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Muscle strength: development of predictive equation for handgrip strength in older adults on the primary health care

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Muscle strength: development of predictive equation for handgrip strength in older adults on the primary health care

Fuerza muscular: desarrollo de una ecuación predictiva para la fuerza de prensión manual en personas adultas mayores de la atención primaria de salud

Maria Luiza Amorim Sena Pereira[1], Marília Conceição de Souza Caceres[2], Marlus Henrique Queiroz Pereira[3], Carolina Cunha de Oliveira[4], Bruno Klécius Andrade Teles[5], Elizabete Regina Araújo de Oliveira[6]

Abstract

Introduction: Monitoring the functional capacity of older adults is fundamental, and Handgrip Strength (HGS) is a consolidated marker of functional status in this age group. This study aimed to develop equations for predicting HGS in community-dwelling older adults in Primary Health Care (PHC). **Methods:** It is a cross-sectional study conducted with 316 older adults, in which a Multiple Linear Regression (MLR) was performed for the right hand (R-HGS) and left hand (L-HGS). The variables sex, age, weight, knee height (KH), arm circumference (AC), triceps skinfold (TSF), and calf circumference (CC) were considered predictors because they were easily obtained in PHC and significantly related to HGS. **Results:** In the final models, the variables sex, age, and KH together explained more than 50 % of the HGS variation. There was agreement between the estimated and measured HGS measurements, both for right and left side. **Conclusions:** It is concluded that the variability of HGS can be explained by age, sex, and KH, which are parameters simple and routinely used to evaluate older adults.

Keywords: handgrip strength, older adults, linear models, primary health care.

Resumen

Introducción: El monitoreo de la capacidad funcional de adultos mayores es fundamental, y la Fuerza de Prensión Manual (FPM) es un buen indicador de la condición física en este grupo de edad. El objetivo de este estudio fue elaborar ecuaciones de predicción de la FPM en una comunidad de personas adultas mayores en la Atención Primaria de Salud (APS). **Métodos:** estudio transversal realizado con 316 personas adultas mayores, en el cual se desarrolló una Regresión Linear Múltiple (RLM) para la mano derecha (FPMd) e izquierda (FPMi). Las variables sexo, edad, peso, altura de la rodilla (AR), circunferencia del brazo (CB), pliegue cutáneo tricipital (PCT) y circunferencia de la pantorrilla (CP) fueron consideradas predictoras, pues son fácilmente obtenidas en la APS y significativamente relacionadas con la FPM. **Resultados:** las variables sexo, edad y AR en conjunto explicaron más del 50% de la variación de la FPM. Hubo concordancia entre las medidas de la FPM estimada y la medida real, tanto en la mano derecha cuanto en la mano izquierda. **Conclusión:** La variabilidad de la FPM puede ser explicada por la edad, sexo y AJ, parámetros simples y comúnmente utilizados en las evaluaciones de salud de personas adultas mayores.

Palabras-clave: fuerza de prensión manual, personas mayores, modelos lineares, atención primaria de salud.

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1. Introduction

The global population has gone through a rapid aging process (United Nations [UN], 2020). Although the advancement of chronological age is not itself a cause of decline in functionality, and robustness is an increasingly frequent concept in gerontology (Maia et al., 2020), older adults may present a series of physiological changes, among which changes in muscle tissues involving different mechanisms (Lima et al., 2019). There is a muscle loss that might occur both in quantity and quality, with decreased strength and risk of impairment of functionality (Cruz-Jentoft et al., 2019).

For this reason, muscle condition of the older adults should be evaluated and one of the ways to identify possible deficits associated with the muscle status of the older adults is by measuring Handgrip Strength (HGS), which can be considered an indicator of overall muscle strength and correlated with strength measurements of other muscle groups, in addition to being considered an aging biomarker (Bohannon, 2019; Lopes et al., 2018). HGS stands out as a predictor of general health status and it is associated with early mortality from all causes, cardiovascular mortality, as well as related to length of hospital stay, physical function and disabilities (Bohannon, 2019; Soysal et al., 2021). The HGS measurement can also be a marker of nutritional and functional status, being associated with other indicators for health monitoring throughout the aging process (Amaral et al., 2020).

Monitoring the functional capacity of the older adults has an important and strategical role, especially in Primary Health Care (PHC), which must be potentially prepared for such evaluations. Thus, HGS measurement is relevant for evaluating older adults, given its impact on functionality and quality of life, in addition to being a criterion for screening and diagnosis of sarcopenia and frailty (Bohannon, 2019; Cruz-Jentoft et al., 2019; Fried et al., 2001). So, there is a need for PHC instrumentalization to measure and include such analysis in the evaluation protocols of older adults to early identify changes in the functional status of this population. However, the dynamometer, the equipment used to measure force, is not eventually an available tool (Soares et al., 2019).

The process of measuring HGS from equations capable of estimating it by using simple variables costs relatively less, it is a process not dependent on sophisticated equipment in the routine of PHC and, therefore, a viable alternative in health units. So, the objective of this study is to develop equations for predicting HGS in older adults in PHC.

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2. Methods

2.1 Characteristics of the study and sampling process

This is a cross-sectional, quantitative study, conducted with older adults, aged 60 years or older, registered in the Family Health Strategy (FHS) of PHC, in the western region of Bahia state, Brazil. Since this is a study for developing of a prediction model, the Transparent Reporting of a multivariable prediction model for Individual Prognosis or Diagnosis (TRIPOD) was used as a guiding document (Moons et al., 2015).

The sample calculation was based on the larger project entitled "Health assessment of the older adults in the municipality of Barreiras, Bahia". The study population consisted of the total number of older adults registered in all Family Health Teams (FHT) in the referred municipality, distributed among the 23 FHTs. The number of participants was calculated with the aid of OpenEpi software (OpenEpi, Atlanta, Georgia), Version 3, considering a confidence level of 95%, sampling error of 5 %, and event probability of 50 %.

The sample size calculated consisted of 356 older adults and, to compensate for possible sample losses, the individuals who was absent or did not agree to participate was replaced by the immediately subsequent individual on the draw list, and this procedure was performed only once for each loss. The selection of the participants took place in two stages: the first was stratified, with allocation proportional to the number of individuals registered by each team; and the second one was a simple random sampling in each team through a draw carried out by Microsoft Excel®.

The eligible individuals were recruited with the help of the Community Health Agents, with the delivery of the invitation and guidance at the home of the older adult, with subsequent scheduling of the day and time of data collection.

2.2 Inclusion and exclusion criteria

Individuals aged 60 years or older, without gender restriction, living in private households in the urban area and registered in the FHS were considered eligible to participate in the study; and the exclusion criteria were applied for older adults who lived in long-term institutions for older adults, who were hospitalized during the data collection period, and those who presented severe cognitive deficit or other health condition identified by the FHS that made the evaluation impracticable were excluded from the study.

2.3 Data collection

All collection procedures were performed by a trained and standardized team. The researchers were organized in pairs to collect data, conducted directly with older adults, from February 2017 to August 2018.

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The data collection included the following steps: identification and welcoming of the elderly person at the reception desk of the Family Health Unit, the place chosen for the data collection; checking the invitation to confirm the appointment and foreseen protocols; reading and then signing the consent form; an interview conducted by the research team; clinical and anthropometric assessment; application of specific scales; performance of the electrical bioimpedance test; delivery of the results of the clinical and anthropometric assessment to the elderly person and referrals, when necessary.

2.3.1 Sociodemographic variables

To obtain information regarding the sociodemographic characteristics of the participants, a previously coded structured questionnaire was applied, and the information was self-reported. The variables collected for this study were the following: sex (male and female), age (in years: 60 to 79 years old; 80 years old or more), education (less than four years of study; four years or more of study), marital status (with marital partner; without marital partner), race/color (black and brown; others).

2.3.2 Anthropometric variables

Weight was measured by using a portable digital scale *Líder* (Líder Balanças, Araçatuba, São Paulo, Brazil), model P200M, without column, with 200-kg capacity and 0.1-kg precision, placing the older adult in the center of the scale and with the arms extended along the body. The Knee Height (KH) was measured with an anthropometric wooden ruler Taylor (Taylor, São Paulo, Brazil), with accuracy of 0.5 centimeters, and the values were incorporated into height predictive formulas (Chumlea et al., 1985). The Body Mass Index (BMI) was calculated by dividing the weight in kilograms by the square of the estimated height in meters. When categorized, the cutoff points for identifying underweight older adults proposed by the Pan American Health Organization (PAHO) were applied (Organización Panamericana de la Salud [OPAS], 2002). Estimated height and BMI were obtained to characterize the sample studied, and they were not included in the regression model, as they were calculated from knee height.

The measurement of arm circumference (AC) was performed by using an inelastic measuring tape graduated in millimeters (Lohman et al., 1988). The triceps skinfold (TSF) was measured with a Sanny clinical adipometer (Sanny, São Bernardo do Campo, São Paulo, Brazil), Ad1009 model, graduated in millimeters and the mean value was recorded after three measurements in the non-dominant arm (Lohman et al., 1988). For measuring the Calf Circumference (CC), an inelastic measuring tape was used, graduated in millimeters, positioned on the maximum circumference of the calf (World Health Organization [WHO], 1995).

2.3.3 Dependent variable

To measure the HGS, the hydraulic hand dynamometer Saehan®, Model SH5001 (Saehan Corporation, 973, Yangdeok-Dong, Masan 630-728, Korea), was used, with the precision of two kilograms-force, calibrated and adjusted in the second position of the handle (Reis & Arantes, 2011). The positioning of the arm followed the guidelines of the American Society of Hand Therapists (ASHT)(Fess, 1992), and two

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measurements were performed on each hand, and the highest value (maximum HGS) was identified for each hand.

2.4 Statistical analysis

The data were initially entered into a Microsoft Excel® spreadsheet and exported to the statistical software R-Project, version 4.01. In the data set with 316 notes, a cleaning was performed by imputing missing or inconsistent data. Three imputation methods were tested for these observations (mean, regression, and multiple imputation by decomposition of singular values). Considering the low occurrence of missing data (0.6 % for age; 3.2 % for right hand HGS – R-HGS; 3.2% for left hand HGS – L-HGS; 0.9% for PC), there was no significant difference between the three methods. However, it was decided to use the imputation from the averages' method as it presented fewer data variability.

Data analysis involved descriptive statistics of the data with measure of central tendency and measure of absolute dispersion, in addition to simple frequency analysis (absolute and relative). The Shapiro-Wilk test was used to assess normality of the variables. Student's t-test or Wilcoxon test was used to compare means of continuous variables between groups, and Pearson's chi-square test or Fisher's exact test was used to assess the association between categorical variables. Pearson's or Spearman's correlation coefficient was applied, with results expressed through scatter plots.

For elaborating the HGS prediction equations, the Multiple Linear Regression (MLR) was performed by considering a model for R-HGS and another model for the L-HGS. Seven variables (age, sex, weight, KH, AC, TSF and CC) were considered predictors for obtaining the models. The selection of variables as predictors before the modeling is admitted due to several aspects related to their feasibility (Moons et al., 2015). Thus, some variables may not necessarily have a moderate or high correlation with HGS, however, such variables were tested because they are easily obtained in the context of the evaluation of the older adults in PHC, as well as depending on simple, low-cost instruments available in the public health system. In addition, the variables contributed to improve the quality of the model fit, which was evaluated according to the R^2 value.

As for the MLR assumptions, the normality evaluation of the residues was performed by the Shapiro-Wilk test, by evaluating the independence of the residues under the Durbin-Watson test and measuring homoscedasticity by the Goldfeld-Quandt test. The multicollinearity was verified by removing independent variables with variance inflation factor (VIF) > 10 from the statistical model.

Finally, the reliability of the prediction models was internally tested by using the Bland-Altman diagram, evaluating the agreement between the HGS measured by the dynamometer and the HGS predicted by the equation. For all tests, a statistical significance level of 5 % was applied.

2.5 Ethical aspects

The largest research of which this study is part was approved by the Local Research Ethics Committee (approval number: 1.447.361/2016). The participation of the older adults in the study was voluntary, unpaid, and depended on their signature or fingerprint on an Informed Consent Form (ICF).

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3. Results

Data were collected from 316 individuals (11.2 % of losses related to refusals, non-location, or non-attendance of the participant), 61.7 % of whom were female. The sociodemographic characteristics of the sample are shown in Table 1. Regarding the age group, 84.3 % of the older adults were between 60 and 79 years old, and the mean age was 70.4 years (±7.3), 70.2 (±6.9) among women and 70.6 (±7.8) among men, without significant difference between sexes. Most older adults have a marital partner (51.6 %), have fewer than four years of study (72.8 %) and self-reported to be black or brown (51.9 %). As for the BMI classification, low weight was present in 34.2 % of the older adults.

Table 1

Characterization of the community-dwelling older adults, distributed by sex (%).

Variable	Male (n = 121)	Female (n = 195)	p-value*
Age (years)			
60 to 79	102 (84.3)	174 (89.2)	0.200
≥80	19 (15.7)	21 (10.8)	
Education (years of study)			
<4	90 (74.4)	140 (71.8)	0.6157
≥4	31 (25.6)	55 (28.2)	
Marital status			
With marital partner	84 (69.4)	79 (40.5)	< 0.001
Without marital partner	37 (30.6)	116 (59.5)	
Race/color			
Black and brown	60 (49.6)	104 (53.3)	0.517
Others	61 (50.4)	91 (46.7)	
BMI			
Low weight	48 (39.7)	60 (30.8)	0.1049
No low weight	73 (60.3)	135 (69.2)	

* Chi-Square test; BMI: Body mass index.

The R-HGS mean was 22.2kg (±7.7), where 28.7kg (±7.0) among men and 18.2 kg (±4.9) women, with a significant difference between the sexes (p<0.001), while the L-HGS mean was 21.3kg (±7.3), 27.3kg (±6.8)

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among men and 17.6kg (±4.5) among women ($p<0.001$). Similarly, men had significantly higher values in the anthropometric variables weight, knee height, height and TSF (Table 2).

Table 2

Anthropometric characterization of the community-dwelling older adults, distributed by sex (mean ± SD).

Variable	Male (n = 121)	Female (n = 195)	p-value*
Age (years)	70.6 (±7.8)	70.2 (±6.9)	0.9631*
Weight (Kg)	71.3 (±14.5)	63.3 (±13.7)	< 0.001*
Height (cm)	169.1 (±5.6)	157.6 (±4.8)	< 0.001**
Knee height (cm)	53.7 (±2.7)	49.1 (±2.6)	< 0.001*
AC (cm)	29.5 (±3.7)	30.2 (±4.8)	0.1506**
TSF (mm)	13.3 (±5.6)	21.5 (±6.8)	< 0.001*
CC (cm)	35.3 (±3.4)	34.9 (±4.1)	0.2860**
BMI (Kg/m^2)	24.8 (±4.5)	25.4 (±5.0)	0.3519*
R-HGS (Kg) (measured)	28.7 (±7.0)	18.2 (±4.9)	< 0.001*
L-HGS (Kg) (measured)	27.3 (±6.8)	17.6 (±4.5)	< 0.001*

* Wilcoxon test; ** Student t test; SD: Standard deviation; AC: Arm circumference; TSF: Triceps skinfold; CC: Calf circunference; BMI: Body mass index; R-HGS: Right-handgrip strength; L-HGS: left-handgrip strength.

The correlations between HGS and the predictive variables of the model are presented in Table 3 for the right and left hands and organized by sex. When evaluated without division per sex (data not shown), the correlations were stronger and significantly correlated with the outcome ($p < 0.05$), however, sex is an important variable in the determination of HGS and relevant to adjust the model.

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Table 3

Spearman's correlation coefficient values between HGS and predictive variables in community-dwelling older adults, presented by sex.

	Male (n = 121)		Female (n = 195)	
	R-HGS	L-HGS	R-HGS	L-HGS
Age	-0.430*	-0.358*	-0.291*	-0.257*
Weight	0.267*	0.188*	0.274*	0.269*
KH	0.253*	0.330*	0.269*	0.223*
AC	0.277*	0.195*	0.221*	0.275*
TSF	0.038**	0.032**	0.149*	0.176*
CC	0.244*	0.202*	0.229*	0.247*

An estimation of grip strength during puberty.

The equations proposed for predicting HGS of the community-dwelling older adults are described in Table 4. The adjusted model with the best result for R-HGS [F(3.312) = 124.0; $p < 0.001$; $R^2 = 0.544$] was consisted of the variables age (Beta = -0.271; t = -6.648; $p < 0.001$), knee height (Beta = 0.494; t = 4.405; $p < 0.001$) and sex (Beta = 8.339; t = 10.526; $p < 0.001$) and for L-HGS [F(3.312) = 106.3; $p < 0.001$; $R^2 = 0.505$] by the variables age (Beta = -0.223; t = -5.570; $p < 0.001$), knee height (Beta = 0.432; t = 3.932; $p < 0.001$), and sex (Beta = 7.800; t = 10.040; $p < 0.001$).

Table 4

Equations proposed for predicting the HGS of community-dwelling older adults.

Laterality	Equation	R^2
R-HGS	R-HGS (Kg) = 13.00 + 0.49 (knee height *) - 0.27(age**) + 8.34 (sex***)	0.54
L-HGS	L-HGS (Kg) = 12.02 + 0.43 (knee height *) - 0.22 (age**) + 7.80 (sex***)	0.50

R-HGS: Right-handgrip strength; L-HGS: Left-handgrip strength. * Knee height (cm); ** Age (full years); ***Female = 0 (zero); Male = 1 (one).

As for the evaluation of the MLR assumptions, in both sides, normality was observed in the distribution of residues by the Shapiro-Wilk test. The value of the Durbin-Watson independence test was 2.071 (R-HGS) and 1.898 (L-HGS), the Goldfeld-Quandt homoscedasticity test was 0.781 (R-HGS) and 0.629 (L-

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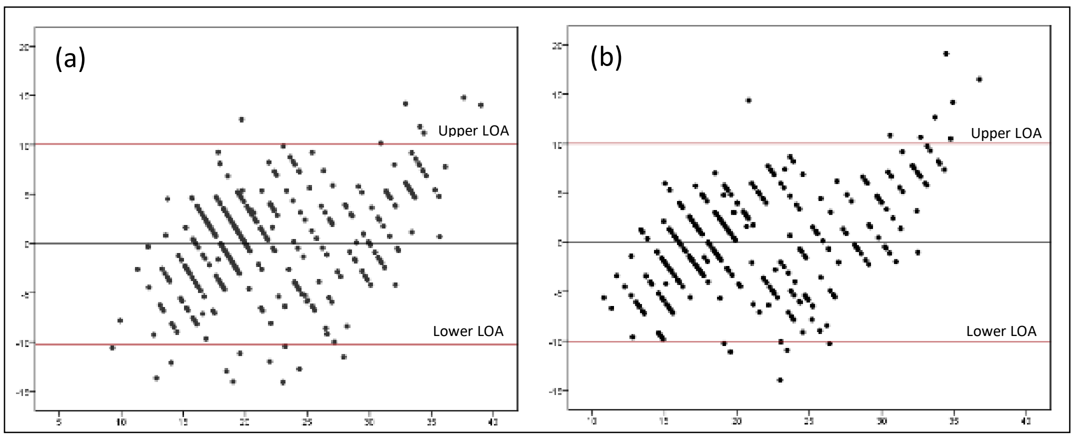
HGS). During the evaluation of multicollinearity between the variables, no Variance Inflation Factor (> 10) was observed.

The reliability of the model was internally evaluated by analyzing the agreement between the HGS measured with the dynamometer and the HGS predicted by the model, as can be observed in the Bland-Altman diagram (Figure 1). There was agreement between the measurements for both the right (bias: 0.000084) and the left side (bias: -0.000137), and the bias was analyzed by the Student's t-test. The lower (LLoA) and upper (ULoA) limits of agreement were, respectively, -10.21 and 10.21 for the right side. For the left side, the LLoA was -10.01 and the ULoA was 10.01.

Figure 1

Bland-Altman diagram showing the agreement between HGS measured with the dynamometer and predicted HGS on the right hand (a) and left hand (b) in community-dwelling older adults (n = 316).



LOA: Limit of agreement.

4. Discussion

The results of this study on the development of a model of a predictive equation for HGS showed that age, sex, and KH explained 54% of the variation in R-HGS and 50% of L-HGS for community-dwelling older adults. The need to develop a predictive equation for HGS arises from the insufficient instrumentalization of the PHC units (Binagwaho & Adhanom Ghebreyesus, 2019), with the eventual absence of a dynamometer, which is the gold standard equipment used for gerontological evaluation and body measuring (Soares et al., 2019).

The use of HGS predictive equations, consisted of simple and frequent variables, has practical advantages that are beyond the issues related to the relative cost of equipment. Even in the absence of the measurement instrument, using HGS as an evaluation criterion is justified because it is considered a predictor of mobility limitation (Delinocente et al., 2021), mortality (Spexoto et al., 2022), complications,

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and increased length of stay, as well as being a significant indicator for these conditions even when adjusted for potentially confounding variables (Bohannon, 2019). Another aspect that makes the use of equations reasonable concerns the execution of the measurement itself. Although it is more simple when compared to other measures, it has strict protocols (Fess, 1992), which can be a limitation in health units, as it requires time and training for the results to be valid and reliable.

In view of this, an alternative easily performed by the professionals who make up the health unit's staff and that requires minimal time and resources is the use of demographic information, such as sex and age, obtained from the individuals' records and basic anthropometric measures to estimate other evaluation parameters less common in PHC, such as HGS.

Thus, considering the feasibility of multivariable models, other equations for predicting HGS by using multiple variables as predictors of the measure were previously proposed for different groups, in different countries and configurations (Andres et al., 2013; Angst et al., 2010; De Blasio et al., 2017; Imrhan & Mandahawi, 2010; Li et al., 2010; Lopes et al., 2018; Niempoog et al., 2007; Novaes et al., 2009; Tveter et al., 2014). However, this study considers the peculiarities of a single age group, in addition to the specific care setting, which may enable its application under similar conditions.

The development of prediction equations should favor the use of simple predictors which are quickly and inexpensively obtained, and relevant to the quality of the model. So it is observed that the variable sex is often used as an independent variable, consisting in most cases the final model as one of the most important predictors (Andres et al., 2013; Angst et al., 2010; Imrhan & Mandahawi, 2010; Lopes et al., 2018; Novaes et al., 2009; Tveter et al., 2014). This fact can be justified by the significant differences between the HGS values obtained in men and women, being higher in males (Dodds et al., 2016). These discrepancies between sexes may be associated with the difference in body composition between men and women, since men tend to have a higher volume of muscle mass compared to women (Bredella, 2017). Other variables that are related to HGS tend to behave differently with the outcome when sex is considered. For this reason (Amaral et al., 2020), the variable was selected in the present study prior to the modeling, as it significantly contributes to the improvement of the quality of the adjustment.

Confirming the idea of accessible variables, anthropometry is a useful and frequently available tool in the practical evaluation of the older adults, especially in the context of the public health system (Closs et al., 2016; Lopes et al., 2018). In this research, the anthropometric variable incorporated in the final model of HGS prediction was KH, a consolidated measure in the anthropometric evaluation of older adults because it is widely used in height estimation and undergoes little change with aging (Closs et al., 2015).

The muscle strength loss is an indicator capable of predicting negative outcomes more expressively than the loss of muscle mass alone and this fact is evident with the advancement of age, leading to limitations (Bohannon, 2019; Soysal et al., 2021). Thus, due to the relationship between age and changes in HGS (Albrecht et al., 2021; Sena Pereira et al., 2022), the variable was also previously selected to compose the prediction model, as well as observed in other studies, regardless the age group studied (Andres et al., 2013; Angst et al., 2010; De Blasio et al., 2017; Imrhan & Mandahawi, 2010; Niempoog et al., 2007; Novaes et al., 2009; Tveter et al., 2014). Thus, in line with the specialized literature, age was significantly correlated

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with HGS in both sexes and contributed to improve the ability to explain the variation of the outcome in the final model.

In general, this study presents a random and representative sample of the group researched, which is characterized by being from the Northeast region of Brazil, consisted of individuals dependent on the public health system in urban areas. They are mostly represented by black or brown people, female, with a marital partner, and low education. A Brazilian study presented a review of the older adult's population in the country (Travassos et al., 2020), addressing sociodemographic conditions, and it concluded that the profile of the Brazilian older adult is mostly consisted of white women from urban areas, with a marital partner, and average schooling of more than four years. However, the same authors made important considerations that do not ignore the continental dimensions of Brazil and the consequent regional differences reflected in the older adult's population. Thus, the sample of this study had sociodemographic characteristics similar to those described for the Brazilian population, but peculiarly specific to the Northeastern Brazil, such as lower education in relation to the national average, and lower proportion of people who self-declare as white (Travassos et al., 2020).

Such attributes of the sample related to similarities with the population of interest, as well as the operationalization of the sampling process described, are some of the aspects that represent potentialities of the study. From a practical point of view, this work proposes to present a model capable of estimating a low HGS, a measure considered to be a predictor of adverse outcomes, especially in older adults, contributing both to the construction of a theoretical and methodological framework for the subject, and to the practical use of the model in similar scenarios. In this sense, important aspects were considered for developing a prediction model, such as the adequate number of events per predictor variable, use of TRIPOD as a guiding reference for the development of the model (Moons et al., 2015), low percentage of data loss, as well as the imputation of missing or inconsistent data. The use of appropriate tests to meet the assumptions of MLR was also considered, and the internal evaluation of the model reliability was performed by using the Bland-Altman diagram. In this regard, an agreement was observed between the estimated and measured HGS on both sides and although the limits of agreement (ULoA and SLoA) are relatively high, a value defined as an acceptable parameter was not found in the literature. A study that tested the agreement by the Bland-Altman method between different prediction equations found limits of agreement with higher values (Soares et al., 2019), which may indicate that the values found in this study are more acceptable.

Although the characteristics of the sample might be described as a potentiality of this study, the reproducibility of the findings in other scenarios is not known. Since the internal reliability has been tested, the external validity of the model has not been evaluated. In the same way, although the sampling process guarantees the representativeness and randomness of the group studied, the number of participants can be considered small, limiting the results, as can the age variability of the sample and the inclusion of men and women in the same regression model.

Another issue concerns the selection of predictors that prioritized the practical obtaining of information, in opposition to purely theoretical or mathematical aspects. To elaborate a plausible model for the PHC

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reality or other situations where the dynamometer is not an available equipment, therefore, other predictors could improve the quality of the model, but not provide the equation with the same viability. Finally, although the results presented are satisfactory, the trend observed in the Bland-Altman concordance diagram might be considered a limitation, even if the assumptions have been met. For this reason, as the next logical step and in line with development studies for prediction models (Moons et al., 2015), it is advisable to update the model with adjustments, and include new viable variables as those used in this study and validation, since prediction equations may be subject to biases.

5. Conclusions

In this study, the variables age, sex, and KH were the ones that had the best feature to explain the HGS variation in the sample, confirming the simplicity of the final equation. The model obtained had its reliability internally evaluated, presenting a good agreement between the values measured directly with the dynamometer and the values predicted by the equation. The use of parameter predictive equations, such as HGS, is a potential option to identify problems and enable early interventions in these individuals, in addition to allowing simple attributes to generate an estimate of the expected HGS in situations where this measure is necessary to improve clinical care efficiency.

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