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Handgrip Strength and Associated Factors in Hospitalized Patients

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Abstract

Background: Handgrip strength (HGS) is a marker of nutrition status. Many factors are associated with HGS. Age, height, body mass index, number of diagnoses, and number and type of drugs have been shown to modify the association between undernutrition and HGS. Nevertheless, other patient characteristics that could modify this association and its joint modifier effect have not been studied yet. *Objective*: To evaluate the association of inpatients' HGS and undernutrition considering the potential modifier effect of cognitive status, functional activity, disease severity, anthropometrics, and other patient characteristics on HGS. *Methods*: A cross-sectional study was conducted in a university hospital. Sex, age, abbreviated mental test score, functional activity score, Charlson index, number of drugs, Patient-Generated Subjective Global Assessment (PG-SGA) score, body weight, mid-arm muscle circumference, adductor pollicis muscle thickness, body height, wrist circumference, hand length, and palm width were included in a linear regression model to identify independent factors associated with HGS (dependent variable). *Results*: The study sample was composed of 688 inpatients (18–91 years old). All variables included in the model were associated with HGS (β, –0.16 to 0.38; $P \leq .049$) and explained 68.5% of HGS. Age, functional activity decline, Charlson index, number of drugs, PG-SGA score, body weight, and wrist circumference had a negative association with HGS. All other studied variables were positively associated with HGS. *Conclusion*: Nutrition status evaluated by PG-SGA was still associated with HGS after considering the joint effect of other patient characteristics, which reinforces the value of HGS as an indicator of undernutrition. (*JPEN J Parenter Enteral Nutr*. 2015;39:322-330)

Keywords

handgrip strength; undernutrition; inpatients; modifying effect

Clinical Relevancy Statement

Handgrip strength (HGS) is a marker of nutrition status. Cognitive status, functional activity, disease severity, anthropometrics, and other patient characteristics are associated with HGS. Age, height, body mass index, number of diagnoses, and the number and type of drugs modify the association between nutrition status and HGS. However, other patient characteristics that could modify this association have not been quantified yet.

The aim of this study was to explore the association between inpatients' HGS and undernutrition, considering the joint effect of disease and other patient characteristics on HGS.

Nutrition status evaluated by the Patient-Generated Subjective Global Assessment was still associated with HGS after considering the modifier effect of other patient characteristics, which reinforces the value of HGS as an indicator of undernutrition.

Introduction

Handgrip strength (HGS) is the most frequently used indicator of muscle function for clinical purposes,[1] since it has been shown to be a strong indicator of functional capacity and is considered a marker of nutrition status.[1,2] The association between nutrition status and HGS is well documented.[1] Handgrip strength reflects early nutrition deprivation and nutrition repletion, before changes in body composition parameters can be detected.[1] This is of major relevance since the early identification of undernourished patients followed by nutrition intervention will improve the clinical course, as well as short- and long-term results.[3,4] HGS measurement devices are noninvasive, quick and easy to

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use, portable, and reliable.[5] Moreover, the Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition have recently recommended reduced HGS values as a criterion for the identification and documentation of undernutrition in clinical practice.[2]

Previous studies have shown that nutrition status indicators such as body weight,[6-11] body mass index (BMI),[7,8,11-14] mid–upper arm circumference,[6,14,15] arm muscle mass,[7,13,14,16,17] and adductor pollicis muscle thickness[8] strongly influence HGS values. Other parameters have also been identified to be associated with HGS, such as sex,[6-8,14,15,18-20] age,[6-8,10-14,18-20] body height,[8,10,11,15,18] cognitive status,[21,22] and disease severity.[9,23] Several authors have also shown in community-dwelling individuals that parameters related to hand anatomy—such as hand[19,24] and wrist[6] circumferences; hand length,[6] width, [6] and breadth[25]; palm hand length[25]; and the average length of index, middle, ring, and small fingers[25]—are associated with HGS. However, the influence of hand anatomy in the association between HGS and undernutrition in inpatients has not been addressed until now.

Some factors have been shown to modify the association between undernutrition and HGS, such as age,[26,27] height,[27] BMI,[12] number of diagnoses,[26] and the number[26] and type of drugs.[12] The modifying effect of these factors was previously evaluated by bivariate analysis of association using correlation coefficients,[26] analysis of HGS by BMI classes,[12] differences in HGS values,[12] or multivariate logistic regression.[27] Nevertheless, other patient characteristics that could modify the association between undernutrition and HGS, such as cognitive status, functional activity, disease severity, anthropometric indicators, and other patient characteristics, have not been studied yet. Moreover, the joint modifier effect that these variables may have in the association between undernutrition and HGS, within the same individuals, has yet to be evaluated.

This study would allow quantifying the association between undernutrition and HGS while considering the joint effect of all these factors. Also, due to the high number of factors described as being associated with HGS, it is important to identify which ones produce greater variations in HGS beyond nutrition status. The evaluation of the effect of the modifying factors in clinical daily practice may lead to an improvement of the HGS value as an indicator of undernutrition.

The objective of the present study was to conduct a comprehensive analysis exploring the association between inpatients' HGS and undernutrition, quantifying the potential modifying effect of cognitive status, functional activity, disease severity, anthropometrics, and other patient characteristics on HGS.

Participants and Methods

Study Population and Design

A cross-sectional study was conducted in a university hospital between July 2011 and May 2013. A consecutive sampling approach was used. From the daily list of inpatients admitted to each ward, those who met inclusion criteria were invited to participate in the study, until the number of patients had reached the total number of beds of the ward. Patients were eligible to participate in the study if they were ≥18 years old, white, with an expected length of hospital stay >24 hours, conscious, cooperative, and able to provide written informed consent. Patients unable to perform the HGS technique, defined as an inability in understanding verbal instructions or having a condition in which the patient could not perform the technique correctly (namely pain), as well as patients with critical illness, defined as failure of at least 1 vital organ[28] and admitted to intensive care units, were excluded from the study. We also excluded pregnant women, individuals in isolation, those who were admitted for procedures that could put them in a critical situation, and those with hemodynamic instability at the time of evaluation. Therefore, inpatients from angiology and vascular surgery; cardiology; digestive, nondigestive, and hepatobiliary surgeries; endocrinology; gastroenterology; internal medicine; nephrology; orthopedics; otolaryngology; and urology wards were considered eligible for this study.

Sample size was calculated assuming an effect size of 0.15, a statistical power of 80%, and a level of significance equal to .05. The minimum required sample size was 135 individuals. To have a representative sample of the hospitalized patients who met inclusion criteria, data collection took place until the number of patients corresponded to twice the total number of beds of all the selected wards (n = 688).

This research was conducted according to the guidelines laid down in the Declaration of Helsinki and approved by the Institutional Review Board and the Ethics Committee of Centro Hospitalar do Porto. Written informed consent was obtained from all study participants.

Data Collection

Demographic data, clinical history, and the number of drugs given to the patient at the time of evaluation were obtained by reviewing the patient's clinical file. The remaining data were collected using a structured questionnaire within 72 hours of admission to the hospital. The possibility of cognitive impairment was assessed using the abbreviated mental test (AMT).[29] This test consists of 10 questions, each scored 1 if correct, and a cutoff score of 7 or 8 out of 10 is suggested to discriminate between cognitive impairment and normality in older adults.[29] In the present study, a score <6 was considered denotative of cognitive impairment.[30-32] Comorbidity was evaluated using the Charlson index.[33] Patient nutrition status was evaluated by the Patient-Generated Subjective Global Assessment (PG-SGA).[34] Functional activity during the month prior to hospital admission was categorized in 4 classes as "normal with no limitations" (score = 0); "not normal, but able to be up and about with fairly normal activities" (score = 1); "not feeling up to the most things, but in bed or chair less than half the day" (score = 2); "able to do little activity and spend most of the day in bed or chair" (score = 3); and "primarily bedridden, rarely out of bed" (score = 4).[34]

Nondominant HGS was measured with a calibrated Jamar Hydraulic Hand dynamometer (Sammons Preston, Bolingbrook, IL), recommended by the American Society of Hand Therapists as the "gold standard" for measurements of HGS.[35] According to the manufacturer recommendations, grip handle was adjusted to accommodate the size and comfort of the participant's hand. Each participant performed 3 measurements with a 1-minute pause between measurements, and the maximum value was chosen as the HGS value.[36] When the individual was unable to perform the measurement with the nondominant hand, the dominant hand was used. To evaluate the influence of hand anatomy in HGS, wrist circumference, hand length, and palm width of the dominant hand were considered for those participants.

Standing height,[37] body weight,[37] mid–upper arm circumference,[37,38] triceps skinfold thickness,[37,38] adductor pollicis muscle thickness,[39] wrist circumference,[37] hand length,[37] and palm width[40] were measured according to standardized procedures. Standing height (cm), mid–upper arm circumference (cm), and wrist circumference (cm) data were obtained with a metal tape (Rosscraft, Innovations Incorporated, Surrey, Canada) with a 0.1-cm resolution, and a headboard was also used for measuring standing height. Body weight (kg) was measured with a calibrated portable beam scale with a 0.5-kg resolution. Triceps skinfold thickness (mm) and adductor pollicis muscle thickness (mm) were measured with a Harpenden caliper (Baty International, Burgess Hill, UK) with a 0.2-mm resolution. Hand length and palm width were measured using a small bone caliper with a 0.1-cm resolution (Kennon Instruments, Vignola, Italy).

For the participants with visible kyphosis or when it was impossible to measure standing height, half-span was measured from the midpoint of the sternal notch to the dactylion[41] with a metal tape (Rosscraft; 0.1-cm resolution). Half-span was converted to height multiplied by 2.[41] If half-span was impossible to obtain, height was estimated from ulna length measured with the same metal tape.[42] For participants on dialytic therapies, dry body weight registered in the clinical file or, when absent, referred by the individual was used. When it was not possible to weigh a patient, body weight predicted from height and mid–upper arm circumference[43] was used as a surrogate measurement.

Data were collected by 2 previously trained nutritionists. The intra- and interobserver technical error of measurement was obtained for all anthropometric measurements, respectively, in 17 and 18 individuals. Intraobserver error varied between 0.2% and 1.7%, and interobserver error varied between 0% and 6.6%, which is considered acceptable for skillful anthropometrists.[44]

Mid-arm muscle circumference (cm) was determined from mid–upper arm circumference and triceps skinfold thickness with the formula devised by Jelliffe.[45] BMI was calculated using the following standard formula: weight (kg)/height^2 (m). BMI classes according to the World Health Organization cutoffs were created.[46]

Statistical Analysis

Descriptive analysis included medians and interquartile range (IQR). HGS was summarized using tertiles by sex, according to the cutoffs of sample distribution stratified by sex. For women, cutoffs were ≤13.2 kilogram-force (kgf), 13.3–19.7 kgf, and ≥19.8 kgf; for men, they were ≤27.7 kgf, 27.8–35.5 kgf, and ≥35.6 kgf. These tertile cutoffs are lower than what is described for healthy adults[47,48] but similar to other samples of inpatients.[49,50] HGS varied between 1.0 and 35.1 kgf for women; median (IQR) was equal to 16.0 (10.0) kgf. For men, HGS values varied between 1.0 and 61.0 kgf, with a median (IQR) of 32.0 (12.2) kgf. HGS values are lower than what is described for healthy individuals[47,48] but similar to other studies involving hospitalized patients.[7,49,50]

The Kolmogorov-Smirnov test was used to evaluate the normality of the variables' distribution. Baseline characteristics of the participants were compared according to PG-SGA nutrition status and across tertiles of HGS using 1-way analysis of variance or the Kruskal-Wallis test depending on the normality of the variables' distribution. Differences in the proportion of individuals <65 and ≥65 years old, as well as for men and women and across BMI classes by PG-SGA nutrition status, were compared using the χ^2 test.

Spearman correlation coefficients between HGS, age, AMT score, functional activity score, Charlson index, number of drugs, PG-SGA score, body weight, mid-arm muscle circumference, adductor pollicis muscle thickness, body height, wrist circumference, hand length, and palm width were determined.

A multivariable linear regression model was built using the method *Enter* to identify independent factors associated with HGS (dependent variable). Sex, age, AMT score, functional activity score, Charlson index, number of drugs, PG-SGA score, body weight, mid-arm muscle circumference, adductor pollicis muscle thickness, body height, wrist circumference, hand length, and palm width were the variables included in the model.

Results were considered significant when $P < .05$. All statistical analyses were carried out using the Software Package for Social Sciences (SPSS) for Windows (version 21.0; SPSS, Inc, an IBM Company, Chicago, IL).

Results

The study sample was composed of 688 participants aged between 18 and 91 years old, with a median (IQR) of 58 (21) years. According to the PG-SGA, 24.1% of the study participants presented with moderate or suspected undernutrition, and 23.8% were severely undernourished. Of all participants, 35.8% were overweight and 22.1% were obese.

Table 1. Sample Characteristics According to Patient Nutrition Status.[a]

Characteristic	Not Undernourished (n = 358)	Moderate or Suspected Undernutrition (n = 166)	Severely Undernourished (n = 164)	*P* Value
Age, median (IQR), y	55 (25)	59 (22)	62 (19)	<.001[b]
<65, No. (%)	259 (72.3)	107 (64.5)	95 (57.9)	.004[c]
≥65, No. (%)	99 (27.7)	59 (35.5)	69 (42.1)	
Sex, No. (%)				
Women	159 (44.4)	76 (45.8)	79 (48.2)	.725[c]
Men	199 (55.6)	90 (54.2)	85 (51.8)	
Hospital ward, No. (%)				
Angiology and vascular surgery	31 (8.7)	11 (6.6)	8 (4.9)	—[d]
Cardiology	17 (4.7)	12 (7.2)	8 (4.9)	
Digestive surgery	24 (6.7)	15 (9.0)	13 (7.9)	
Nondigestive surgery	38 (10.6)	6 (3.6)	6 (3.7)	
Hepatobiliary surgery	21 (5.9)	16 (9.6)	13 (7.9)	
Endocrinology	13 (3.6)	3 (1.8)	10 (6.1)	
Gastroenterology	12 (3.4)	9 (5.4)	3 (1.8)	
Internal medicine	59 (16.5)	58 (34.9)	43 (26.2)	
Nephrology	35 (9.8)	11 (6.6)	10 (6.1)	
Orthopedics	29 (8.1)	11 (6.6)	42 (25.6)	
Otolaryngology	27 (7.5)	3 (1.8)	1 (0.6)	
Urology	52 (14.5)	11 (6.6)	7 (4.3)	
BMI, No. (%)				
Underweight	5 (1.4)	6 (3.6)	11 (6.7)	<.001[c]
Normal weight	117 (32.7)	73 (44.0)	78 (47.6)	
Overweight	136 (38.0)	54 (32.5)	56 (34.1)	
Obese	100 (27.9)	33 (19.9)	19 (11.6)	
LOS, median (IQR), d	5 (5)	8 (7)	9 (8)	<.001[b]
HGS, median (IQR), kgf	26.4 (15.2)	20 (15.4)	21.1 (17.0)	<.001[b]
Women	20.0 (9.3)	14.6 (8.0)	14.0 (8.0)	<.001[b]
Men	34.0 (11.0)	28.0 (12.1)	30.0 (12.8)	<.001[b]
<65 y	27.7 (17.3)	20.0 (16.0)	23.0 (20.7)	<.001[b]
≥65 y	25.0 (17.0)	22.0 (15.0)	18.0 (13.5)	.001[b]

BMI, body mass index; HGS, handgrip strength; IQR, interquartile range; kgf, kilogram-force; LOS, length of hospital stay.
[a]Patient nutrition status was evaluated by the Patient-Generated Subjective Global Assessment.
[b]Kruskal-Wallis test.
[c]χ^2 test.
[d]*P* value was not determined given the low number of observations in some cells.

Participants' characteristics according to PG-SGA nutrition status and across tertiles of HGS and sex are presented respectively in Tables 1 and 2. Undernourished participants were older, had a longer length of hospital stay, and had a lower HGS; this group also included a lower proportion of overweight and obese patients. From the lowest to the highest HGS tertiles, decreasing median values in age, number of drugs taken by the participants, and Charlson index and PG-SGA scores were observed. In turn, from the lowest to the highest HGS tertiles, increasing median values in participants' height and a decline in functional activity were found. For men, from the lowest to the highest HGS tertiles, increasing median values in participants' body weight, mid-arm muscle circumference, adductor pollicis muscle thickness, wrist circumference, and hand length were also observed.

In this sample of hospitalized patients, for bedridden patients or those with conditions limiting their ability to stand, it was necessary to resort to alternative anthropometric indicators to estimate height or weight.[38] Standing height was measured in 359 participants. Height was estimated from half-span for 317 participants and from ulna length for 12 participants. Body weight predicted from height and mid–upper arm circumference was used for 169 participants, and dry body weight registered in the clinical file or referred by the individual was used for 21 inpatients. Fifty-five individuals performed the measurements of HGS with their dominant hand.

HGS was positively correlated with AMT score, body weight, mid-arm muscle circumference, adductor pollicis muscle thickness, body height, wrist circumference, hand length, and palm width and negatively correlated with age, number of

Table 2. Sample Characteristics According to Handgrip Strength Tertiles.

	HGS Tertiles (n = 688)							
	Women				Men			
	Lowest, ≤13.2 kgf (n = 104)	Middle, 13.3–19.7 kgf (n = 98)	Highest, ≥19.8 kgf (n = 112)		Lowest, ≤27.7 kgf (n = 115)	Middle, 27.8–35.5 kgf (n = 134)	Highest, ≥35.6 kgf (n = 125)	
Characteristic	Median (Interquartile Range)			*P* Value	Median (Interquartile Range)			*P* Value
Age, y	62 (25)	58 (21)	46 (23)	<.001[a]	64 (18)	63 (19)	52 (20)	<.001[b]
Abbreviated mental test (score)	9 (2)	9 (2)	9 (1)	.136[b]	10 (1)	10 (1)	10 (1)	.094[b]
Functional activity (score)	2 (3)	1 (2)	0 (1)	<.001[b]	1 (3)	0 (1)	0 (1)	<.001[b]
Charlson index	2 (3)	1 (2)	0 (2)	.005[b]	2 (3)	2 (2)	1 (2)	<.001[b]
Drugs (n)	10 (6)	8 (7)	6 (8)	<.001[b]	11 (8)	9 (7)	8 (8)	<.001[b]
PG-SGA (score)	7(7)	6 (6)	3 (4)	<.001[b]	7 (5)	5 (7)	3 (4)	<.001[b]
Body weight, kg	62.5 (17.4)	62.0 (18.4)	68.0 (20.5)	.011[a]	68.3 (19.5)	72.3 (18.6)	79.0 (19.1)	<.001[a]
Mid-arm muscle circumference, cm	21.8 (4.0)	22.5 (4.3)	22.4 (4.8)	.350[a]	23.7 (4.6)	24.8 (3.5)	26.5 (3.3)	<.001[a]
Adductor pollicis, mm	19.4 (6.1)	19.2 (5.4)	20.4 (5.5)	.331[a]	20.1 (3.9)	22.1 (5.7)	24.0 (6.0)	<.001[a]
Body height, cm	154 (11)	155 (9)	158 (10)	<.001[a]	166 (10)	170 (11)	173 (9)	<.001[a]
Wrist circumference, cm	16.0 (1.6)	16.0 (1.5)	16.0 (1.7)	.399[a]	17.0 (1.7)	17.3 (1.7)	17.5 (1.5)	.002[a]
Hand length, cm	16.7 (1.2)	16.7 (1.0)	17.2 (1.3)	.001[b]	17.9 (1.4)	18.3 (1.1)	18.7 (1.3)	<.001[b]
Palm width, cm	7.6 (0.6)	7.6 (0.6)	7.7 (0.5)	.347[b]	8.4 (0.6)	8.6 (0.5)	8.6 (0.6)	<.001[b]

HGS, handgrip strength; kgf, kilogram-force; PG-SGA, Patient Generated Subjective Global Assessment.
[a]One-way analysis of variance.
[b]Kruskal-Wallis test.

drugs, functional activity, and PG-SGA scores (Table 3). The correlation between PG-SGA and HGS was weak to moderate. Number of drugs and AMT, functional activity, and PG-SGA scores shared a similar strength of relationship to HGS.

A multivariable linear regression analysis was conducted to identify independent factors associated with HGS, and the following variables were included in the model: sex, age, AMT score, functional activity score, Charlson index, number of drugs, PG-SGA score, body weight, mid-arm muscle circumference, adductor pollicis muscle thickness, body height, wrist circumference, hand length, and palm width. All variables were significantly associated with HGS (β, –0.16 to 0.38; $P \leq .049$) and explained 68.5% of HGS (Table 4). Age presented a negative association with HGS as well as functional activity score, Charlson index, number of drugs, PG-SGA score, body weight, and wrist circumference. All other studied variables were positively associated with HGS. Male sex had the greatest influence on HGS, explaining 14.4% of the variability. Anthropometric indicators of hand anatomy also exhibited a high association with HGS; hand length explained 5.3% of the variability, wrist circumference 2.6%, and palm width 2%. Mid-arm muscle circumference and age were also important contributors to the model since they explained respectively 5.3% and 2.6% of HGS variability.

Multivariable linear regression analysis was conducted according to sex and age groups (<65 vs ≥65 years) (data not shown). Many variables lost their statistical significance, but the directions of the associations between each variable included in these models and HGS were the same as the model presented in Table 4, except for body weight, which was positively associated with HGS for women and for participants ≥65 years old.

Discussion

To our knowledge, this is the first study conducted in hospitalized patients exploring the association between undernutrition and HGS that has accounted for the effect of known modifier factors, including hand anatomy, anthropometric and clinical indicators, and other patient characteristics. Sex; age; cognitive status; functional activity; disease severity evaluated by the Charlson index and number of drugs; undernutrition evaluated by the PG-SGA; nutrition status anthropometric indicators such as body weight, mid-arm muscle circumference, and adductor pollicis muscle thickness; and other anthropometric indicators such as body height, wrist circumference, hand length, and palm width were all associated with HGS. It was therefore shown that a multiplicity of parameters is associated

Table 3. Nonparametric Correlations Between Studied Factors Associated With Handgrip Strength.

Factors	Palm Width, cm	Hand Length, cm	Wrist Circumference, cm	Body Height, cm	Adductor Pollicis, mm	Mid-arm Muscle Circumference, cm	Body Weight, kg	PG-SGA (Score)	Drugs (n)	Charlson Index	Functional Activity (Score)	Abbreviated Mental Test (Score)	Age, y	HGS, kgf
HGS, kgf	0.625[a]	0.606[a]	0.429[a]	0.663[a]	0.355[a]	0.470[a]	0.383[a]	–0.290[a]	–0.213[b]	–0.012[c]	–0.286[a]	0.230[a]	–0.201[a]	1.0
Age, y	0.125[b]	0.049[c]	0.214[a]	–0.189[a]	–0.005[c]	0.026[c]	–0.030[c]	0.280[a]	0.199[a]	0.205[a]	0.158[a]	–0.126[b]	1.0	
Abbreviated mental test (score)	0.170[a]	0.125[b]	0.107[b]	0.205[a]	0.072[c]	0.119[b]	0.138[a]	–0.102[b]	–0.089[b]	0.042[c]	–0.119[b]	1.0		
Functional activity (score)	–0.070[c]	–0.085[b]	–0.037[c]	–0.110[b]	–0.127[b]	–0.064[c]	–0.097[b]	0.574[a]	0.168[a]	0.162[a]	1.0			
Charlson index	0.109[b]	0.085[b]	0.089[b]	0.099[b]	0.007[c]	–0.007[c]	0.005[c]	0.169[a]	0.182[a]	1.0				
Drugs (n)	0.049[c]	0.026[c]	0.108[b]	–0.019[c]	–0.004[c]	0.022[c]	–0.051[c]	0.248[a]	1.0					
PG-SGA (score)	–0.062[c]	–0.061[c]	–0.066[c]	–0.140[a]	–0.194[a]	–0.183[a]	–0.280[a]	1.0						
Body weight, kg	0.491[a]	0.391[a]	0.662[a]	0.449[a]	0.545[a]	0.753[a]	1.0							
Mid-arm muscle circumference, cm	0.555[a]	0.388[a]	0.674[a]	0.386[a]	0.570[a]	1.0								
Adductor pollicis, mm	0.428[a]	0.216[a]	0.543[a]	0.213[a]	1.0									
Body height, cm	0.645[a]	0.759[a]	0.493[a]	1.0										
Wrist circumference, cm	0.742[a]	0.580[a]	1.0											
Hand length, cm	0.694[a]	1.0												
Palm width, cm	1.0													

HGS, handgrip strength; kgf, kilogram-force; PG-SGA, Patient-Generated Subjective Global Assessment.
[a] $P < .001$.
[b] $P < .05$.
[c] $P > .05$.

Table 4. Factors Associated With Handgrip Strength (kgf) by Multivariable Linear Regression Analysis.

Model[a]	β	95% CI	*P* Value[b]
Sex (male vs female)	0.38	7.06 to 10.33	<.001
Age, y	–0.16	–0.15 to –0.07	<.001
Abbreviated mental test (score)	0.05	0.04 to 1.05	.034
Functional activity (score)	–0.11	–1.50 to –0.51	<.001
Charlson index	–0.05	–0.53 to 0.00	.049
Drugs (n)	–0.07	–0.23 to –0.06	.002
PG-SGA (score)	–0.07	–0.34 to –0.03	.020
Body weight, kg	–0.09	–0.12 to 0.00	.040
Mid-arm muscle circumference, cm	0.23	0.52 to 1.02	<.001
Adductor pollicis, mm	0.11	0.12 to 0.41	<.001
Body height, cm	0.13	0.05 to 0.24	.004
Wrist circumference, cm	–0.16	–1.93 to –0.62	<.001
Hand length, cm	0.23	1.29 to 2.45	<.001
Palm width, cm	0.14	1.10 to 2.79	<.001

CI, confidence interval; kgf, kilogram-force; PG-SGA, Patient Generated Subjective Global Assessment.
[a]R^2 = 0.685.
[b]*P* value by linear regression analysis.

with HGS, and present study results indicate that individuals who are younger, are taller, or have larger hands produce greater HGS values, and so these variables may modify the association between undernutrition and HGS.

There is vast scientific evidence that sex[6-8,14,15,18,19] and age[6-8,10,12-14,18,19] are strongly associated with HGS and that HGS data should be stratified for sex and age.[6,8,18,20] The present study results are consistent with this previous evidence since male sex and age were strongly associated with HGS, explaining respectively 14.4% and 2.6% of HGS variability.

Studies conducted among adults and older people had already shown the association between hand dimensions and HGS.[6,19,24,25] To our knowledge, this is the first study to show that hand length, palm width, and wrist circumference are strongly associated with inpatients' HGS (β, –0.016 to 0.23; *P* < .001). Despite the adjustment of the dynamometer grip handle to the participant's hand, hand length was strongly associated with HGS, explaining 5.3% of HGS variability.

It is well documented that body height strongly influences HGS.[6,8,10,11,15,18,20] Taller individuals have longer arms and a better generation of power, contributing to higher HGS values.[20] Body height was associated with HGS in the presented multivariable model but also strongly correlated with hand length and mid-arm muscle circumference. Thus, hand length and body muscle mass may in part explain the strong correlation between HGS and body height found in this and previous studies.

In this research, higher wrist circumference values were associated with lower HGS. Moreover, wrist circumference was strongly and positively correlated with body weight. Given that weight is related to body fat and muscle mass,[20] as well as the high prevalence of overweight and obese individuals, these results may reflect a closer positive association of wrist circumference with body fat and hence the negative association with HGS.

A negative association was found between body weight and HGS. Again, one possible explanation is the high prevalence of overweight and obese participants in this study sample. In a longitudinal cohort study composed of 963 adults and older people, overweight and obese participants exhibited a greater decline in HGS than did normal-weight participants.[9] Greater body weight could be associated with sarcopenic obesity and inflammation or insulin resistance, which are known to be related to reduced HGS values.[51-53]

Although reference data display HGS values for age, sex, and height, HGS descriptions according to the anthropometric factors evaluated—namely, wrist circumference, hand length, and palm width—are not available. Further research is needed to identify if, besides the stratification by sex and age, adjustments of HGS data to these anthropometric variables will improve HGS value as an indicator of undernutrition. Sex and age are routinely assessed on hospital admission. Furthermore, measurement of parameters related to hand anatomy is quick and easy to obtain without mobilizing the patient and is appropriate for clinical practice.

The correlation between PG-SGA and HGS was weak to moderate, and number of drugs, AMT score, functional activity score, and PG-SGA score shared a similar strength of relationship to HGS. However, the use of correlation as a synonym for association can be misleading[54] because it does not take into consideration if the association between each variable and HGS is affected by other variables. The multivariable linear regression model obtained in the study explained a large proportion of HGS variability (68.5%). The relationship between PG-SGA and HGS is unique because despite the inclusion of a multiplicity of factors known to modify HGS—namely, indicators related to nutrition status such as mid-arm muscle circumference, adductor pollicis muscle thickness, and body weight—PG-SGA was still associated with HGS. In line with previous evidence, sex and age were strongly associated with HGS in the presented multivariable model. It was also shown that hand anatomy anthropometric indicators were strongly associated with inpatients' HGS and that hand length was more strongly associated with HGS than height. Thus, it is of utmost importance to study if the adjustment of HGS data to individuals' hand length improves the satisfactory diagnostic capacity of HGS for undernutrition identification.[1,27]

The wide age range of this sample (18–91 years) empowers these study results. Moreover, participants included in this study came from a variety of hospital wards, ensuring a wide spectrum of patients and relevant pathologies. Present sample HGS values and tertile cutoffs are comparable to other samples of inpatients.[7,49,50] These aspects strengthen the external validity of the study results for hospitalized patients.

Although the AMT was developed to discriminate cognitive impairment of older adults, it is also has been applied in adults younger than 65 years,[55-58] but its validity in detecting dementia outside of older populations is, to our knowledge, limited to individuals older than 59 years.[32] In the present study, a score <6 was considered denotative of cognitive impairment since this cutoff has shown the best combination of sensitivity (80%) and specificity (89%) in a mixed sample of adults and older adults.[32] Given the low education level of the present sample, this lower score was used, which is consistent with lower validated cutoffs of the Mini-Mental State Examination for the Portuguese population.[30,31] Nevertheless, the ability of the AMT to detect the possibility of cognitive impairment of Portuguese adults remains to be confirmed.

In the multivariable linear regression analysis conducted according to sex and age (<65 vs ≥65 years), many variables lost their statistical significance, which can be due to the smaller sample size used in each model. The lack of statistical power to conduct separate models to find if factors associated with HGS are different according to sex and age is also recognized as a study limitation. Further research should evaluate the association between undernutrition and HGS, quantifying the potential modifying effect of the studied variables across sex and age subgroups.

Present results first show that HGS is an indicator of nutrition status, even after considering other individual factors associated with HGS. It is important to stress that some of these factors are themselves strong indicators of undernutrition, such as adductor pollicis muscle thickness, mid-arm muscle circumference, and body weight. It is also worth noticing that the association between functional activity and HGS was also significant after controlling for all these indicators. This evidence supports the new guidelines developed by the Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition for the identification and documentation of undernutrition in clinical practice where diminished functional status, defined as reduced HGS, is one recommended characteristic for the diagnosis of undernutrition.[2]

All the studied variables were significantly associated with HGS. However, in this multivariable analysis, nutrition status evaluated by PG-SGA was still associated with HGS after considering the joint effect of anthropometric and other patient characteristics known to modify HGS, which reinforces HGS value as an indicator of undernutrition in clinical practice.

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