Association of handgrip strength with self-reported diseases in adults in Rio Branco, Acre State, Brazil: a population-based study

Associação da força de preensão manual com morbidades referidas em adultos de Rio Branco, Acre, Brasil: estudo de base populacional

Asociación entre la fuerza de prensión manual con las morbilidades referidas en adultos de Rio Branco, Acre, Brasil: estudio de base poblacional

Cledir de Araújo Amaral [1]
Margareth Crisóstomo Portela [2]
Pascoal Torres Muniz [3]
Edson dos Santos Farias [4]
Thiago Santos de Araújo [3]
Orivaldo Florêncio de Souza [3]

[1] Instituto Federal do Acre, Rio Branco, Brasil.
[2] Escola Nacional de Saúde Pública Sergio Arouca, Fundação Oswaldo Cruz, Rio de Janeiro, Brasil.
[3] Centro de Ciências da Saúde e do Desporto, Universidade Federal do Acre, Rio Branco, Brasil.
[4] Departamento de Educação Física, Universidade Federal de Rondônia, Porto Velho, Brasil.

Correspondence
C. A. Amaral
Instituto Federal do Acre.
Av. Brasil 920, Rio Branco, AC 69903-068, Brasil.
cledir.amaral@ifac.edu.br

Abstract

This study aimed to analyze the association of handgrip strength with self-reported diseases and multimorbidity among adults in Rio Branco, Acre State, Brazil, through a population based survey involving 1,395 adults of both sexes. Associations by sex were estimated by logistic regression analysis. The mean handgrip strength in men (44.8kg) is higher than in women (29kg) and decrease with age. The mean handgrip strength difference between those classified as strong and weak was 21kg and 15.5kg for men and woman, respectively. Controlling for age group, body mass index and physical activity when it was relevant, men with low handgrip strength were more likely to have hypertension [OR = 2.21 91.35; 3.61)], diabetes [OR = 4.18 (1.35; 12.95)], musculoskeletal disorders [OR = 1.67 (1.07; 2.61)] and multimorbidity [OR = 1.99 (1.27; 3.12)]. Among woman, associations between handgrip strength and cardiovascular disease, dyslipidemia, musculoskeletal disorders and multimorbidity were not sustained in the multivariate models. This study endorses the use of handgrip strength as a health biomarker.

Handgrip Strength; Morbidity; Health Surveys

Resumo

Este estudo objetivou analisar a associação da força de preensão manual com morbidades referidas e multimorbidade em adultos de Rio Branco, Acre, Brasil, mediante inquérito de base populacional com 1.395 adultos de ambos os sexos. As associações, por sexo, foram estimadas com a técnica de regressão logística. A média de força de preensão manual nos homens (44,8kg) é maior que entre as mulheres (29kg) e reduz com a idade. A diferença da força de preensão manual média entre aqueles classificados como fortes e fracos foi 21kg e 15,5kg, para homens e mulheres, respectivamente. Controlando para a faixa etária, índice de massa corporal e atividade física quando relevante, homens com baixa força de preensão manual tiveram maiores chances de ocorrência de hipertensão [OR = 2,21 (1,35; 3,61)], diabetes [OR = 4,18 (1,35; 12,95)], distúrbio musculoesquelético [OR = 1,67 (1,07; 2,61)] e multimorbidade [OR = 1,99 (1,27; 3,12)]. Nas mulheres, associações entre força de preensão manual e evento cardiovascular, dislipidemia, distúrbio muscolesquelético e multimorbidade não se mantiveram nos modelos multivariados. Este estudo endossa o uso da força de preensão manual como biomarcador de saúde.

Força da Mão; Morbidade; Inquéritos de Saúde

http://dx.doi.org/10.1590/0102-311X00062214

Introduction

Handgrip strength is recognized as an estimator of overall strength and has been presented as a biomarker for important health outcomes [1]. Studies with predominantly middle-aged and elderly individuals show that low handgrip strength is associated with sarcopenia [2], functional limitations and disabilities [3], falls [4], decreased bone mineral density, and increased fracture risks [5], and is considered a useful marker for frailty in the elderly [6]. Among men 40 to 68 years of age followed for 25 years, low handgrip strength was predictive of functional limitations and disabilities, while higher handgrip strength apparently protected against these conditions in old age, indicating that handgrip strength can be used for early screening of individuals at increased risk of physical disability in old age [4]. Mean decline in handgrip strength during the follow-up period was 8-9kg and was inversely associated with age and blood glucose, but directly associated with cognitive function, body mass index (BMI), and hemoglobin level [7].

In addition to disorders inherent to the musculoskeletal system, low handgrip strength has also been associated with changes in nutritional status [8], post-surgical clinical complications [9], length of hospital stay [10], various chronic diseases [11,12], and mortality [13], although the mechanisms of these associations are not well understood.

Low handgrip strength has been associated with increased odds of anxiety, stroke, chronic kidney disease (CKD), chronic obstructive pulmonary disease (COPD), and hyperthyroidism in men and anemia, falls, and kyphosis in women [10]. Among men and women 30 to 72 years of age followed for 22 years, handgrip strength decline was associated with incidence of chronic diseases such as cardiovascular events, diabetes mellitus, chronic bronchitis, chronic back pain, hypertension, and asthma as well as important weight loss, physical inactivity, and persistent smoking [12]. According to a Brazilian study, women with metabolic syndrome showed lower mean handgrip strength than healthy ones [14]. A study in men in the United States found a protective effect of muscle strength against metabolic diseases, regardless of cardiopulmonary fitness and overweight [15]. Several studies have found an association between diabetes mellitus and decreased handgrip strength [16,17,18].

The 37-year follow-up of a cohort of one million men starting with their enlistment in the Swedish Army (mean age 18.2 years) identified an inverse relationship between handgrip strength and risk of heart disease and stroke [19]. Meanwhile, the seven-year monitoring of older elderly showed less variation in handgrip strength among elders with higher initial handgrip strength, regardless of gender, with handgrip strength being an important predictor of mortality [13].

Potential prediction of morbidity based on measurement of handgrip strength suggests the variable's use as a biomarker in the assessment of health conditions in the population. This emphasizes the importance of accumulating knowledge from studies in different contexts to determine cut-off points for different diseases, not currently available in the literature.

Despite evidence from international studies, we are unaware of any epidemiological study on the topic in Brazil and that includes a wide age spectrum. The current study thus aimed to begin filling this gap by analyzing the association between handgrip strength and specific diseases and multimorbidity among adults in Rio Branco, Acre State, Brazil.

Methods

A cross-sectional study was conducted with adults in Rio Branco, under the research project *Health and Nutrition of Children and Adults in Rio Branco, Acre*, from November 2007 to October 2008.

A two-stage probabilistic cluster sample was used, with 35 census tracts as the primary units, 31 in the urban area and four in the rural area. Twenty-five households were randomly selected in each census tract and represented the secondary units, increased by 15% to compensate for losses or refusals, totaling 977 households, where all residents 18 years or older and able to answer the questions were asked to participate in the study.

The selected sample consisted of 1,516 adults from 18 to 96 years of age (the procedures have been presented elsewhere [20]). Pregnant women and participants who did not perform the handgrip strength test were excluded from the survey, leading to a loss of 121 subjects (7.8%), with no statistically significant difference according to socio-demographic profile. The final sample included 1,395 participants, considering the demographic characteristics (age and gender), leisure-time physical activity, and self-reported diseases, as well as the biometric variables height, weight, and handgrip strength.

The independent handgrip strength variable was obtained with a hydraulic hand-held dynamometer (SAEHAN SH5001, Saehan Corp., Dangjin, South Korea) with kgf resolution. The assessment adopted the sitting position with the elbow in 90° flexion, following procedures used by the American Society of Hand Therapists [21]. The handgrip strength score was the higher value of two measurements of the dominant hand. Individuals were classified into tertiles according to their handgrip strength score – strong (highest tertile), moderate strength (middle tertile), and weak (lowest tertile).

The dependent variables for self-reported diseases were identified by the individual's account of diagnosis by a health professional for the following conditions: hypertension, diabetes mellitus, cardiovascular events (myocardial infarction, stroke), dyslipidemia (high cholesterol or triglycerides), depression, chronic kidney disease, and musculoskeletal disorders (tendonitis, repetitive strain injury, spine or back disease, arthritis, non-infectious rheumatism, gout, and osteoporosis). The multimorbidity variable was built adopting the definition of the simultaneous occurrence of two or more chronic diseases in the same individual. A value of 1 for "yes" and 2 for "no" was assigned to each variable indicating occurrence of the disease.

The covariates were age, leisure-time physical activity, and BMI. Age was categorized in two groups, 18-39 years and 40 years and older. Leisure-time physical activity was defined according to weekly frequency and duration. According to recommendations by the World Health Organization (WHO) [22], individuals totaling 150 minutes of moderate physical activity or 75 minutes of vigorous activity were classified as active, and those who did not achieve these levels were considered sedentary. BMI was defined as weight divided by height-squared, using WHO [23] cutoff points: underweight (BMI < 18.5); normal weight (BMI = 18.5 to 24.9); overweight (BMI 25 to 29.9); and obese (BMI ≥ 30).

Data were double-entered and validated using Epi Info 6.04 (Centers for Disease Control and Prevention, Atlanta, USA).

In the descriptive analysis, we verified the absolute and relative frequencies of all the variables analyzed by gender and the estimated differences in frequencies between men and women using Pearson's chi-square test, with significance set at $\alpha = 0.05$.We also obtained handgrip strength measures of central tendency and dispersion according to gender and age group.

For men and women, logistic regression models estimated the magnitude of association as odds ratio (OR) between the dependent variables indicating diseases and handgrip strength in tertiles, with the highest handgrip strength tertile (strong) as the reference. Three models were estimated for each dependent variable: the first model focused on crude association between disease and handgrip strength; the second model on age group-adjusted association; and the third model on association adjusted for age group, BMI, and when relevant, leisure-time physical activity. Age group-handgrip strength interaction was tested. Significance was set at $\alpha = 0.05$.

All the analyses took into account the effect of the sample design and weights of observations, using SAS version 9.3 (SAS Inst., Cary, USA) *surveyfreq*, *surveymeans*, and *surveylogistic* procedures.

The research project that collected the data used in this study was approved by the Ethics Research Committee of the Federal University of Acre under Protocol n. 2307.001150/2007-22 and obtained informed consent from each participant.

Results

With the sample expansion using the sampling weights, the 1,395 observations corresponded to 248,479 individuals. Estimates point to a predominantly female population (54.6%) aged up to 39 years (59.3%). There were statistically significant differences ($p < 0.05$) between genders in the distributions of type of physical activity, BMI, hypertension, dyslipidemia, depression, musculoskeletal disorders, and multimorbidity (Table 1).

Overall mean handgrip strength was 36kg (44.8kg in men and 29kg in women). Regardless of gender, handgrip strength was also higher in the 18-39-year age group than in 40 years and over. In the handgrip strength analysis per tertile, strong and weak men had a mean handgrip strength of 55.3kg and 34.1kg, respectively, while strong and weak women had a mean handgrip strength of 36.1kg and 20.6kg, respectively (Table 2).

Table 3 shows the results for the three logistic regression models used in the analysis of associations between different diseases and handgrip strength for men. After adjusting for age group, the odds of hypertension were statistically higher among individuals classified as moderately strong or weak, as well as for diabetes mellitus, musculoskeletal disorders, and multimorbidity among weak individuals when as compared to the reference group of individuals classified as strong. Considering the models with adjustment by age group, BMI, and (when relevant) by leisure-time physical activity, despite some variation in the magnitude of associations by adjusting only for age, the results remained consistent. The odds of all the target diseases were higher in the older age group, while increased BMI was significant for the occurrence of hypertension, diabetes, dyslipidemia, and multimorbidity. Lei-

Table 1

Socio-demographic and health characteristics of adults in Rio Branco, Acre State, Brazil, 2007-2008.

Variáveis	Men			Women			Total			χ² ***
	n	Number expanded *	% **	n	Number expanded *	% **	n	Number expanded *	%	
Age (years)										0.002
18-39	392	70,844	62.8	432	76,595	56.5	824	147,439	59.3	
≥ 40	234	42,020	37.2	337	59,021	43.5	571	101,040	40.7	
Leisure-time physical activity										< 0.001
Active	227	40,606	36.0	113	18,974	14.0	340	59,580	24.0	
Sedentary	399	72,258	64.0	656	116,641	86.0	1,055	188,899	76.0	
BMI										0.001
Underweight	11	1,852	1.6	35	6,195	4.6	46	8,047	3.2	
Normal	319	58,561	52.0	341	60,279	44.5	660	118,840	47.9	
Overweight	202	35,988	32.0	241	42,818	31.6	443	78,806	31.8	
Obese	92	16,159	14.4	151	26,184	19.3	243	42,342	17.1	
Self-reported diseases										
Hypertension										0.003
No	477	85,197	75.8	522	92,082	67.9	999	177,280	71.5	
Yes	147	27,255	24.2	247	43,533	32.1	394	70,788	28.5	
Cardiovascular events										0.319
No	594	107,076	95.2	742	130,792	96.4	1,336	237,868	95.9	
Yes	30	5,377	4.8	27	4,823	3.6	57	10,200	4.1	
Chronic kidney disease										0.780
No	568	102,337	91.0	700	122,818	90.6	1,268	225,155	90.8	
Yes	56	10,116	9.0	69	12,798	9.4	125	22,913	9.2	
Diabetes mellitus										0.599
No	592	106,865	95.0	735	129,540	95.5	1,327	236,404	95.3	
Yes	32	5,588	5.0	34	6,076	4.5	66	11,664	4.7	
Dyslipidemia										< 0.001
No	533	96,210	85.6	595	105,429	77.7	1,128	201,639	81.3	
Yes	91	16,242	14.4	174	30,187	22.3	265	46,429	18.7	
Depression										< 0.001
No	560	100,947	89.8	575	100,505	74.1	1,135	201,453	81.2	
Yes	64	11,505	10.2	194	35,110	25.9	258	46,615	18.8	
Musculoskeletal disorders										< 0.001
No	411	73,994	65.8	405	71,119	52.4	816	145,113	58.5	
Yes	213	38,458	34.2	364	64,497	47.6	577	102,955	41.5	
Multimorbidity										< 0.001
No	437	78,665	69.7	424	74,079	54.6	861	152,744	61.5	
Yes	189	34,199	30.3	345	61,536	45.4	534	95,735	38.5	
Total	626	112,864	45.4	769	135,615	54.6	1,395	248,479	100.0	

BMI: body mass index.

* Number expanded from weights and sample design;

** Percentage from number expanded;

*** p-value of Pearson's chi-square test.

sure-time physical activity was positively associated with multimorbidity.

Table 4 presents the results corresponding to the previous table but for women, showing associations between classification as weak (versus strong) and cardiovascular events, dyslipidemia, musculoskeletal disorders, and multimorbidity, only in the model adjusted for other variables.

Table 2

Distribution of handgrip strength in kg by age group and handgrip strength tertile by gender in adults in Rio Branco, Acre State, Brazil, 2007-2008.

Age group	Mean	Median	Minimum *	Maximum **	Standard error	Coefficient of variation
Men						
18-39 years	46.6	45.8	18	83	0.48	0.010
≥ 40 years	41.6	41.4	12	77	0.81	0.020
Handgrip strength						
Strong	55.3	54.0	50	83	0.37	0.006
Moderate	44.9	45.0	41	49	0.17	0.004
Weak	34.2	36.0	12	40	0.43	0.011
Total	44.8	44.4	12	83	0.50	0.011
Mulher						
18-39 years	30.5	29.8	11	60	0.34	0.011
≥ 40 years	27.0	26.8	10	46	0.46	0.017
Handgrip strength						
Strong	36.0	35.0	32	60	0.25	0.007
Moderate	28.4	28.0	26	31	0.09	0.004
Weak	20.6	21.0	10	25	0.23	0.011
Total	29.0	28.6	10	60	0.35	0.012
Total	36.1	33.9	10	83	0.36	0.010

* Minimum: lower limit;
** Maximum: higher limit.

Table 3

Logistic regression analysis of handgrip strength tertiles and self-reported diseases in men in Rio Branco, Acre State, Brazil, 2007-2008.

Reported diseases	OR (95%CI) (model 1) *	OR (95%CI) (model 2) **	OR (95%CI) (model 3) ***
Hypertension			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.89 (1.19; 3.00)	1.77 (1.08; 2.90)	2.05 (1.19; 3.54)
Weak	2.31 (1.47; 3.64)	1.72 (1.09; 2.69)	2.21 (1.35; 3.61)
Age ≥ 40 years	-	4.08 (2.52; 6.60)	3.53 (2.14; 5.83)
BMI	-	-	1.10 (1.04; 1.15)
p-value trend #	< 0.001	0.021	0.001
% agreement ##	42.3	61.6	73.8
Cardiovascular event			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.52 (0.45; 5.19)	1.35 (0.40; 4.48)	1.42 (0.43; 4.68)
Weak	2.53 (0.76; 8.51)	1.77 (0.57; 5.46)	1.83 (0.60; 5.58)
Age ≥ 40 years	-	4.82 (2.08; 11.18)	4.38 (1.78; 10.78)
BMI	-	-	1.04 (0.96; 1.12)
p-value trend #	0.110	0.296	0.263
% agreement ##	42.1	59.5	67.4

(continues)

Table 3 (continued)

Reported diseases	OR (95%CI) (model 1) *	OR (95%CI) (model 2) **	OR (95%CI) (model 3) ***
Chronic kidney disease			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.28 (0.64; 2.57)	1.21 (0.60; 2.44)	1.17 (0.57; 2.37)
Weak	0.99 (0.50; 1.93)	0.82 (0.40; 1.69)	0.77 (0.36; 1.64)
Age ≥ 40 years	-	2.10 (1.03; 4.28)	2.21 (1.05; 4.64)
BMI	-	-	0.97 (0.93; 1.02)
p-value trend #	0.965	0.562	0.468
% agreement ##	36.1	52.6	60.0
Diabetes mellitus			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.62 (0.58; 4.57)	1.42 (0.49; 4.14)	1.67 (0.54; 5.14)
Weak	4.54 (1.50; 13.76)	3.16 (1.06; 9.47)	4.18 (1.35; 12.95)
Age ≥ 40 years	-	5.29 (2.20; 12.75)	4.31 (1.82; 10.23)
BMI	-	-	1.11 (1.05; 1.18)
p-value trend #	0.008	0.042	0.014
% agreement ##	50.8	69.8	79.5
Dyslipidemia			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.98 (0.55; 1.73)	0.83 (0.46; 1.50)	0.98 (0.52; 1.88)
Weak	1.36 (0.78; 2.39)	0.88 (0.48; 1.62)	1.31 (0.71; 2.40)
Age ≥ 40 years	-	6.00 (3.86; 9.33)	5.16 (3.33; 7.99)
BMI	-	-	1.16 (1.10; 1.22)
p value trend #	0.277	0.716	0.382
% agreement ##	36.5	64.3	80.2
Depression			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.86 (0.93; 3.74)	1.78 (0.88; 3.57)	1.78 (0.88; 3.58)
Weak	0.87 (0.43; 1.76)	0.73 (0.35; 1.52)	0.73 (0.36; 1.50)
Age ≥ 40 years	-	2.01 (1.14; 3.55)	2.01 (1.12; 3.63)
BMI	-	-	1.00 (0.93; 1.07)
p-value trend #	0.673	0.340	0.339
% agreement ##	41.6	55.5	55.6
Musculoskeletal disorders			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.48 (0.96; 2.28)	1.38 (0.86; 2.19)	1.34 (0.85; 2.09)
Weak	2.28 (1.45; 3.59)	1.76 (1.13; 2.74)	1.67 (1.07; 2.61)
Age ≥ 40 years	-	3.61 (2.54; 5.14)	3.73 (2.54; 5.47)
BMI	-	-	0.98 (0.94; 1.02)
p-value trend #	< 0.001	0.013	0.027
% agreement ##	42.2	60.9	68.3

(continues)

Table 3 (continued)

Reported diseases	**OR (95%CI) (model 1) ***	**OR (95%CI) (model 2) ****	**OR (95%CI) (model 3) *****
Multimorbidity			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.42 (0.93; 2.18)	1.30 (0.83; 2.02)	1.41 (0.90; 2.22)
Weak	2.34 (1.51; 3.63)	1.72 (1.09; 2.73)	1.99 (1.27; 3.12)
Age ≥ 40 years	-	4.72 (3.35; 6.64)	3.80 (2.67; 5.41)
BMI	-	-	1.06 (1.01; 1.11)
Leisure-time physical activity	-	-	1.72 (1.09; 2.71)
p-value trend #	< 0.001	0.022	0.003
% agreement ##	42.5	64.1	74.0

95%CI: 95% confidence interval; BMI: body mass index; OR: odds ratio.

* Model 1: crude analysis;

** Model 2: adjusted for age;

*** Model 3: adjusted for age, BMI, and physical activity, when relevant;

p-value trend = trend test of OR between handgrip strenght tertiles;

% agreement = model adherence percentage.

Table 4

Logistic regression analysis of handgrip strength tertiles and reported diseases in women in Rio Branco, Acre State, Brazil, 2007-2008.

Reported diseases	**OR (95%CI) (model 1) ***	**OR (95%CI) (model 2) ****	**OR (95%CI) (model 3) *****
Hypertension			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.81 (0.58; 1.13)	0.74 (0.51; 1.05)	0.90 (0.60; 1.36)
Weak	1.17 (0.79; 1.74)	0.81 (0.53; 1.22)	1.03 (0.64; 1.64)
Age ≥ 40 years	-	3.25 (2.47; 4.28)	2.22 (1.61; 3.05)
BMI	-	-	1.44 (1.05; 1.96)
p-value trend #	0.495	0.287	0.947
% agreement ##	38.1	57.7	73.4
Cardiovascular event			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.89 (0.32; 2.44)	0.81 (0.30; 2.14)	0.81 (0.29; 2.25)
Weak	2.46 (1.11; 5.47)	1.66 (0.72; 3.81)	1.65 (0.70; 3.89)
Age ≥ 40 years	-	4.09 (1.47; 11.36)	4.14 (1.59; 10.81)
BMI	-	-	1.00 (0.94; 1.06)
p-value trend #	0.037	0.233	0.246
% agreement ##	45.0	63.1	64.9

(continues)

Table 4 (continued)

Reported diseases	OR (95%CI) (model 1) *	OR (95%CI) (model 2) **	OR (95%CI) (model 3) ***
Chronic kidney disease			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.65 (0.34; 1.25)	0.63 (0.33; 1.22)	0.65 (0.34; 1.24)
Weak	0.69 (0.34; 1.39)	0.62 (0.31; 1.23)	0.64 (0.32; 1.26)
Age ≥ 40 years	-	1.41 (0.71;2.79)	1.36 (0.69; 2.66)
BMI	-	-	1.01 (0.97; 1.06)
p-value trend #	0.291	0.169	0.191
% agreement ##	37.4	47.0	54.5
Diabetes mellitus			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.90 (0.32; 2.49)	0.80 (0.29; 2.20)	0.78 (0.29; 2.09)
Weak	1.34 (0.49; 3.70)	0.81 (0.31; 2.14)	0.87 (0.35; 2.19)
Age ≥ 40 years	-	6.70 (2.88; 15.58)	5.85 (2.33;1 4.66)
BMI	-	-	1.03 (0.96; 1.10)
p-value trend #	0.591	0.683	0.790
% agreement ##	37.6	63.7	71.9
Dyslipidemia			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.79 (0.51;1.22)	0.70 (0.46;1.05)	0.79 (0.52;1.18)
Weak	1.63 (1.03;2.57)	1.05 (0.66;1.66)	1.25 (0.79;1.97)
Age ≥ 40 years	-	4.48 (3.16;6.35)	3.56 (2.37;5.39)
BMI	-	-	1.08 (1.03;1.12)
p value trend #	0.055	0.862	0.369
% agreement ##	42.0	62.7	74.1
Depression			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	1.04 (0.72;1.50)	1.01 (0.70;1.46)	1.06 (0.73;1.54)
Weak	1.38 (0.93;2.04)	1.16 (0.77;1.75)	1.23 (0.82;1.87)
Age ≥ 40 years	-	1.73 (1.35;2.21)	1.59 (1.19;2.13)
BMI	-	-	1.03 (0.99;1.06)
p-value trend #	0.122	0.487	0.327
% agreement ##	36.6	44.5	59.1
Musculoskeletal disorders			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.92 (0.67;1.27)	0.84 (0.61;1.14)	0.83 (0.60;1.14)
Weak	1.73 (1.23;2.44)	1.17 (0.78;1.76)	1.16 (0.76;1.78)
Age ≥ 40 years	-	3.84 (2.85;5.17)	3.85 (2.80;5.30)
BMI	-	-	1.00 (0.97;1.03)
p-value trend #	0.002	0.528	0.553
% agreement ##	40.2	60.5	66.8

(continues)

Table 4 (continued)

Reported diseases	OR (95%CI) (model 1) *	OR (95%CI) (model 2) **	OR (95%CI) (model 3) ***
Multimorbidity			
Handgrip strength			
Strong	1.00	1.00	1.00
Moderate	0.89 (0.64;1.23)	0.78 (0.55;1.11)	0.87 (0.61;1.23)
Weak	1.70 (1.18;2.45)	1.06 (0.71;1.59)	1.24 (0.83;1.85)
Age ≥ 40 years	-	4.93 (3.73;6.50)	4.10 (3.07;5.48)
BMI	-	-	1.07 (1.03;1.10)
p-value trend #	0.006	0.859	0.337
% agreement ##	40.5	62.9	73.8

95%CI: 95% confidence interval; BMI: body mass index; OR: odds ratio.

* Model 1: crude analysis;

** Model 2: adjusted for age;

*** Model 3: adjusted for age, BMI, and physical activity, when relevant;

p-value trend = trend test of OR between handgrip strenght tertiles;

% agreement = model adherence percentage.

Interaction terms between age and handgrip strength were tested in the multivariate models in Table 3 and 4, but were not statistically significant ($p < 0.05$).

Discussion

The results showed associations between handgrip strength and self-reported hypertension, diabetes, musculoskeletal disorders and multimorbidity in men only. Reduced muscle strength, a condition known as dynapenia [2], was observed in the 40-and-over age group.

The study found significant differences in the magnitude and gradient of muscle strength between men and women, corroborating previous studies [11,24], which can be explained by hormonal differences inherent to gender.

There was no statistically significant association between low handgrip strength and the cardiovascular events. However, metabolic syndrome, an important risk factor for cardiovascular disease that results precisely from the combination of dyslipidemia, hyperglycemia, and hypertension [25], was shown to be individually associated with handgrip strength in men. The components of metabolic syndrome are thus associated with chronic systemic inflammation and increased interleukin-1 and -6 (IL-1 and IL-6) and tumor necrosis factor-alpha (TNF-α) [26]. High levels of inflammatory markers such as IL-6 and C-reactive protein (CRP) increase the risk of muscle strength loss in older men and women [27], who thus tend to decline in physical function and increase in functional disability, dependence in activities of daily living, and mortality [28,29]. Evidence have been reported on the progressive reduction of handgrip strength in the presence of catabolic biomarkers (CRP, IL-6, IL-1RA, TNF-α) [30], which increase oxidative stress, reducing muscle mass and causing consequent loss of strength in the elderly [2,31,32].

The present results corroborate other studies showing that diabetic men have lower handgrip strength than their non-diabetic peers, but the same was not evident among women [11,17]. Prospective studies indicate that type-2 diabetes reduces muscle strength and mass [18], and that higher strength protects against the development of diabetes [33]. In vitro and in vivo clinical evidence attests that hyperglycemia affects contractile function and muscle strength [34].

This study also agrees with others identifying the association between low strength and hypertension in men, but not in women [35,36]. It has been reported that resistance training appears to prevent metabolic disorders such as dyslipidemia, impaired fasting glucose, pre-hypertension, and increased waist circumference, but not hypertension [37], while recognizing that increased strength may improve vascular health and reduce complications [38] and mortality among hypertensive individuals [39]. The statistical association between handgrip strength and hypertension may mean that muscle strength expresses overall individual fitness [40] more than a direct relationship with hypertension.

The association between low handgrip strength and musculoskeletal disorders in men from Rio Branco appears to echo the relationship between handgrip strength and overall strength, which itself reflects operation of the musculoskeletal system [1]. Low strength has already been associated with history of falls in both sexes and with kyphosis in women [11]. This study's findings thus highlight the importance of using handgrip strength as a health biomarker, realizing that reduced levels of muscle strength may lead to disability and functional limitations, particularly among older individuals [2,3,41]. The assessment of handgrip strength during middle age could allow early identification of risks of future disability [3], dependence in activities of daily living, and cognitive decline in older age [4]. It can also play a role in predicting fracture risks [5] and tracking sarcopenia [2].

Part of the modeling process in this study focused on differentiating between individuals 60 years and older and 40-59 years of age, confirming the role of aging in the occurrence of diseases and providing relatively consistent results. However, the small number of strong individuals in the 60-and-older group, especially among men, led to loss of power in the inferences.

Future studies should contribute to understanding the effect of handgrip strength in older individuals, as well as differences observed here in the role of handgrip strength as a predictor of morbidity between men and women.

As far as we know, this is the first study to test interaction between handgrip strength and age when assessing the association between handgrip strength and diseases. The findings do not indicate potentiation or attenuation of the effect of low handgrip strength with older age in the occurrence of diseases.

The study has some limitations, such as the inability to make causal inferences. The statistical associations should only be considered as such, with due caution concerning assumptions about which variables precede which. Another limitation is the lack of clinical parameters for diseases, although self-reported chronic diseases express an approximate measure of the information obtained by clinical examination [42].

We highlight that this research was unprecedented in Brazil, as the first Brazilian population-based study with adults that assesses handgrip strength and diseases. The models used here also considered the effect of handgrip strength adjusted by the main variables published in the literature: age, BMI, and leisure-time physical activity.

Resumen

El objetivo fue analizar la asociación de la fuerza de prensión manual con las morbilidades y multimorbilidad entre los adultos en Rio Branco, Acre, Brasil, mediante una encuesta poblacional con 1.395 adultos de ambos sexos. Las asociaciones, por sexo, se estimaron mediante regresión logística. La media de la fuerza de prensión manual en los hombres (44,8kg) es mayor que en las mujeres (29kg) y disminuye con la edad. La diferencia de la fuerza de prensión manual media entre los clasificados como fuertes y débil fue 21kg y 15,5kg para hombres y mujeres, respectivamente. Controlando por edad, índice de masa corporal y la actividad física, cuando sea pertinente, los hombres con baja fuerza de prensión manual son más propensos a sufrir de hipertensión [OR = 2,21 (1,35; 3,61)], diabetes [OR = 4,18 (1,35; 12,95), trastorno musculoesquelético [OR = 1,67 (1,07; 2,61)] y multimorbilidad [OR = 1,99 (1,27; 3,12)]. Entre las mujeres, las asociaciones entre fuerza de prensión manual y evento cardiovascular, dislipidemia, trastorno musculoesquelético y multimorbilidad no se mantuvieron en los modelos multivariados. Este estudio respalda el uso de fuerza de prensión manual como un biomarcador de la salud.

Fuerza de la Mano; Morbilidad; Encuestas Epidemiológicas

Conclusion

The findings confirm the association between low handgrip strength and chronic diseases, musculoskeletal disorders, and multimorbidity among men, supporting the measurement of muscle strength with a hand-held dynamometer as a useful, relatively low-cost, and easy-to-apply marker for clinical evaluation and monitoring of individual health conditions, especially in primary care.

The study also indicates the need for further epidemiological research to improve our understanding of the findings based on clinical parameters for diseases and focused on specific age groups, explaining the differences between men and women and contributing to proposals of reference values and cutoff points for health risks.

Contributors

C. A. Amaral participated in the data processing, analysis, and interpretation, literature review, and writing of the article. M. C. Portela collaborated in the analysis and interpretation of the results presented in the new version, as well as in the final revision. P. T. Muniz and T. S. Araújo contributed to the data collection and critical revision of the article. E. S. Farias participated in the critical revision and approval of the final version. O. F. Souza collaborated in the data organization, analysis, and interpretation, critical revision of the article, and approval of the final version.

Acknowledgments

The authors wish to thank the agencies CNPq (Call for Projects, UFAC-FIOCRUZ, case n. 620024/2008-9) and Capes (PROCAD-NF 1442/2007 and PROCAD-NF 2557/2008 programs) for funding the program of collaboration between the Master's Program in Collective Health at the Federal University of Acre and the Graduate Studies Program in Public Health and the Environment at the Oswaldo Cruz Foundation.

References

1. Bohannon RW. Are hand-grip and knee extension strength reflective of a common construct? Percept Mot Skills 2012; 114:514-8.
2. Manini TM, Clark BC. Dynapenia and aging: an update. J Gerontol A Biol Sci Med Sci 2012; 67: 28-40.
3. Rantanen T, Guralnik JM, Foley D, Masaki K, Leveille S, Curb JD, et al. Midlife hand grip strength as a predictor of old age disability. JAMA 1999; 281:558-60.
4. Taekema DG, Gussekloo J, Maier AB, Westendorp RG, De Craen AJ. Handgrip strength as a predictor of functional, psychological and social health. A prospective population-based study among the oldest old. Age Ageing 2010; 39:331-7.
5. Cheung C-L, Tan KCB, Bow CH, Soong CSS, Loong CHN, Kung AW-C. Low handgrip strength is a predictor of osteoporotic fractures: cross-sectional and prospective evidence from the Hong Kong Osteoporosis Study. Age (Dordr) 2012; 34:1239-48.
6. Syddall H, Cooper C, Martin F, Briggs R, Aihie Sayer A. Is grip strength a useful single marker of frailty? Age Ageing 2003; 32:650-6.
7. Charles LE, Burchfiel CM, Fekedulegn D, Kashon ML, Ross GW, Sanderson WT, et al. Occupational and other risk factors for hand-grip strength: the Honolulu-Asia Aging Study. Occup Environ Med 2006; 63:820-7.
8. Cucinotta D, Frondini C, Paletti P, Reggiani A, Lancellotti F, Galletti L. The importance of assessment of nutritional status for the extension of an independent longevity. Arch Gerontol Geriatr Suppl 2002; 8:123-8.
9. Bragagnolo R, Caporossi FS, Dock-Nascimento DB, Aguilar-Nascimento JE. Handgrip strength and adductor pollicis muscle thickness as predictors of postoperative complications after major operations of the gastrointestinal tract. E Spen Eur E J Clin Nutr Metab 2011; 6:e21-6.
10. Kerr A, Syddall HE, Cooper C, Turner GF, Briggs RS, Sayer AA. Does admission grip strength predict length of stay in hospitalised older patients? Age Ageing 2006; 35:82-4.
11. Cheung C-L, Nguyen US, Au E, Tan KCB, Kung AW. Association of handgrip strength with chronic diseases and multimorbidity: a cross-sectional study. Age (Dordr) 2013; 35:929-41.
12. Stenholm S, Tiainen K, Rantanen T, Sainio P, Heliövaara M, Impivaara O, et al. Long-term determinants of muscle strength decline: prospective evidence from the 22-year mini-Finland follow-up survey. J Am Geriatr Soc 2012; 60:77-85.
13. Oksuzyan A, Maier H, Mcgue M, Vaupel JW, Christensen K. Sex differences in the level and rate of change of physical function and grip strength in the Danish 1905-cohort study. J Aging Health 2010; 22:589-610.
14. Tibana RA, Tajra V, César D, Farias DL, Teixeira TG, Prestes J. Comparação da força muscular entre mulheres brasileiras com e sem síndrome metabólica. Conscientiae Saúde (Impr.) 2011; 10:708-14.

15. Jurca R, Lamonte MJ, Church TS, Earnest CP, Fitzgerald SJ, Barlow CE, et al. Associations of muscle strength and fitness with metabolic syndrome in men. Med Sci Sports Exerc 2004; 36:1301-7.
16. Cetinus E, Buyukbese MA, Uzel M, Ekerbicer H, Karaoguz A. Hand grip strength in patients with type 2 diabetes mellitus. Diabetes Res Clin Pract 2005; 70:278-86.
17. Sayer AA, Dennison EM, Syddall HE, Gilbody HJ, Phillips DI, Cooper C. Type 2 diabetes, muscle strength, and impaired physical function: the tip of the iceberg? Diabetes Care 2005; 28:2541-2.
18. Park SW, Goodpaster BH, Strotmeyer ES, Kuller LH, Broudeau R, Kammerer C, et al. Accelerated loss of skeletal muscle strength in older adults with type 2 diabetes: the health, aging, and body composition study. Diabetes Care 2007; 30:1507-12.
19. Silventoinen K, Magnusson PK, Tynelius P, Batty GD, Rasmussen F. Association of body size and muscle strength with incidence of coronary heart disease and cerebrovascular diseases: a population-based cohort study of one million Swedish men. Int J Epidemiol 2009; 38:110-8.
20. Lino MZR, Muniz PT, Siqueira KS. Prevalência e fatores associados ao excesso de peso em adultos: inquérito populacional em Rio Branco, Acre, Brasil, 2007-2008. Cad Saúde Pública 2011; 27: 797-810.
21. Fess EE. Documentation: essential elements of an upper extremity assessment battery. In: Hunter JM, Mackin, EJ, Callahan AD, editors. Rehabilitation of the hand and upper extremity. 5th Ed. Saint Louis: Mosby; 2002. p. 263-84.
22. World Health Organization. Global recommendations on physical activity for health. Geneva: WHO Press; 2010.
23. World Health Organization. Obesity: preventing and managing the global epidemic. Geneva: World Health Organization; 2000. (WHO Technical Report Series, 894).
24. Schlussel MM, Anjos LA, Vasconcellos MTL, Kac G. Reference values of handgrip dynamometry of healthy adults: a population-based study. Clin Nutr 2008; 27:601-7.
25. Xavier HT, Izar MC, Faria Neto JR, Assad MH, Rocha VZ, Sposito AC, et al. V diretriz brasileira de dislipidemias e prevenção da aterosclerose. Arq Bras Cardiol 2013; 101 Suppl 1:1-22.
26. Calabro P, Yeh ET. Intra-abdominal adiposity, inflammation, and cardiovascular risk: new insight into global cardiometabolic risk. Curr Hypertens Rep 2008; 10:32-8.
27. Schaap LA, Pluijm SM, Deeg DJ, Visser M. Inflammatory markers and loss of muscle mass (sarcopenia) and strength. Am J Med 2006; 119:526.e9-17.
28. Visser M, Pahor M, Taaffe DR, Goodpaster BH, Simonsick EM, Newman AB, et al. Relationship of interleukin-6 and tumor necrosis factor-alpha with muscle mass and muscle strength in elderly men and women: the Health ABC Study. J Gerontol A Biol Sci Med Sci 2002; 57:M326-32.
29. Reuben DB, Judd-Hamilton L, Harris TB, Seeman TE; MacArthur Studies of Successful Aging. The associations between physical activity and inflammatory markers in high-functioning older persons: MacArthur Studies of Successful Aging. J Am Geriatr Soc 2003; 51:1125-30.
30. Stenholm S, Maggio M, Lauretani F, Bandinelli S, Ceda GP, Di Iorio A, et al. Anabolic and catabolic biomarkers as predictors of muscle strength decline: the InCHIANTI study. Rejuvenation Res 2010; 13:3-11.
31. Howard C, Ferrucci L, Sun K, Fried LP, Walston J, Varadhan R, et al. Oxidative protein damage is associated with poor grip strength among older women living in the community. J Appl Physiol (1985) 2007; 103:17-20.
32. Leite LEA, Resende TL, Nogueira GM, Cruz IBM, Schneider RH, Gottlieb MGV. Envelhecimento, estresse oxidativo e sarcopenia: uma abordagem sistêmica. Rev Bras Geriatr Gerontol 2012; 15: 365-80.
33. Wander PL, Boyko EJ, Leonetti DL, McNeely MJ, Kahn SE, Fujimoto WY. Greater hand-grip strength predicts a lower risk of developing type 2 diabetes over 10 years in leaner Japanese Americans. Diabetes Res Clin Pract 2011; 92:261-4.
34. Helander I, Westerblad H, Katz A. Effects of glucose on contractile function, [Ca2+]i, and glycogen in isolated mouse skeletal muscle. Am J Physiol Cell Physiol 2002; 282:C1306-12.
35. Yoon JH, So WY. Associations of hypertension status with physical fitness variables in korean women. Iran J Public Health 2013; 42:673-80.
36. Cavazzotto TG, Tratis L, Ferreira SA, Fernandes RA, Queiroga MR. Muscular static strength test performance: comparison between normotensive and hypertensive workers. Rev Assoc Med Bras 2012; 58:574-9.
37. Churilla JR, Magyari PM, Ford ES, Fitzhugh EC, Johnson TM. Muscular strengthening activity patterns and metabolic health risk among US adults. J Diabetes 2012; 4:77-84.
38. Cook MD, Heffernan KS, Ranadive S, Woods JA, Fernhall B. Effect of resistance training on biomarkers of vascular function and oxidative stress in young African-American and Caucasian men. J Hum Hypertens 2013; 27:388-92.
39. Artero EG, Lee DC, Ruiz JR, Sui X, Ortega FB, Church TS, et al. A prospective study of muscular strength and all-cause mortality in men with hypertension. J Am Coll Cardiol 2011; 57:1831-7.
40. Swain DP, Franklin BA. Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. Am J Cardiol 2006; 97:141-7.
41. Barbosa AR, Souza JMP, Lebrão ML, Laurenti R, Marucci MFN. Functional limitations of Brazilian elderly by age and gender differences: data from SABE Survey. Cad Saúde Pública 2005; 21:1177-85.
42. Theme Filha MM, Szwarcwald CL, Souza Junior PRB. Medidas de morbidade referida e inter-relações com dimensões de saúde. Rev Saúde Pública 2008; 42:73-81.

Submitted on 15/May/2014
Final version resubmitted on 23/Dec/2014
Approved on 09/Jan/2015