HAND GRIP STRENGTH IN HEALTHY YOUNG AND OLDER BRAZILIAN ADULTS: DEVELOPMENT OF A LINEAR PREDICTION MODEL USING SIMPLE ANTHROPOMETRIC VARIABLES

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Original scientific paper
UDC: 796.012.11:303

Abstract:

Hand grip strength (HGS) is important not only in its own right, but as an indicator of overall body strength and future outcomes as well. As we have found no studies on the HGS predictive models including Brazilian adults younger than 50 years of age, we aimed to develop a novel predictive equation using demographic and anthropometric attributes for subjects aged between 18 and 71 years. This is a cross-sectional study in which 203 (105 women) apparently healthy young and older adults were evaluated. A hydraulic dynamometer was used to measure HGS, according to the American Society of Hand Therapists recommendations. Several models were tested using age, body mass (W), body height (H), body mass index (BMI), level of physical activity (IPAQ) and gender as explanatory variables. Automated variable selection using the forward stepwise method was applied. The overall performance measures of the regression consisted of the R^2 value adjusted for the number of variables retained in the proposed model, as well as of the standard error of the difference. Regression's diagnosis using Pearson's correlation coefficient, multicollinearity assessment and analysis of residuals were also performed to verify specific performance of the model. Statistical significance was considered at $p<.05$ for all analyses. Regarding the dominant (D) body side, the adjusted R^2 value obtained by the stepwise method was .683. The variables age and IPAQ classification did not significantly increase the adjusted R^2 value and therefore were excluded from the model ($p>.100$). For the non-dominant body side (ND), the adjusted R^2 was .640. The final prediction models for the dominant body side was $HGS_P D=20.108\times H+0.083\times W+13.265\times sex_{male=1}-8.737$, whereas for the non-dominant body side it was $HGS_P ND= 9.23\times H+0.086\times W+14.671\times sex_{male=1}+5.904$. Simple personal attributes, such as gender, body height and body mass can predict the expected values of HGS of the dominant and non-dominant upper limbs for Brazilian adults between 18 and 71 years.

Key words: *muscle strength, regression analysis, isometric contraction, hand strength*

Introduction

Handgrip strength test (HGS) is an easy to perform, non-invasive and low cost method of assessing maximal voluntary force of the hand. It has been used for the assessment in hand therapy patients, as well as a predictor of overall body strength and functional performance in different groups of individuals. A low HGS has been associated with clinical conditions such as anaemia, prolonged hospitalization, low bone mineral density, nutritional status, and others (Fernandes & Marins, 2011; Günther, Bürger, Rickert, Crispin, & Schluz, 2008; Novaes, Miranda, Silva, Tavares, & Dourado, 2009; Singh, 2004; Spruit, Sillen, Groenen, Wouters, & Franssen, 2013; White, Dixon, Samuel, & Dtokes, 2013). Hand dynamometry is also used as a predictor of postoperative morbidity and mortality, and as a functional index of nutritional status, showing associations with body composition data (Novaes, et al., 2009). As reference HGS values are required to make judgments about a patient's physical performance, some anthropometric variables, like body height, body mass, hand length, hand width and gender, have been used to set predictive equations (Aghazadeh, Lee, & Waikar, 1993; Chandrasekaran, et al., 2010; Chatterjee & Chowdhuri, 1991; MacDermid, Fehr, & Lindsay, 2002; Merkies, et al., 2000; Vaz, Hunsberger, & Diffey, 2002). Schlüssel, dos Anjos, de Vasconcellos, and Kac (2008) published values for HGS in healthy Brazilian adults using a representative sample of 1,122 males and 1,928 females. Although these authors have provided mean, median and percentile values for each decade of life from 20 to ≥70 years of age, they have not proposed a predictive HGS equation. On the other hand, two reference equations for middle-aged and elderly people were described by Novaes et al. (2009) using a sample of only 54 Brazilian subjects. Nonetheless, the small sample size and the lack of a proper statistical assessment of the equation's performance (Pearson's correlation coefficient and *t*-test rather than the limits of agreement between the direct and indirect methods for the prediction of HGS) are important limitations of the study. Since we have found no studies on the HGS predictive models applied to Brazilian young and older adults, in this study we aimed to develop a novel Brazilian predictive equation using demographic and anthropometric attributes.

Methods

This is a cross-sectional study in which 203 apparently healthy adults (105 women) were evaluated. Sample size was planned based on the ideal number of events (200 events) required for the validation of multivariate models (Collins, Ogundimu, & Altman, 2016). The Institutional Ethics Committee approved the study and all the subjects who agreed to participate signed a consent form. Data collection took place between August 2014 and May 2015, including the subjects recruited from the general population of Rio de Janeiro, state of Rio de Janeiro, Brazil.

Healthy sedentary, irregularly active or active subjects were included in the study, according to the *International Physical Activity Questionnaire* (IPAQ) (Matsudo, et al., 2001) classification. Subjects classified as "very active" were considered not representative of the general population (outliers) and were not included in the study. Also, individuals with debilitating upper limbs comorbidities or difficulties in walking, those who suffered from stroke, peripheral vascular disease, musculoskeletal disorders, pulmonary or cardiac disease, or having history of thoracic surgery or cognitive impairment were not included in the study.

Body mass was measured using a mechanical scale with the maximal capacity of 150 kilograms and sensitivity of 0.1 kilogram (Filizola S.A., Brazil). Body height was assessed using a stadiometer coupled to the scale. The body mass index (BMI) was calculated according to the following equation: BMI=body mass (kg)/body height (m^2). The subjects also responded to the short version of the IPAQ to check the level of physical activity according to their daily activities (Ceschini, Andrade, Oliveira, Araújo Júnior, & Matsudo, 2009; Craig, et al., 2003; Guedes, Lopes, & Guedes, 2005; Matsudo, et al., 2001; Novaes, et al., 2009).

HGS assessment was conducted using a hydraulic dynamometer (Model SH5001, Saehan Corporation, Korea), and following the American Society of Hand Therapists recommendations (Fess, 1992): subjects were seated with the arm parallel to the body, flexed at the elbow to 90°, and the forearm in a neutral position. Wrist flexion or extension was not allowed. Three measurements were performed in each hand, alternating the dominant (HGS-D) and non-dominant (HGS-ND) sides, with a one-minute rest interval between the tests. The subject's dominant side was defined according to the self-reported preferred hand while performing daily activities. The highest value obtained for each hand was used in the data analysis (Günther, et al., 2008; Innes, 1999). The subjects were instructed to perform their maximal effort during the test. The standardized instructions "When I say go, grip as hard as you can until I say stop" and "Harder… harder… harder… relax" were given prior and throughout the test, respectively (Shechtman & Sindhu, 2013).

Statistical analysis

Several models were tested using the subsets of anthropometric and demographic variables commonly used as predictors of HGS_M. Continuous (age, in years; body mass, in kilograms; body height, in meters; BMI, in kg/m^2) and dichotomous (sex, male=1) variables were entered in the model via a forward stepwise method using the adjusted R^2 value as a criterion for either entry or removal of the variables. The results of IPAQ were categorized as an ordinal variable ("active"=3; "insufficiently active"=2; "sedentary"=1) and also entered in the model. Separated sets of prediction equations for HGS_P were developed for the dominant and non-dominant body sides (HGS_P-D and HGS_P-ND, respectively). Automated variable selection using the forward stepwise method was chosen to avoid the selection of noisy variables from the initial set of independent variables carefully chosen according to our study aims and previous studies (Novaes, et al., 2009; Schlüssel, et al., 2008) as recommended (Sun, Shook, & Kay, 1996).

Overall performance measures of the regression consisted of the R^2 value adjusted for the number of variables retained in the proposed model, as well as of the standard error ($SE = \sqrt{s^2/n}$) of the difference (bias=HGS_M–HGS_P). Specific performance of the new prediction model was assessed by the regression diagnosis and calibration analyses as follows (Collins, et al., 2014).

Regression diagnosis was performed using Pearson's correlation coefficient between the dependent (both HGS-D_P and HGS-ND_P) and independent (age, body mass, body height, BMI, sex, and IPAQ) variables and among the independent ones. Lower and upper confidence intervals [$CI_{95\%}$] were calculated for the Pearson's correlation assuming a bivariate normal distribution. Multicollinearity was assessed using the variance inflation factor (VIF); a VIF>5 indicated that the associated regression coefficients were poorly estimated (Marquardt, 1970). Analysis of residuals was also performed using empirical distributions of residuals (Toutenburg, 2002) and the one-sample Kolmogorov-Smirnov test was used with the Lilliefors correction to test the null hypothesis of normality of distribution of residues.

Calibration was verified by the assessment of calibration plot (HGS_M *vs.* HGS_P, along with the regression lines showing slope and intercept) and limits of agreement (LOA) plot. Briefly, the LOA plots the difference (measured – predicted) against the mean of these two measurements to investigate any relationship between the measurement error and the true value (that is not known beforehand and thus the mean is used as its best estimate) (Bland & Altman, 2010). The bias was tested against 0 with the one sample Student's *t*-test. The error was determined as the SD of the bias. The LOA plot was used to determine bias and agreement between the values predicted by the equations and those measured. Limits of agreement were defined as upper and lower $CI_{95\%}$ and were determined by the mean differences ±1.96SD.

A complete-case analysis was conducted because no missing data occurred. Data was initially tabulated in Excel (Microsoft Corporation, U.S.A.) and statistical analysis was performed using SPSS 22 (IBM Corp., U.S.A.). Descriptive results are shown as M±SD and frequency (%) for the continuous and categorical variables, respectively. Predicted values were calculated by the simplified model using the coefficients rounded to three digits of precision. Statistical significance was considered at $p<.05$ for all analyses.

Results

Out of the 206 initially recruited subjects, three were classified as very active (IPAQ) and were excluded from the study. Among the remaining 203 subjects, 98 were male (48.3%) and 105 (51.7%) female. Anthropometric and demographic data are presented in Table 1. The right hand was prevalently reported as dominant in 175 participants (86.2%). To analyse the distribution of the sample by age, subjects were divided into the following groups: 18-29 years (n=69; 34%), 30-39 years (n=77; 37.9%), 40-49 years (n=41; 20.2%) and 50 years or older (n=16; 7.9%).

Table 1. Sample characteristics (N=203)

Variables	M±SD	Median [Minimum; Maximum]
Age (years)	34.7±10.9	34.0 [18; 71]
Body mass (kg)	77.7±17.2	76.7 [44.8; 152.3]
Body height (m)	1.68±0.09	1.68 [1.47; 191]
BMI (kg/m²)	27.3±5.3	26.0 [18.4; 43.7]
HGS-D (kgf)	38.0±10.7	38.0 [12.0; 63.0]
HGS-ND (kgf)	35.2±10.9	33.0 [11.0; 76.0]

Note. BMI: body mass index; HGS-D: dominant hand handgrip strength; HGS-ND: non-dominant hand handgrip strength.

The subjects presented with the following BMI classification: 1% below the ideal body mass, 37.0% within the normal range, 35.5% as overweight and 26.6% as obese. When classified according to the IPAQ, 108 (53.2%) subjects were sedentary, 78 (38.4%) insufficiently active and 17 (8.4%) physically active.

Regression diagnosis

Both the HGS_M-D and HGS_M-ND were correlated with sex (r=.805 $CI_{95\%}$=[0.750; 0.848] and r=.789 $CI_{95\%}$=[0.730; 0.836], p<.001), body height (r=.696 $CI_{95\%}$=[0.617; 0.761] and r=.638 $CI_{95\%}$=[0.549; 0.713], p<.001) and body mass (r=.473 $CI_{95\%}$=[0.359; 0.573] and r=.448 $CI_{95\%}$=[0.331; 0.552], p=.001). In contrast, age was not significantly correlated to either HGS_M-D (r=-.043 $CI_{95\%}$=[-0.180; 0.095], p=.539) or HGS_M-ND (r=-.054 $CI_{95\%}$=[-0.190; 0.084], p=.539). Finally, IPAQ classification was not significantly correlated to either HGS_M-D (r=-.051 $CI_{95\%}$=[-0.187; 0.087], p=.470) or HGS_M-ND (r=-.012 $CI_{95\%}$=[-0.149; 0.126, p=.860).

Significant association among the independent variables included the paired analysis of: sex and body mass (r=.403 $CI_{95\%}$=[0.281; 0.512]; p<.001) and body height (r=.726 $CI_{95\%}$=[0.654; 0.758]; p<.001); body mass and height (r=.494 $CI_{95\%}$=[0.382; 0.591], p<.001); and body height and age (r=-.150 $CI_{95\%}$=[-0.282; -0.013], p=.032). IPAQ classification was not significantly correlated with any independent variable (r=-.078 $CI_{95\%}$=[-0.213; 0.060] or lower, p=.269 or higher). Evidence of multicollinearity was not noticed for either models of HGS-D (VIF_{sex}=2.129, $VIF_{body\ mass}$=1.330, VIF_{height}=2.357) and HGS-ND (VIF_{sex}=2.129, $VIF_{body\ mass}$=1.330, VIF_{height}=2.357).

The final model and its overall performance

Regarding the dominant body side, the adjusted R^2 values obtained using the stepwise method started with .646 including sex (*S*) as the first variable. Entering the variables body mass (*W*) and height (*H*) significantly increased the adjusted R^2 values to .671 and .683, respectively. The inclusion of age and IPAQ classification did not significantly increase the adjusted R^2 value and therefore they were excluded from the model (p>.100). Similar results were observed for the non-dominant body side; the adjusted R^2 values, obtained using the stepwise method, started with .620 including the variable *S* as the first variable. Entering the variable *W* significantly increased the adjusted R^2 values to .639. The inclusion of *H* increased the adjusted R^2 value to .640, though without statistical significance (*p*>.100). Further inclusion of *A* or IPAQ classification did not increase the adjusted R^2 value (p>.100), therefore they were not retained in the final model (Table 2). The final prediction models for HGS_P-D (equation 1; adjusted R^2=.683, SE of bias=0.4 kgf) and HGS_P-ND (equation 2; adjusted R^2=.640, SE of bias=0.5 kgf) are:

(1) $HGS_pD = 20.108H + 0.083W + 13.265sex_{male=1} - 8.737$

(2) $HGS_pND = 9.234H + 0.086W + 14.671sex_{male=1} + 5.904$

Model's calibration

Regarding the model for HGS_P-D, there was no obvious relation between the bias and the mean (Figure 1, top); the bias±SD was 0.0±6.0 kgf (Figure 1, middle). The histogram plot of differences (residues; Figure 1 bottom) showed no apparent skew, so the assumption of normality of distribution was not violated (p=.200). The $CI_{95\%}$ for the bias was [-1; 1] kgf, and the LOA and respective 95%CI for the lower and upper LOA were -12 kgf [-13; -10] and 12 kgf [10; 13], respectively.

Regarding the model for the prediction of HGS_P-ND, there was no obvious relation between the bias and the mean (Figure 2, top); the bias±SD was 0.0±6.5 kgf (Figure 2, middle). The histogram plot of differences (residues; Figure 2 bottom) showed no apparent skew, so the assumption of normality of distribution was not violated (p=0.089). The 95%CI for the bias was [-1; 1] kgf, and the LOA and respective $CI_{95\%}$ for the lower and upper LOA were -13 kgf [-14; -11] and 13 kgf [11; 14], respectively.

Discussion and conclusions

The present study introduces a new model to predict the HGS using simple anthropometric variables. Descriptive analysis showed higher values on the dominant body side, which is in accordance with previous studies (Crosby, Wehbé, & Mawr, 1994; Luna-Heredia, Martín-Pena, & Ruiz-Galiana, 2005; Schlüssel, et al., 2008; Singh, 2004). Conversely, some authors did not compare the dominant and non-dominant side, but the left and right body sides (Hanten, et al., 1999). Although there is some evidence showing lower HGS values among left-handed subjects (Crosby, et al., 1994), we believe that the most proper comparison is achieved when hand dominance has been considered because of the hand usage in daily life activities.

Besides the overall quality of prediction (high R^2 value and low prediction error), the major advantage of our model rests in its simplicity. Different from other authors, we did not include additional measurements, like thumb length, hand shape, hand size, middle finger length, or forearm circumference (Fallahi & Jadidian, 2011; Hanten, et al., 1999; Li, Hewson, Duchêne, & Hogrel, 2010; Nicolay & Walker, 2005). In spite of considering only three parameters and gender, we found a determination coefficient above .60, which is similar or even higher than that observed in other studies on the HGS predictive models (Novaes, et al., 2009; Li, et al., 2010). Although a more detailed discussion about statistics is beyond of the scope of our study, a discussion about the applied methods might be

Table 2. Multivariate regression analysis for the prediction of handgrip strength in healthy subjects (N=203)

Model		Coefficient [$CI_{95\%}$]	Std. Error	*t*	Sig.
HGS-D					
	Intercept	-8.737 [-29.761; 12.287]	10.662	-.819	.414
	Sex (male=1)	13.265 [10.830; 15.700]	1.235	10.742	<.001
	Body mass (kg)	0.083 [0.027; 0.140]	0.028	2.937	.004
	Body height (m)	20.108 [6.558; 33.659]	6.872	2.926	.004
HGS-ND					
	Intercept	5.904 [-16.872; 28.680]	11.550	.511	.610
	Sex (male = 1)	14.671 [12.033; 17.309]	1.338	10.967	<.001
	Body mass (kg)	0.086 [0.025; 0.146]	0.031	2.785	.006
	Body height (m)	9.234 [-5.445; 23.914]	7.444	1.240	.216

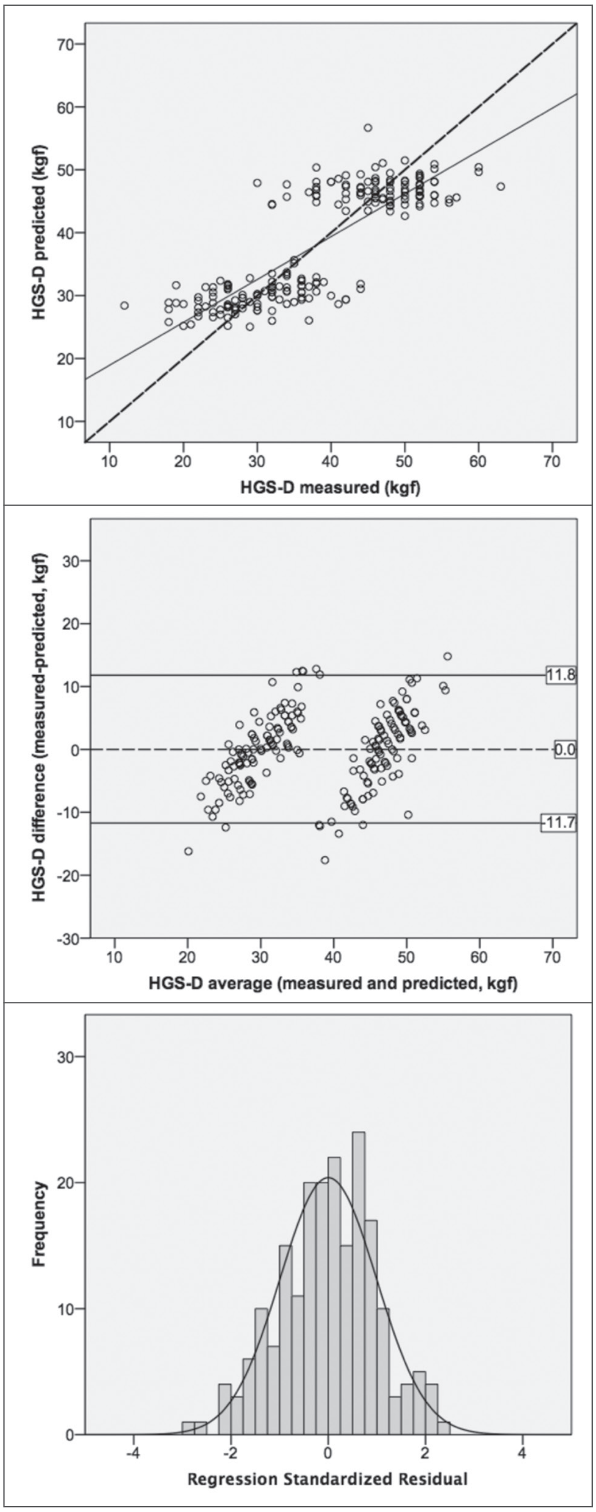

Figure 1. Analyses of the multivariable linear regression model for the handgrip strength prediction (dominant body side, HGS-D). Top: Calibration plot of the measured versus predicted handgrip strength. Middle: Limits of agreement plot of the averaged values and the bias (measured − predicted values). Bottom: Histogram of residues of the model for the prediction of handgrip strength.

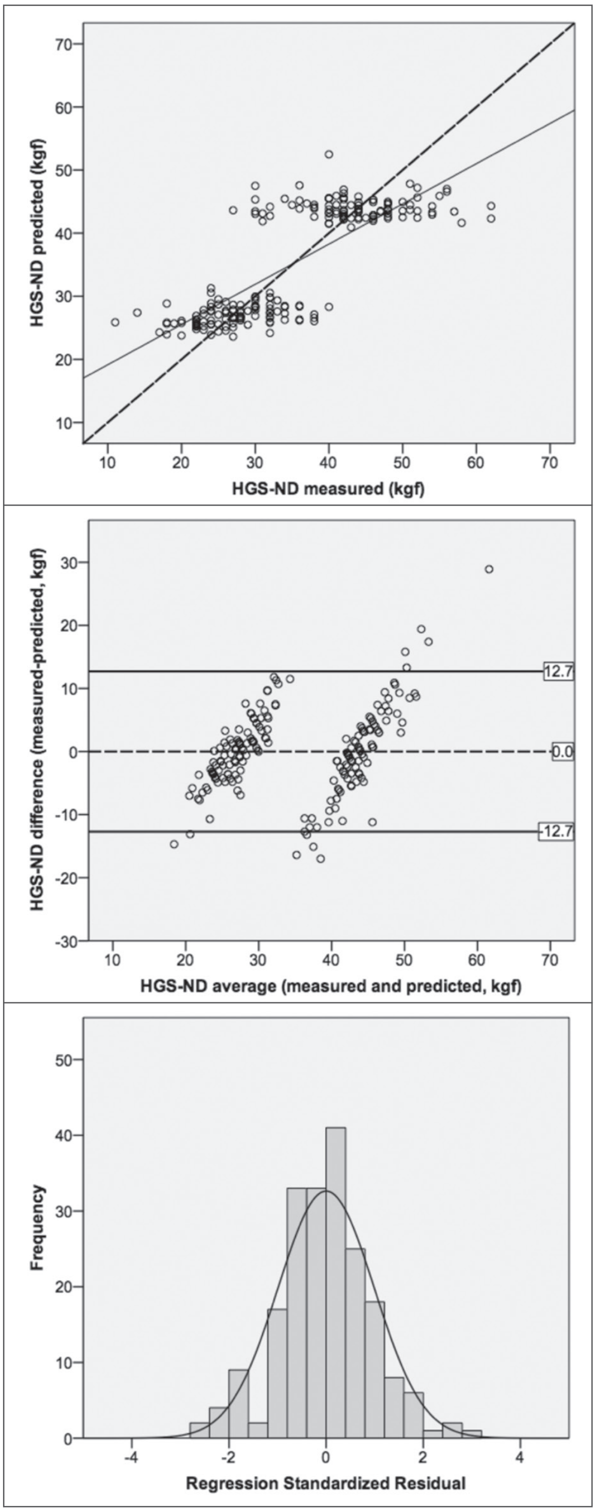

Figure 2. Analyses of the multivariable linear regression model for the handgrip strength prediction (non-dominant body side, HGS-ND). Top: Calibration plot of the measured versus predicted handgrip strength. Middle: Limits of agreement plot of the averaged values and the bias (measured − predicted values). Bottom: Histogram of residues of the model for the prediction of handgrip strength.

advantageous for the reader. Novaes et al. (2009) relied solely on the Pearson's correlation coefficient and *t*-tests to ensure validity of their predictive equation. It has been acknowledged for more than two decades (Bland & Altman, 1990, 2010) that using these two statistics methods to assess agreement between indirect and direct methods can be misleading – if not inappropriate. The Pearson's correlation coefficient evaluates relation but not agreement between two variables. In addition, Student's *t*-test is irrelevant since the null hypothesis of no difference has already been expected; as a matter of fact, it would be surprising if H0 has been rejected. Alternative methods for the assessment of the equation performance would be a random split of the sample into two groups to perform the stages of model's development and validation. Such method is statistically ineffective because it reduces the power of the statistical analysis in both stages (Collins, et al., 2014). Therefore, using LOA to assess the relationship between the measured and predicted measurements is not only simpler to do and to interpret, but it is also a proper method if the intention is to use the indirect method when the direct one is not available. Using appropriate statistical methods for the assessment of the indirect method in comparison with the direct one strengthens the findings of our study and, altogether, strongly suggests that our prediction equation can be used in the abovecited scenario. As in other studies, the univariate analysis showed strong association between body height, body mass and HGS, probably because of a higher percentage of fat-free mass in taller and heavier subjects (Crosby, et al., 1994; Hanten, et al., 1999; Luna-Heredia, et al., 2005; Novaes, et al., 2009; Schlüssel, et al., 2008; Spruit, et al., 2013). Conversely, although BMI is present in some previously described predictive equations (Budziareck, Duarte, & Barbosa-Silva, 2008; Luna-Heredia, et al., 2005), it did not show significant association with HGS in the univariate analysis in our study.

Since body height and body mass are directly correlated to HGS, and body height is inversely proportional to BMI, this is also an expected result. Moreover, BMI is more likely to be associated with fat mass instead of fat-free mass, which could be correlated to the HGS. Age information contributed little to the model, probably because the HGS is rather constant until the 5th decade of life with a significant decline thereafter (Bohannon, Peolsson, Massy-Westropp, Desrosiers, & Bear-Lehman, 2006; Nicolay & Walker, 2005; Schlüssel, et al., 2008). Günter et al. (2008) observed an increase of grip strength until its maximum about the age of 35 years. Further on, increasing age was inversely related to grip strength. Similarly, Dodds et al. (2014), when analysing HGS data from 49,964 participants of 12 general population studies in Great Britain, found an increase to its peak in early adult life, maintenance through to midlife, and a decline from midlife onwards. Thus, the correlation between age and HGS is unlikely or positive below the 4th or 5th decade of life and negative above these limits, precluding a significant association when using samples of a wide age range, as in our study.

Models are valid within the domain in which they were developed and validated (Collins, et al., 2014). Particularly, it is worth noticing that our sample was constituted of different proportions regarding age ranges, with most of the participants up to 39 (71.9%) and 49 years (92.1%). Concerning the physical activity level as measured by the IPAQ, we did not find any association with HGS or other variables. This result is in accordance with the study of Günter et al. (2008), who observed no influence of the type of occupation on the HGS. Different from most of the studies, the physical activity level was used as a selection criterion in our work, thus preventing the inclusion of very active subjects (as athletes or people under regular exercise programs). Therefore, most of the subjects in our sample were sedentary and only a very little fraction was physically active, which is in accordance with the overall population physical activity level distribution (Guedes, et al., 2005) and strengthen the external validity of our study.

In our study we performed three HGS measurements and used the higher recorded value. Although some authors used the mean HGS values, the maximum value among three or more recordings has been preferred in most of the studies. Whether the maximal or average value is of better clinical interest remains debatable. When evaluating 50 men and 50 healthy women, Haidar, Kumar, Bassi, and Deshmukh (2004) concluded that the difference between the mean and maximal value was negligible, however they expressed their preference to the use of maximum strength in clinical practice due to the extended time needed to calculate the average value. Additionally, these authors reported that a single measurement of maximum strength might be insufficient, since a part of their volunteers performed better in the second or third measurement. The usage of mean values from repeated trials has been reported to increase reliability of the measure due to the "regression to the mean" phenomenon (Haidar, et al., 2004). Regarding the protocol used in our study, we followed the ASHT recommendations. This is one of the two recognized international guidelines for HGS recording, and has been widely used in clinical practice and research studies. The other international guideline was established by the European Test of Physical Fitness (EUROFIT), where, different from the arm position used in our study, the individual performs the HGS manoeuvre with the elbow extended. As there is no consensus on the best protocol, studies as that by Chau et al. (1997) and Vianna, Oliveira and Araújo (2007) used the EUROFIT guidelines, while the others, such as Figueiredo, Sampaio, Mancini and Nascimento (2006) and Anakwe, Huntley and McEachan (2007) used the ASHT protocol. Since the two protocols provide different results because of the elbow being either extended or flexed (Pereira, Menacho, Takahashi, & Cardoso, 2011), it is important to observe from which protocol the predicted values or predictive equation was obtained. The ability to predict performance is influenced by factors such as muscle fiber-type composition, variation in structure of the bones, muscles, tendons and ligaments, level of fitness and training, health and physiological state of the subject at the time of testing, and psychological motivation (Nicolay & Walker, 2005). Moreover, the procedures used to collect data on hand grip strength (e.g. type of a dynamometer, subjects' position, handling position, etc.) have also been described to influence the obtained measures (Schlüssel, et al., 2008). Although all these variables might interfere with the hand grip performance, the major factors that compromise HGS measures are: not calibrating the dynamometer, not following a standardized test-administration protocol, and a client not exerting to the maximum (Shechtman & Sindhu, 2013). In our study, all subjects underwent the same protocol, and the used dynamometer was previously validated (Reis & Arantes, 2011). As the subjects had no cognitive or upper limb impairments and were instructed throughout the tests, we believe that sincerity of effort, which is a basic premise of a valid grip strength test, has not negatively influenced our results. A comparison with previous methods (Novaes, et al., 2009; Schlüssel et al., 2008) would be of interest, but it was not performed due to several issues. First, indirect methods (such as predictive equations) should be compared to its counterpart method – i.e. the direct method – to assess its performance (Collins, et al., 2014). The comparison of a new indirect method with other indirect ones may cause error propagation due to cumulative uncertainties in each model. Second, the study of Schlüssel et al. (2008) provided percentile-based reference values (P10 to P90) for HGS, but did not develop a prediction equation for HGS. Although an analysis of frequency of our cases within P50 is possible, it is not a true comparison of agreement between the methods. Third, to compare our results with the equation developed by Novaes et al. (2009) it would require data on the arm circumference – which are not available in our sample – and the same set of statistical procedures used to compare the agreement between the direct and our model. Therefore, future studies aiming to compare indirect methods should address the mentioned issues to provide a comprehensive assessment of their statistical performance.

Although some previous studies used large sample sizes (Bohannon, et al., 2006; Günther, et al., 2008; Schlüssel, et al., 2008), the only study that proposed a predictive Brazilian equation (Novaes, et al., 2009) included only 54 subjects. As reported in Methods, the sample size in our study is relatively small, but it is almost four times greater than that from Novaes et al. (2009), and was planned based on the ideal number of events required for validation of multivariate models (Collins, et al., 2016). The other potential limitation of our study relies upon the fact that the subjects were recruited from the population of a single Brazilian state, thus limiting validity of the predictive equations for the general Brazilian population. Ideally, a representative sample including subjects from different Brazilian regions would improve generalizability of our results. However, according to the last national census, the Rio de Janeiro population is highly miscegenated and internal migratory movements are intense, reducing the racial and ethnic differences between Brazilian states (IBGE., 2010). Nonetheless, future studies are necessary to assess validity of the predictive equation proposed in this study for the Rio de Janeiro and general Brazilian population. The most important advantage of this study is the introduction of a novel HGS predictive equation using easy-to-obtain variables with an overall performance similar to more complex models found in literature. This tool may be useful for clinical practice assessments and patients' follow up, as well as for future research involving muscle strength and/or nutritional status measurements.

In conclusion, simple personal attributes, such as gender, body height and body mass can adequately predict the expected values of HGS of the dominant and non-dominant upper limbs for Brazilian adults aged between 18 and 71 years.

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Submitted: August 24, 2015
Accepted: January 31, 2017
Published Online First: September 21, 2017

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