non-dominant hand), age and the other anthropometric variables

	HSD[a]	HSND[b]	p value
APM (mm)[c]	0.71	0.70	<0.001
Height (cm)	0.62	0.62	<0.001
Weight (kg)	0.55	0.54	<0.001
BMI (kg/m^2)[d]	0.20	0.18	<0.001
Age (years)	−0.29	−0.28	<0.001

[a] HSD: handgrip strength dominant hand.
[b] HSND: handgrip strength non-dominant hand.
[c] APM: adductor pollicis muscle.
[d] Body mass index.

Table 5 Results from multiple linear regression of handgrip strength (backward selection of variables)

	Dominant HS[a,b]			Non-dominant HS[a,c]		
	β values	SE (β)	*p* value	β values	SE (β)	*p* value
Gender	−11.47	1.01	<0.001	− 11.88	1.00	<0.001
Age[d]	−1.90	0.25	<0.001	− 1.57	0.21	<0.001
Professional activity with no manual effort	−2.06	0.95	0.03	—	—	—
APM[e]	0.85	0.10	<0.001	0.82	0.10	<0.001
Constant	37.37	3.82	<0.001	33.94	3.80	<0.001

[a] HS: handgrip strength.
[b] Adjusted $R^2 = 0.69$.
[c] Adjusted $R^2 = 0.68$.
[d] Age in decades from 21 years old.
[e] APM: adductor pollicis muscle.

Two other studies in the literature presented reference values for healthy populations. However, the values showed in these studies differ from the results from the present study: one of the studies showed smaller values[13] and the other, larger values than our results.[9] Potential explanations for such discrepancy may include differences in the samples with regard to the number of subjects in each age group and gender, and the use of measuring instruments of different brands.

Although the strong correlations between HS and other anthropometric variables, such as weight, height, and BMI, are biologically coherent, these variables by themselves are not sensitive enough to detect small modifications in nutritional status. Other studies in the literature demonstrate the superiority of HS for such evaluation. Gottschal and coworkers[12] compared different methods for nutritional evaluation, including BMI, SGA, and HS, in a sample of patients with liver cirrhosis. None of the patients in this study were considered as malnourished according to BMI; however, malnutrition was diagnosed in 38% of patients by SGA, and in 85.7% by HS.

Norman and coworkers[7] found significantly lower HS levels in malnourished patients. This study did not use reference HS values to diagnose malnutrition, but only confirmed its lower values in patients previously classified as malnourished.

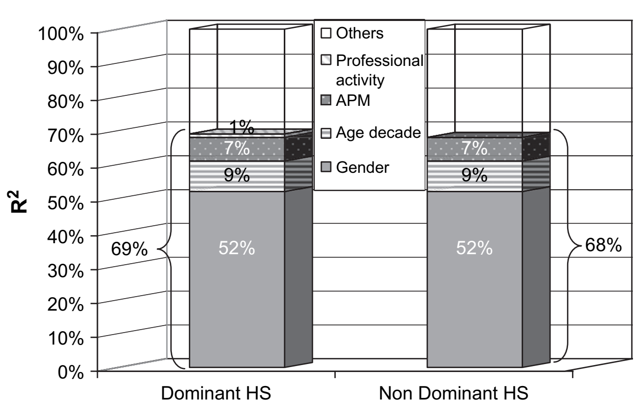

Figure 2 Contribution of each variable (R^2) to the total variability of HS after linear regression analysis.

The aim of the present study is to present reference values for HS in a population considered as healthy, so that these values can later be used to identify variations in hospitalized patients, that is, to identify the depletion of muscular function.

Even after adjustment for gender and age, APM remained as an important determinant of HS. Other variables strongly correlated with HS, such as BMI, lost their association after adjustment for the remaining variables. HS is the only muscle that, due to it anatomic characteristics, allows for direct evaluation of thickness.[17] Tests of its function, including contraction following stimulation of the ulnar nerve, are restricted to research settings.[20] The combination of a muscular measurement method (APM) with a functional evaluation (HS) appears ideal for the early detection of structural and functional modifications in muscle. Such measurements could prove useful both for early diagnosis of malnutrition and for monitoring the responses of patients undergoing nutritional interventions. The cross-sectional nature of the present study does not allow interpretation in this regard, but a recent longitudinal study showed that handgrip strength was a sensitive tool to identify the muscle response after a nutritional therapy.[21]

Conclusion

According to the results of the present study, HS values vary according to age group and gender, which highlights the importance of using different reference values for each of these groups. Differences in age become more marked after age 60 years. Values below 5th percentile of reference values can be considered abnormal.

In addition to gender and age, we have shown that APM thickness is a significant determinant of HS. Future studies may be able to demonstrate an association of these parameters with nutritional status—as measures of muscular mass (APM) and function (HS)—as well as with variation in status following nutritional intervention.

Further studies are also needed to determine reference values in populations with varying degree of malnutrition, and to determine the sensitivity and specifity of these reference values. Prospective studies will be needed to determine whether muscle-associated changes due to nutritional status can be detected using these novel methods (HS and APM), either alone or in combination.

Conflict of interest statement

None declared.

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MBB conceived of the study, participated in its design and coordination, performed the data analyses, and drafted the manuscript. RRPD performed part of collection of data. MCGBS participated in the design of the study, performed the statistical analysis and data analyses and drafted the manuscript. All authors read and approved the final manuscript.

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