REFERENCE VALUES FOR HANDGRIP STRENGTH

IN AMONG HEALTHY YOUNG ADULTS

Andrés Vivas[1], Jorge Enrique Correa[1], Robinson Ramírez-Vélez[2*].

[1]Centro de Estudios en Medición de la Actividad Física (CEMA), Escuela de Medicina y Ciencias de la Salud, Universidad del Rosario, Bogotá D.C, Colombia

[2]Grupo de Investigación en GICAEDS. Programa de Cultura Física, Deporte y Recreación, Universidad Santo Tomás, Bogotá, D.C, Colombia.

Running head: Reference values for Handgrip strength

*Corresponding Author:

Robinson Ramírez-Vélez
Universidad Santo Tomás, Carrera 9 Nº 51-23. Bogotá, D.C, Colombia
Phone: +55(1) 587 8797 ext. 1811, Fax: +55(1) 8578850

E-mail: robin640@hotmail.com

Abstract

Background: Isometric grip strength, evaluated with a handgrip dynamometer, is a marker of current nutritional status and cardiometabolic risk and future morbidity and mortality. We present reference values for handgrip strength in healthy young Colombian adults (aged 18 to 29 years).

Methods: The sample comprised 5.647 (2.330 men and 3.317 women) apparently healthy young university students (mean age, 20.6±2.7 years) attending public and private institutions in the cities of Bogota and Cali (Colombia). Handgrip strength was measured two times with a TKK analogue dynamometer in both hands and the highest value used in the analysis. Sex- and age-specific normative values for handgrip strength were calculated using the LMS method and expressed as tabulated percentiles from 3 to 97 and as smoothed centile curves (P_3, P_{10}, P_{25}, P_{50}, P_{75}, P_{90} and P_{97}).

Results: Mean values for right and left handgrip strength were 38.1±8.9 and 35.9±8.6 kg for men, and 25.1±8.7 and 23.3±8.2 kg for women, respectively. Handgrip strength increased with age in both sexes and was significantly higher in men in all age categories. The results were generally more homogeneous amongst men than women.

Conclusions: Sex- and age-specific handgrip strength normative values among healthy young Colombian adults are defined. This information may be helpful in future studies of secular trends in handgrip strength and to identify clinically relevant cut points for poor nutritional and elevated cardiometabolic risk in a Latin American population. Evidence of decline in handgrip strength before the end of the third decade is of concern and warrants further investigation.

Keywords: Adults; Dynamometer; Grip strength**;** Reference values.

Introduction

Low handgrip strength (HGS), as determined with a handgrip dynamometer, is recognized as a marker of poor nutritional status and early marker of nutritional deprivation[1]. Low HGS is a predictor of poor clinical outcomes in hospitalized patients including longer length of stay, complications and mortality[1-3]. Lower HGS in middle aged and elderly subjects has been shown to predict functional limitations, disability[2,3] and cardiovascular and all-cause mortality[4]. There is also accumulating evidence that from an early age HGS is inversely associated with cardiometabolic risk factors[5-7] and that lower HGS in young adulthood is a predictor of cardiovascular disease and mortality[8,9] in adulthood, independent of body mass index and cardiorespiratory fitness[10]. Notably, while strength and muscle mass are well correlated, associations between HGS and markers of health or health outcomes appear to persist after adjusting for the latter[1-9]. Therefore, the assessment of muscle function or "muscle quality" permitted by handgrip dynamometry may be an earlier and more sensitive marker of poor outcomes associated with malnutrition[1,10,11]. The relatively low cost and the simplicity and speed with which HGS can be measured also make it attractive tool for clinical or naturalistic settings[11].

Numerous studies have evaluated the association between HGS and current or future health in different age groups, in healthy populations and those with disease, and from diverse geographic regions[12-23]. These analyses consistently show higher HGS in males at all ages except in children, with peak grip strength observed in the fourth decade followed by a gradual decline in both genders[12-23]. Nonetheless, there is a paucity of data in Latin American populations and reference values for handgrip strength for the Colombian population following a standardized protocol such as that of the American Society of Hand Therapists (ASHT)[18] are lacking. Population-specific reference values are important for tracking of secular trends for handgrip in the population and to enable the screening and identification both of low handgrip strength as a risk factor, as well as reductions in muscle strength associated with poor nutritional status or underlying disease.

Therefore the principle aim of this study was to establish reference values for handgrip strength in healthy Colombian adults. We also aimed to evaluate sex and age related differences amongst the population.

Methods

Subjects

The study included 5.647 apparently healthy young adult volunteers (2.330 men and 3.317 women) aged 18-29 years (mean, 20.6 ± 2.7 years). Participants were students from the Universities Rosario, Manuela Beltrán and Santo Tomas in Bogota, and the University of Valle in Cali, Colombia, who were recruited via research advertisement and invitations. Inclusion criteria were: (1) no movement restriction in the upper extremities, (2) no self-reported history of inflammatory joint disease, neurological disorder or injury to the upper extremity and (3) not athletes participating at the elite level. Subjects with a medical or clinical diagnosis of major systemic disease (including malignant conditions such as cancer), type 1 or 2 diabetes mellitus, high blood pressure, hypothyroidism/hyperthyroidism, a history of drug or alcohol abuse, were regularly using multivitamin preparations, a body mass index (BMI) ≥ 35 kg•m^{-1} and inflammatory (trauma, contusions) or infectious conditions were also excluded from the study. Written informed consent was obtained for all subjects, and ethical approval was granted by the Medical Ethics Committee of the University of Manuela Beltrán. The study conforms to the principles outlined in the Declaration of Helsinki.

Anthropometric measurements

All measurements were obtained at the same time of the day (between 7:00 and 9:00 am). Anthropometric measurements were performed with the participants wearing light apparel, with no shoes. Body weight was measured to the nearest 0.05 kg, using a calibrated scale (Tanita BWB-800A®; Tanita, Corp., Tokyo, Japan). Height was measured to the nearest 0.1 cm, using a stadiometer (SECA 220®; Seca, Ltd, Hamburg, Germany) and body mass index (BMI) calculated.

Handgrip strength assessment

Handgrip strength was measured using a standard adjustable handle analogue handgrip dynamometer T-18 TKK SMEDLY III® (Takei Scientific Instruments Co., Ltd, Niigata, Japan), previously shown to have high reliability in young men (r=0.88-0.98)[4]. Handgrip strength was measured with the subject in a standing position with shoulder adducted and neutrally rotated, arms parallel but not in contact with the body. The participants were asked to squeeze the handle maximally for 3-5 seconds, but no verbal encouragement was given during the test. Two trials were performed on each side, alternately, with a rest period of at least 1 min between trials of the same hand. Two trials of the test was performed with the maximum score for each hand recorded in kilograms (kg). Thus, the reference values of handgrip strength presented here combine the results of left and right-handed subjects, without consideration of hand dominance. The data was collected over a period of 16 months (between November 2012 and March 2014) during which time the handgrip dynamometers were calibrated periodically. Five assessors were trained in the use of the dynamometer and the implementation of the protocol, which they practiced prior to the assessments.

Statistical analysis

Anthropometric characteristics and handgrip strength of the study sample are presented as means, standard deviation (SD) and 95% confidence intervals [CI 95%], unless otherwise indicated. We analysed sex- and age-group differences in the anthropometric and handgrip strength variables by two-way analysis of variance, unless otherwise stated. Analyses of handgrip strength were done by age and gender and are presented as left hand, right hand and average of the two. Normalized handgrip strength was calculated by dividing handgrip strength (kg) by body weight (kg). The Kolmogorov-Smirnov test was used to assess Normality for all variables. To provide percentile values for sample, we analysed handgrip strength outcome data by maximum penalised likelihood using the LMS statistical method for men and women separately. The maximum power required to obtain normality was calculated for each age-group series and the trend was then summarized by a smooth (L) curve. The trends observed for the mean (M), and coefficient of variation (S) were similarly smoothed. These LMS curves contained information to enable any centile curve to be drawn and to convert measurements into exact standard deviation scores. For the construction of the percentile curves, data were imported into the LmsChartMaker software (V. 2.3; by Tim Cole and HuiqiPan) and the L, M and

S curves estimated. Test and retest (T1 and T2) were compared between men and women by means of Bland-Altman plots in a sub-sample of 294 subjects (144 men and 150 women) over a 7 day period between test administrations. Bland-Altman plots represent the differences between the handgrip strength values measured during the test and retest sessions against the means of these values. Except for the LMS method calculations, we used SPSS V. 21.0 software for Windows (SPSS, Chicago, Illinois, USA), and the significance level was set at 0.05.

Results

Anthropometric characteristics and handgrip strength outcomes of the study sample by sex are shown in table 1.

Table 1. Characteristics of the study sample by sex

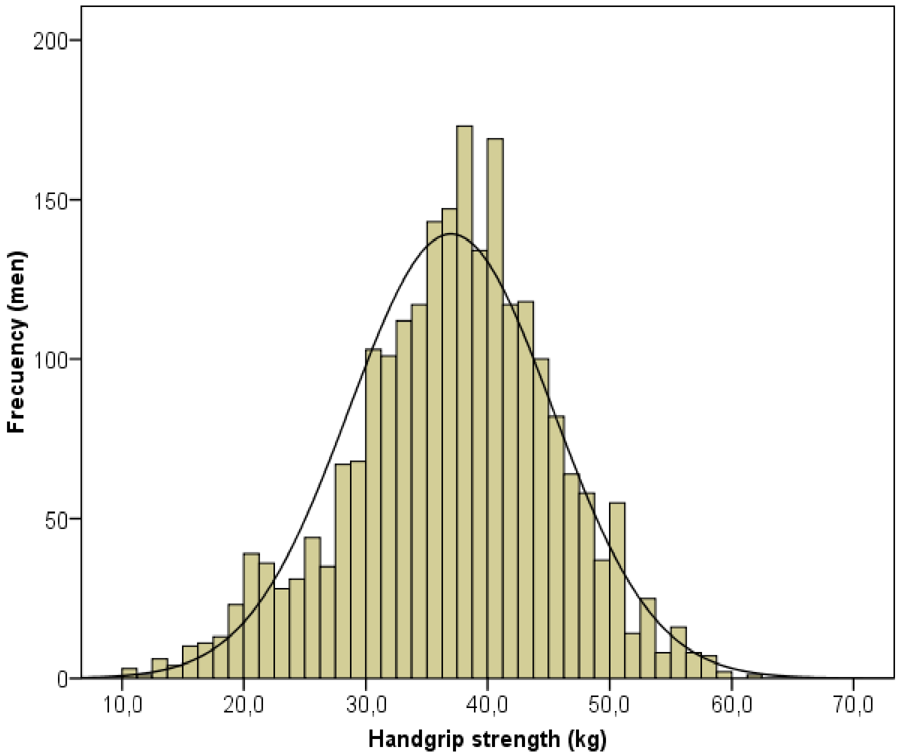
	All (n=5.647)	Women (n=3.317)	Men (n=2.330)	Sex difference	Age trend
Age (years)	20.6 ± 2.7 (20.5-20.7)	20.4 ± 2.6 (20.4-20.5)	20.9 ± 2.9 (20.7-21.0)	>	>
Body mass (kg)	61.5 ± 11.4 (61.2-61.8)	57.2 ± 9.4 (56.9-57.6)	67.6 ± 11.2 (67.2-68.1)	>	>
Height (m)	1.59 ± 0.06 (1.59-1.59)	1.59 ± 0.06 (1.59-1.59)	1.72 ± 0.06 (1.59-1.59)	>	>
Body mass index (kg•m^{-1})	22.7 ± 3.3 (22.6-22.8)	22.6 ± 3.3 (22.5-22.7)	22.9 ± 3.3 (22.7-23.0)	>	>
Left handgrip strength (kg)	28.5 ± 10.4 (28.3-28.8)	23.3 ± 8.2 (23.1-23.6)	35.9 ± 8.6 (35.6-36.3)	>	>
Right handgrip strength (kg)	30.4 ± 10.8 (30.1-30.7)	25.1 ± 8.7 (24.8-25.3)	38.1 ± 8.9 (37.7-38.4)	>	>
Average handgrip strength (kg)	24.2 ± 8.1 (23.9-24.5)	24.2 ± 8.1 (24-24.5)	37.1 ± 8.3 (36.6-37.3)	>	>
Normalized handgrip strength	0,49 ± 0.19 (0.48-0.50)	0.43 ± 0.16 (0.42-0.43)	0.58 ± 0.2 (0.57-0.59)	>	>

Data are shown as mean ± standard deviation, 95% confidence interval (95% CI). The symbol > in the “sex difference” column, the variable is significantly ($p<0.05$) higher in men than in women. Likewise, the symbol > in the “age trend” column, the variable tends to increase by increases in age.

Overall, handgrip strength was significant higher in men. The handgrip strength and age values were not gaussian-distributed (Panel A and B).

Figure 1. Normal distribution by sex of handgrip strength. Panel A: men; Panel B: women.

A.



B

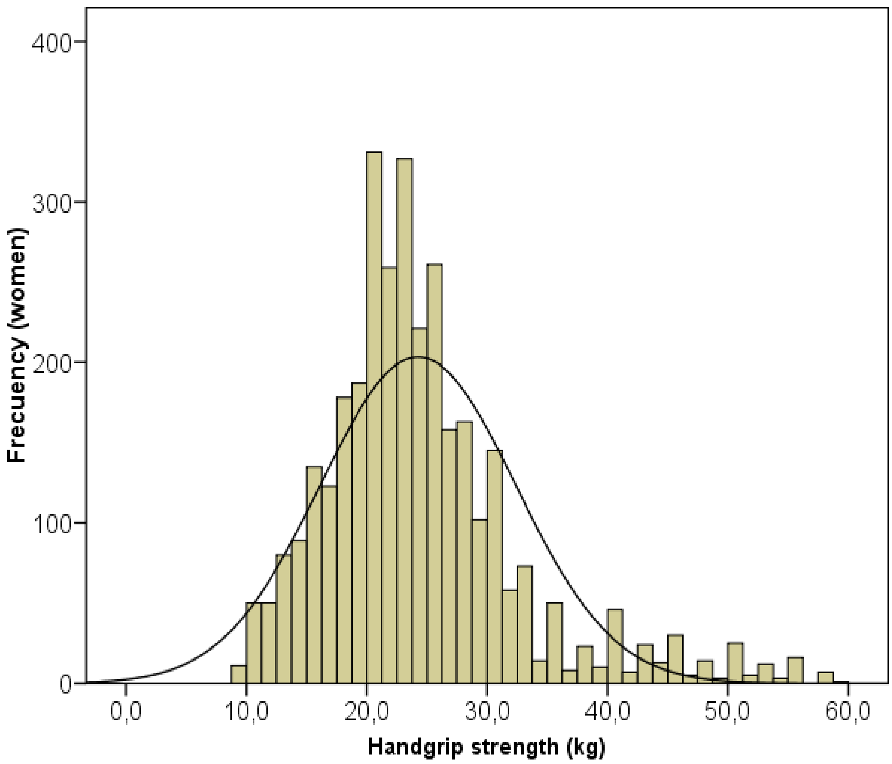


Figure 2, shows the Bland-Altman plot in a sub-sample of 294 subjects (144 men and 150 women) over a 7 day period between test administrations. The limits of agreement (95% confidence intervals) between the measurement 1 and measurement 2 are shown for the right hand (Panel A) the left hand (Panel B) and the average strength (Panel C) by sex. Intrarater reliability was assessed by determining the interclass correlation coefficient (ICC). Agreement between repetitions was observed in each assessment (ICC = 0,562, CI95% 0.443 to 0.645).

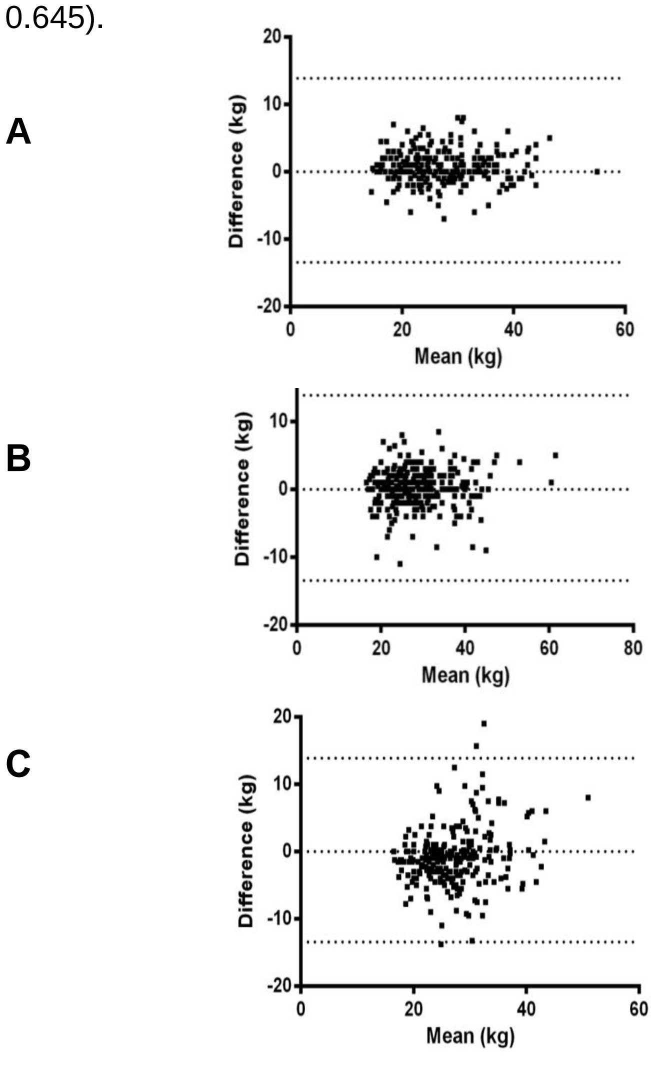


Figure 2. Reliability of weight's trials of handgrip test by Bland-Altman plots (n = 294 subjects). Central line represents mean difference (bias) between dynamometers weight score and know weight. Upper and lower broken lines represent 95% limits of agreement (mean difference ± 1.96 SD of differences). Panel A: right hand test (mean difference 0.238, CI95% -5.241 to 5.719). Panel B: left hand test (mean difference 0.884, CI95% - 3.713 to 5.482). Panel C: average handgrip (mean difference – 1.935, CI95% -17.043 to 13.172).

Tables 2 and 3, show the normative values for handgrip strength in the young adults, classified according to sex and age and expressed in percentiles from 5 to 95. In addition, handgrip strength values increased with age, Table 2-3.

	N	Mean	SD	P3	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{97}
Left handgrip strength (kg)										
18 +	457	35,6	7,2	22,0	25,0	30,5	36,0	41,0	45,0	49,0
19 +	419	35,9	7,5	21,0	25,0	31,0	36,0	41,0	46,0	50,0
20 +	367	36,1	7,6	20,5	25,9	31,0	36,0	41,0	46,6	51,0
21 +	290	36,7	7,7	20,4	27,0	31,0	36,5	42,0	48,0	50,0
22 +	177	36,2	7,1	20,7	26,0	31,3	36,0	41,8	45,0	49,5
23 +	143	37,3	7,2	22,0	27,7	33,0	36,5	42,0	47,0	50,0
24 +	107	35,0	8,0	20,4	22,3	29,3	35,3	41,0	46,0	50,0
25 +	93	37,3	8,2	19,6	26,5	31,9	39,0	43,0	47,0	52,0
26 +	81	38,9	6,8	25,0	30,1	32,0	39,0	45,0	47,0	50,0
27 +	71	36,0	6,1	24,0	30,0	32,5	35,0	39,0	47,0	50,0
28 +	67	34,7	5,7	20,0	26,8	30,8	35,0	39,0	42,0	44,0
29 +	58	34,7	5,7	20,0	26,8	30,8	35,0	39,0	42,0	44,0
Right handgrip strength (kg)										
18 +	457	37,9	7,2	23,8	28,0	33,5	38,0	42,5	47,0	51,8
19 +	419	37,9	7,7	22,0	27,0	33,0	38,5	43,0	48,0	52,5
20 +	367	38,4	7,6	23,9	28,0	33,0	39,0	44,0	49,5	53,0
21 +	290	39,2	7,3	24,0	29,0	34,0	40,0	45,0	48,5	51,5
22 +	177	39,2	7,5	22,0	30,0	34,5	40,0	44,5	49,5	53,0
23 +	143	39,0	7,6	24,0	29,4	34,0	39,0	45,0	50,0	51,7
24 +	107	37,7	8,5	22,0	25,0	32,0	37,5	45,0	50,0	53,3
25 +	93	38,9	8,2	22,1	26,7	33,5	41,0	44,8	49,0	54,8
26 +	81	41,4	6,1	30,0	31,4	38,0	41,0	45,0	49,8	53,5
27 +	71	38,2	6,4	26,0	30,0	33,8	38,0	41,5	49,0	55,0
28 +	67	36,6	6,1	25,0	27,0	31,8	36,5	42,0	44,7	47,0
29 +	58	39,0	8,1	25,0	25,0	34,5	39,5	43,5	54,0	54,0
Average handgrip strength (kg)										
18 +	457	36,8	7,0	23,0	26,7	32,0	37,5	42,0	45,5	49,5
19 +	419	37,3	7,2	22,9	27,6	32,5	37,5	42,0	47,0	50,9
20 +	367	37,3	7,4	21,5	27,5	32,5	37,5	42,4	47,3	51,2
21 +	290	38,2	7,2	24,9	28,9	33,2	38,0	43,0	49,0	50,9
22 +	177	37,5	6,8	21,8	27,9	32,5	37,8	42,9	45,6	49,7
23 +	143	38,4	7,0	23,5	29,0	34,5	38,0	43,0	47,9	50,0
24 +	107	36,3	7,7	22,0	25,8	30,5	37,0	42,5	46,8	50,6
25 +	93	38,9	7,6	21,5	28,7	34,0	40,1	44,0	47,7	52,5
26 +	81	40,0	6,5	26,3	31,6	34,0	40,0	45,5	47,9	50,5
27 +	71	37,1	5,8	25,0	31,0	34,3	36,3	39,9	47,5	50,5
28 +	67	35,9	5,6	21,0	28,0	31,9	36,5	40,0	42,7	44,3

29 +	58	38,2	6,7	27,5	27,5	32,5	39,5	42,4	49,0	49,0
Normalized handgrip strength (kg)										
18 +	457	0,55	0,13	0,30	0,37	0,46	0,55	0,63	0,69	0,79
19 +	419	0,55	0,13	0,30	0,38	0,46	0,55	0,63	0,71	0,81
20 +	367	0,54	0,14	0,27	0,36	0,46	0,55	0,63	0,71	0,82
21 +	290	0,56	0,14	0,30	0,41	0,47	0,56	0,65	0,75	0,85
22 +	177	0,55	0,13	0,26	0,39	0,47	0,56	0,65	0,71	0,77
23 +	143	0,57	0,14	0,28	0,39	0,50	0,56	0,64	0,74	0,89
24 +	107	0,53	0,14	0,27	0,33	0,43	0,53	0,63	0,74	0,81
25 +	93	0,57	0,13	0,30	0,40	0,47	0,59	0,66	0,72	0,77
26 +	81	0,61	0,12	0,39	0,47	0,50	0,61	0,70	0,77	0,93
27 +	71	0,56	0,14	0,26	0,44	0,49	0,54	0,60	0,76	0,97
28 +	67	0,54	0,09	0,32	0,41	0,48	0,54	0,60	0,66	0,69
29 +	58	0,58	0,13	0,40	0,40	0,48	0,59	0,65	0,83	0,83

Table 2. Selected percentiles (P) of tests assessing right hand, left hand, average handgrip and normalized handgrip strength stratified by age categories in men.

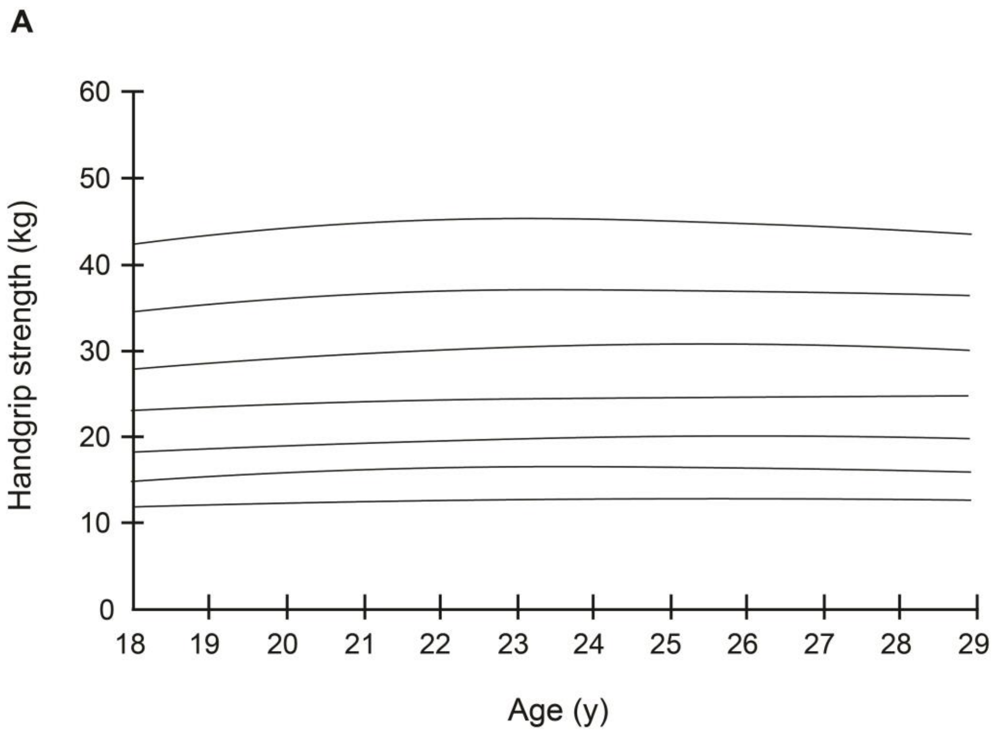
	N	Mean	SD	P3	P_{10}	P_{25}	P_{50}	P_{75}	P_{90}	P_{97}
Left handgrip strength (kg)										
18 +	802	21,3	5,7	11,0	13,7	18,0	21,0	25,0	29,0	32,5
19 +	617	21,5	6,0	11,0	13,0	17,1	22,0	25,0	30,0	33,0
20 +	544	21,9	5,9	10,0	14,0	18,0	21,5	26,0	30,0	32,2
21 +	366	22,6	5,5	12,0	16,0	19,0	22,0	26,8	30,0	33,6
22 +	232	21,9	5,7	10,9	14,0	19,0	21,0	25,3	30,0	33,2
23 +	181	23,1	5,9	11,0	15,0	19,0	23,0	27,0	30,0	35,0
24 +	129	22,3	5,4	11,4	15,0	19,0	22,0	25,0	30,0	33,3
25 +	90	22,8	6,3	10,2	15,0	18,0	23,0	28,0	30,0	35,5
26 +	101	22,2	5,1	12,5	14,2	19,0	21,0	26,0	30,0	32,9
27 +	106	20,8	5,8	10,0	14,4	16,3	20,0	24,0	27,6	37,9
28 +	98	23,8	6,3	12,0	14,5	19,0	24,0	29,5	30,5	35,0
29 +	51	22,6	4,9	16,0	16,3	20,5	22,0	24,0	30,4	37,0
Right handgrip strength (kg)										
18 +	802	23,0	6,2	12,0	15,0	19,5	23,0	26,5	31,0	35,9
19 +	617	23,5	6,7	12,0	15,0	19,0	23,5	27,5	32,0	40,0
20 +	544	23,7	6,4	11,0	15,0	20,0	23,0	28,0	32,0	37,0
21 +	366	24,5	6,0	12,5	18,0	20,0	24,0	29,0	32,0	38,0
22 +	232	23,8	6,5	12,0	15,3	20,0	23,0	27,5	32,0	40,0
23 +	181	24,9	6,4	12,0	17,3	20,0	24,9	29,0	32,7	40,0
24 +	129	24,1	5,8	12,0	17,0	20,3	24,0	26,8	32,0	39,1
25 +	90	25,6	7,6	10,8	16,5	19,9	25,1	31,0	36,5	41,5
26 +	101	24,2	5,6	14,6	15,8	20,0	23,0	28,0	31,8	37,5
27 +	106	24,0	7,8	11,1	15,8	18,5	22,8	27,1	40,0	42,0
28 +	98	25,5	6,4	13,0	16,0	21,0	25,5	30,5	33,0	38,0
29 +	51	25,2	6,5	18,0	18,0	22,1	24,0	26,6	40,0	40,0
Average handgrip strength (kg)										

18 +	802	22,3	5,9	12,0	14,5	18,8	22,3	25,5	30,0	35,0
19 +	617	22,5	6,1	11,9	14,5	18,0	22,5	26,3	30,1	35,0
20 +	544	23,0	6,1	11,0	15,0	19,0	22,5	27,0	31,0	35,7
21 +	366	23,8	5,8	13,0	17,0	20,0	23,3	27,5	31,3	37,5
22 +	232	23,1	6,1	12,0	15,2	20,0	22,0	26,4	31,0	37,5
23 +	181	24,1	6,1	12,2	16,6	20,0	23,8	27,7	31,0	38,5
24 +	129	23,4	5,6	12,5	16,5	20,0	23,3	25,9	31,0	37,7
25 +	90	24,5	7,1	11,0	16,1	19,1	24,4	29,0	32,4	40,0
26 +	101	23,5	5,6	14,1	15,8	20,0	22,3	27,0	30,9	37,6
27 +	106	22,4	6,6	11,5	15,4	17,5	21,4	25,1	31,3	40,7
28 +	98	24,7	6,3	13,0	15,5	20,3	25,0	29,9	32,0	37,5
29 +	51	24,6	6,7	17,0	17,4	21,6	23,3	25,9	39,9	40,8
Normalized handgrip strength (kg)										
18 +	802	0,39	0,11	0,21	0,25	0,32	0,38	0,45	0,51	0,63
19 +	617	0,39	0,11	0,21	0,25	0,31	0,39	0,46	0,52	0,62
20 +	544	0,40	0,11	0,19	0,26	0,32	0,39	0,47	0,54	0,61
21 +	366	0,41	0,11	0,22	0,29	0,34	0,40	0,48	0,54	0,64
22 +	232	0,40	0,11	0,21	0,27	0,34	0,38	0,46	0,54	0,67
23 +	181	0,42	0,11	0,21	0,28	0,34	0,41	0,48	0,54	0,68
24 +	129	0,41	0,10	0,22	0,28	0,34	0,40	0,45	0,54	0,70
25 +	90	0,42	0,13	0,19	0,27	0,32	0,42	0,50	0,57	0,75
26 +	101	0,40	0,09	0,25	0,27	0,34	0,38	0,46	0,53	0,62
27 +	106	0,38	0,11	0,20	0,27	0,30	0,36	0,43	0,49	0,72
28 +	98	0,43	0,12	0,23	0,27	0,35	0,43	0,52	0,56	0,69
29 +	51	0,41	0,10	0,29	0,30	0,37	0,40	0,43	0,56	0,71

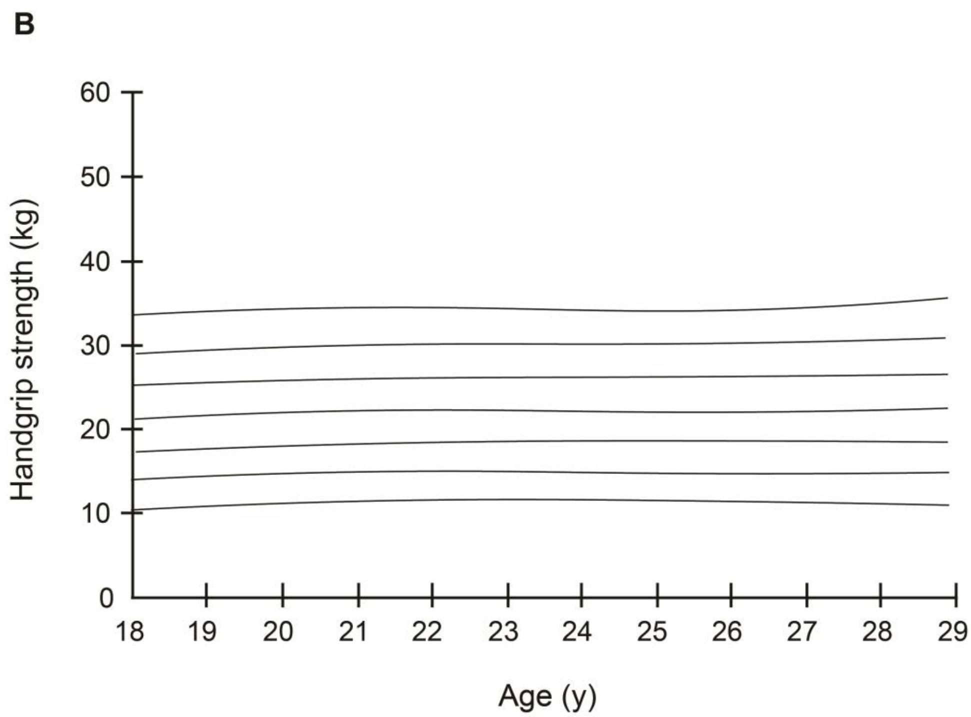
Table 3. Selected percentiles (P) of tests assessing right hand, left hand, average handgrip and normalized handgrip strength stratified by age categories in women.

Figures 3-4 show smoothed centile curves (P_3, P_{10}, P_{25}, P_{50}, P_{75}, P_{90} and P_{97}) for handgrip strength according to sex and age categories. The figures show that handgrip strength is higher and generally more homogenous in men than women.

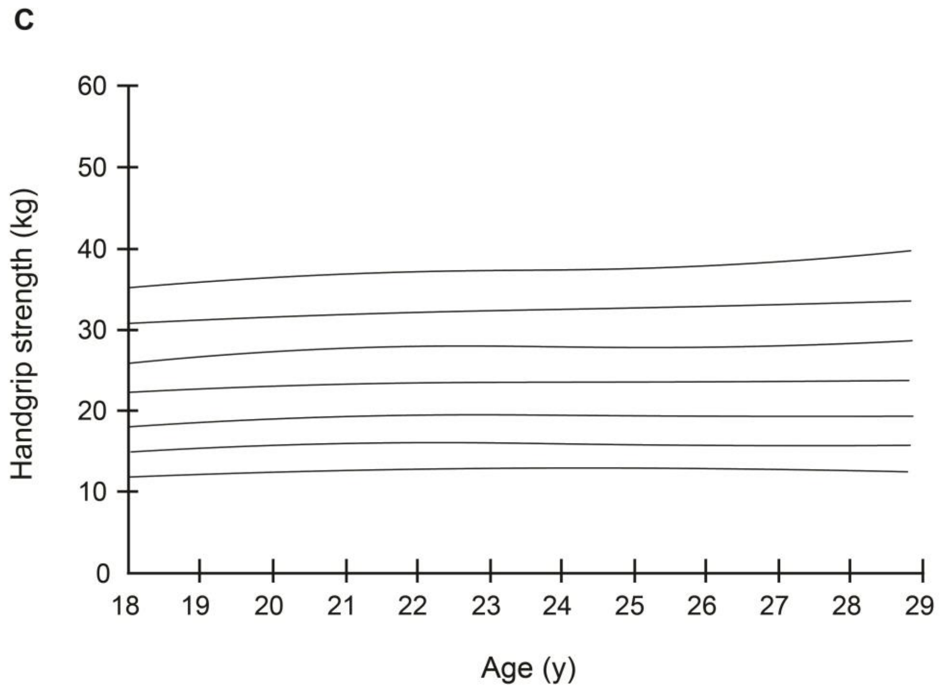
Figure 3



A. Right Grip strength test



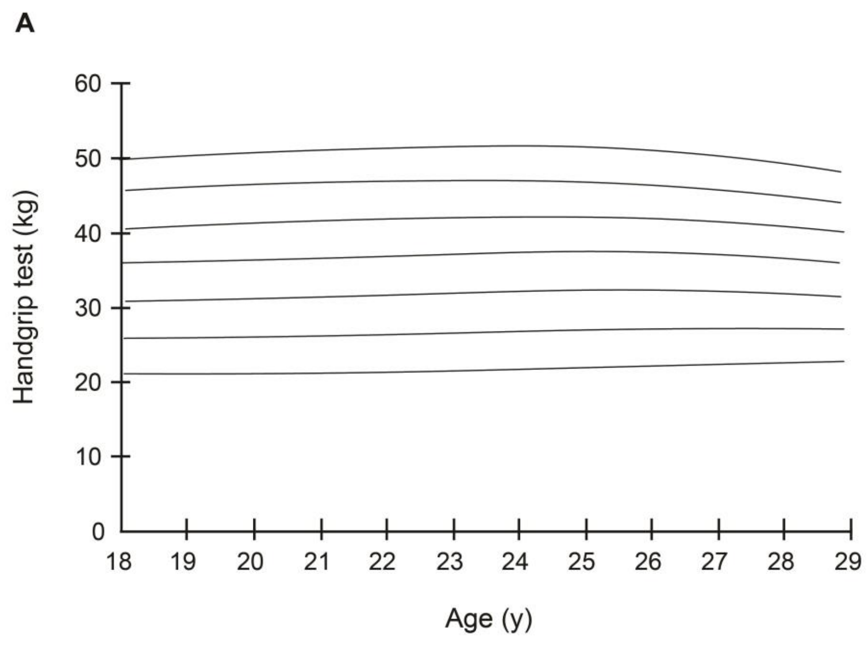
B. Left Grip strength test



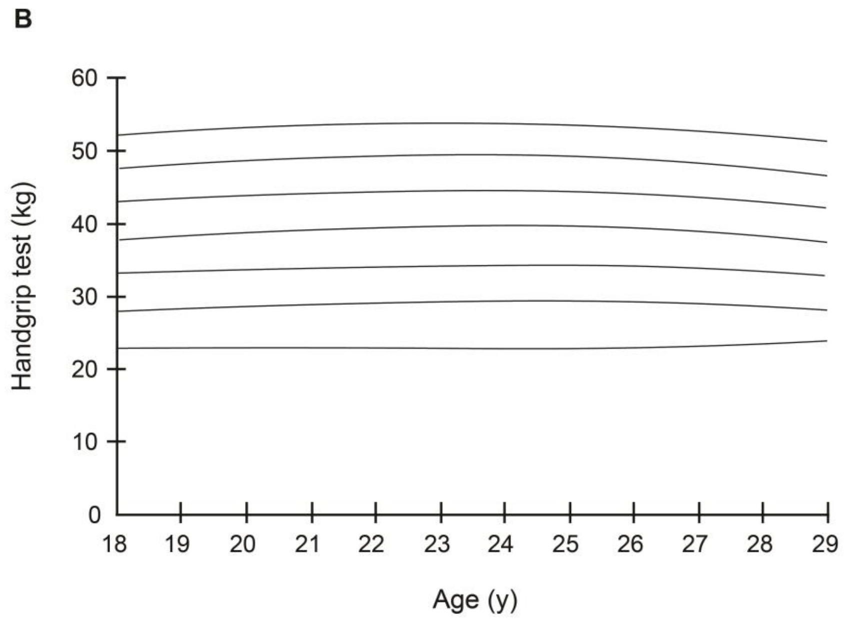
C. Average hand grip test.

Figure 3. Smoothed (LMS method) centile curves (from the bottom to the top: P_3, P_{10}, P_{25}, P_{50}, P_{75}, P_{90} and P_{97}) of handgrip strength in men tests assessing right hand maximal strength, left hand maximal strength, average handgrip maximal strength and normalized handgrip strength.

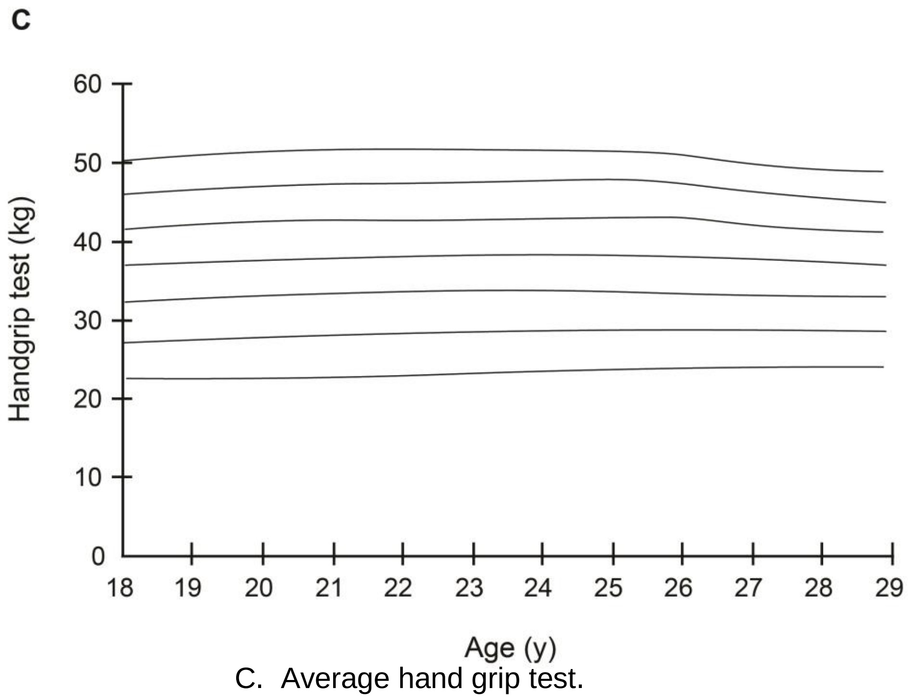
Figure 4.



A. Right Grip strength test



B. Left Grip strength



C. Average hand grip test.

Figure 4. Smoothed (LMS method) centile curves (from the bottom to the top: P_3, P_{10}, P_{25}, P_{50}, P_{75}, P_{90} and P_{97}) of handgrip strength in women tests assessing right hand maximal strength, left hand maximal strength, average handgrip maximal strength and normalized handgrip strength.

Discussion

The main objective of this study was to establish age and sex reference values for handgrip strength among healthy young Colombian adults and to compare values across the age range sampled. Our findings in this population confirm the common finding of higher HGS in adult males compared with adult female subjects reported internationally[2,13-23]. Greater height and body mass in men (particularly lean body mass), both strong correlates of HGS[5,6,] are the principle explanations for these differences. Furthermore, recreational physical activity levels are also positively associated with HGS and are generally lower in women[19]. Also in accordance with previous studies are the right hand *vs.* left hand strength differences observed by Mathiowetz et al.[13,15]

Several previous reports suggest that HGS peaks in early adulthood and declines progressively after the third decade of life[1,11,13,25,26]. Normative data for grip strength are usually presented notable format or as centile curves as a function of age[13-23]. Across the age categories sampled in the present study, the highest values were slightly lower than two relatively recent studies of HGS in Brazilian men aged 18-30[20] and 20-29[21] respectively, and Italian University students[22] and substantially lower than reported for Danish men aged 19-29[19]. In contrast, mean values among women in the present study were similar to Montalcini et al.[22] and Schlussel et al.[21], slightly lower than Aadahl et al.[19] and slightly higher than Budziarek et al.[20] than the means reported in these studies.

While international comparisons of HGS using the same methodology are lacking, varying values for HGS in different regions and ethnicities are evident [23,24]. These may be accounted for anthropometric differences[13-23], such as height and body composition, which vary between populations and ethnicities[19-

[23,25] and are important determinants of HGS[19-26]. In addition, “Epigenetic” factors such as early life social conditions[25] and birthweight [26,27] are also associated with HGS, making it difficult to draw conclusions about the source of ostensibly international or inter-ethnic differences[19-26], particularly if potential differences in the socioeconomic background of the sample are not taken into consideration.

Methodological differences, such as associated with the specific dynamometer used, the measurement protocol or the summary data (i.e mean or peak values) reported may also contribute to variations in reported values and may also make comparisons of normative data difficult to interpret[13-23]. Systematic bias has been reported when comparing different dynamometers[18] while, differences in joint and body position modulate force output in the handgrip test[28] .

Amongst the substantial normative handgrip strength publications[13-23,25,29], few summarise data obtained with instrumentation, procedures or measures recommended by the ASHT[18]. Standardisation is important in order to allow valid comparisons within or between countries, for the assessment of longitudinal or secular trends and to be able to reliably detect poor strength in the clinical setting and identify individuals who may gain particular benefit from interventions. However, the maximum value among these trials has commonly been used by many previous researchers[13-26], and the US National Health and Nutrition Survey (NHANES) will report the maximum of the left and right combined[29]. Similarly, assessment with the elbow extended is a position which results in higher force output and is used in a number of studies of HGS of strength and health in youth fitness test batteries[29].

These studies tend to use age bands of 10 years or larger, making it difficult to identify the age at which peak grip strength is attained or when the most significant or largest declines in handgrip strength occur[11,19.] In order to evaluate age related changes across young adulthood, as well as to establish age-related reference values in adults more precisely we assessed and compared HGS between relatively narrow age bands. We observed that the right and the left handgrip strength in 27 to 29 year old men was significantly lower than those of men aged 18 to 20 (Table 2) but not those of the intermediate age category (x to Y). Similarly, women aged 21 to 23 ,showed significantly higher levels of mean strength compared with those in the age groups (18 to 29 years), and their left hand grip scores were lower than those in the younger groups, from 18 to 20 years, although they were stronger than those in the older group (27 to 29 years) (Table 3). These findings appear to suggest the attainment of peak HGS in the middle of the third decade and evidence of strength decline in the current population at an earlier age than reported in a number of previous cross-sectional studies[11,19]. This finding needs however to be interpreted with caution since the present study is not longitudinal and as such may also reflect secular changes in muscle strength which have been reported internationally[19]. There is also limited contemporary data with which to compare the present findings, and few span the late adolescent and 3rd decade of life with HGS data generally reported for age bands of 10 years or more. Recent data in a representative sample of Brazilian adults (n=3.050) mean HGS was higher in the 30-39 compared to the 20-29 age category, with lower values observed from aged 40 and beyond[21,23]. Similarly, in a population based sample of Danish adults (n =3.471) mean values in 30-39 year olds were higher than those aged 20-29, with peak values reached in the 30-39 age category in women and 40-49 in men, with declines evident thereafter[19]. In this context, our findings of declining HGS during the third decade, which only appears to concur with a study in a sample of 300 Brazilian adults (Budziareck et al.)[20] that observed a significant reduction in HGS each decade after age 21, should be confirmed in a larger and more representative sample of Colombian adults.

Correct interpretation of HGS data requires comparing the score obtained in a particular person with normative values for the general population with the same sex and age[19,21-23]. Despite the lack of a universal clinical cut-point for HGS, the utility of handgrip strength as an auxiliary procedure to assess the nutritional status in clinical practice is evident[1,11]. Klidjian et al.[30] used the value equal to 85% of handgrip strength mean values observed in a healthy sample as the cut-off point to identify the patients at elevated risk of complications in the post-surgical period. Despite it's non ‘‘physiologic rationale’’ this cut-point was very useful clinically and HGS was the most sensitive of a number of functional tests in the prediction of complications[1]. Poor HGS has also been shown to be related to the current cardiometabolic health in youth and adults and risk of future morbidity and mortality[31] and in most of these studies[2-9], the lower tertile or quartile was associated with elevated risk. On this basis, the 20th or 25 percentile curves obtained in this study could be used as a cut-point, below which the level of handgrip strength can be considered inadequate [32] Norman et al.[11] showed that patients who presented HGS values in the lowest quartiles 1 and 2 of the sample distribution at admission were at increased risk of being nutritionally-at-risk.

Limitations

A limitation of this study was that the participants were recruited from three universities in two cities, which may affect generalizability of our results to the Colombian population as whole. The present study sample was compared to corresponding cohorts of 18–30-year old university students in the Colombian national data registry (DANE: Departamento Administrativo Nacional de Estadistica) for the years 2010 to 2012 for age, education and place of residence. It was determined that the present sample was not fully representative due to the underrepresentation of individuals from the central region of the country. Therefore, additional work is needed to more fully characterise HGS within the Colombian population and to identify population-specific cut-points for "healthy"/ "adequate" HGS and for other components of muscular fitness, ideally combined with evaluation of markers or nutritional or cardiometabolic health or prospectively with clinical outcomes[1,11]. It is important to note that despite the common use of handgrip strength as a tool for assessment of muscle function in clinical settings, and its considerable attention as an indicator both of current nutrition status and cardiometabolic health and future risk of morbidity and mortality[1-11]. Few these studies examining these associations have included people from Latin American populations[10,11].

Future research

The new preliminary normative values for handgrip strength in men and women aged 18 to 29 years will be useful in clinical practice. However, our study might open the way to the diffusion of the handgrip strength assessment for more clinical use, and it might be useful to identify people who could benefit from early nutritional or pharmacological programs[33].

Conclusion

This study presents age-, gender- and side specific reference values for handgrip strength for young Colombian or Latin-American adults. The norms can be used in lieu of more limited data previously available from individual studies in smaller samples.

Competing interests

No author had any conflict of interest.

Acknowledgements

The authors would like to acknowledge Universidad Santo Tomas for the financial support to the GICAEDS Group (Grant N. FODEIN-USTA 2014 Nº 2013004).

Reference

1. Flood A, Chung A, Parker H, Kearns V, O'Sullivan TA: **The use of hand grip strength as a predictor of nutrition status in hospital patients.** *Clin Nutr* 2014, **33**:106-114.
2. Rantanen T, Guralnik JM, Foley D, Masaki K, Leveille S, Curb JD, White L: **Midlife hand-grip strength as a predictor of old age disability.** *JAMA* 1999, **281**:558-560.
3. Al Snih S, Markides KS, Ray L, Ostir GV, Goodwin JS: **Handgrip strength and mortality in older Mexican Americans.** *J Am Geriatr Soc* 2002, **50**:1250-1256.
4. Ortega FB, Silventoinen K, Tynelius P, Rasmussen F: **Muscular strength in male adolescents and premature death: cohort study of one million participants.** *BMJ* 2012, **20**;345:e7279.
5. 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**:110-118.

6. Rantanen T, Harris T, Leveille SG, Visser M, Foley D, Masaki K, Guralnik JM: **Muscle strength and body mass index as long-term predictors of mortality in initially healthy men.** *J Gerontol A Biol Sci Med Sci* 2000, **55**:M168-173.
7. Gale CR, Martyn CN, Cooper C, Sayer AA: **Grip strength, body composition, and mortality.** *Int J Epidemiol* 2007, **36**:228-235.
8. Lopez-Jaramillo P, Cohen DD, Gómez-Arbeláez D, Bosch J, Dyal L, Yusuf S, Gerstein HC; for the ORIGIN Trial Investigators. **Association of handgrip strength to cardiovascular mortality in pre-diabetic and diabetic patients: A subanalysis of the ORIGIN trial.** *Int J Cardiol.* 2014;174:458-461.
9. Matos CM, Silva LF, Santana LD, Santos LS, Protásio BM, Rocha MT, Ferreira VL, Azevedo MF, Martins MT, Lopes GB, Lopes AA: **Handgrip strength at baseline and mortality risk in a cohort of women and men on hemodialysis: a 4-year study.** *J Ren Nutr* 2014, **24**:157-162.
10. Timpka S, Petersson IF, Zhou C, Englund M: **Muscle strength in adolescent men and risk of cardiovascular disease events and mortality in middle age: a prospective cohort study.** *BMC Medicine* 2014, **12**:62.
11. Norman K, Stobaus N, Gonzalez MC, Schulzke J-D, Pirlich M: **Hand grip strength: outcome predictor and marker of nutritional status.** *Clin Nutr* 2010, **30**:135-142.
12. Angst F, Drerup S, Werle S, Herren DB, Simmen BR, Goldhahn J: **Prediction of grip and key pinch strength in 978 healthy subjects.** *BMC Musculoskelet Disord* 2010, **11**:94.
13. Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S: **Grip and pinch strength: normative data for adults.** *Arch Phys Med Rehabil* 1985, **66**:69-72.

14. Günther CM, Bürger A, Rickert M, Crispin A, Schulz CU: Grip strength in healthy Caucasian adults: reference values. *J Hand Surg Am* 2008, **33**:558-565.

15. Mathiowetz V, Kashman N, Volland G, Weber K, Dowe M, Rogers S: Grip and pinch strength: normative data for adults. *Arch Phys Med Rehabil* 1985, **66**:69-74.

16. Desrosiers J, Bravo G, Herbert R, Dutil E: **Normative data for the grip strength of elderly men and women.** Am J Occup Ther 1995, **49**:637-644.

17. Hanten WP, Chen WY, Austin AA, Brooks RE, Carter HC, Law CA, Morgan MK, Sanders DJ, Swan CA, Vanderslice AL: Maximum grip strength in normal subjects from 20 to 64 years of age. *J Hand Ther* 1999, **12**:193-200.

18. Fess EE. Grip strength. In: Casanova JS, editor. **Clinical assessment recommendations.** 2nd ed. Chicago: *American Society of Hand Therapists*, **1992**. p. 41–5.

19. Aadahl M, Beyer N, Linneberg A, Thuesen BH, Jørgensen T: **Grip strength and lower limb extension power in 19–72-year-old Danish men and women: the Health 2006 study.** *BMJ Open* 2011, **1**:e000192.

20. Budziareck MB, Pureza Duarte RR, Barbosa-Silva MC: **Reference values and determinants for handgrip strength in healthy subjects.** *Clin Nutr* 2008, **27**:357-362.

21. Schlüssel MM, dos Anjos LA, de Vasconcellos MT, Kac G: **Reference values of handgrip dynamometry of healthy adults: A population-based study.** *Clin Nutr* 2008, **27**:601-607.

22. Montalcini T, Migliaccio V, Yvelise F, Rotundo S, Mazza E, Liberato A, Pujia A: **Reference values for handgrip strength in young people of both sexes.** *Endocrine* 2013, **43**:342-345.

23. Forrest KY, Bunker CH, Sheu Y, Wheeler VW, Patrick AL, Zmuda JM: **Patterns and correlates of grip strength change with age in Afro-Caribbean men.** *Age Ageing* 2012, **41**:326-332.

24. Triana-Reina HR, Ramírez-Vélez R: **Association of muscle strength with early markers of cardiovascular risk in sedentary adults.** *Endocrinol Nutr* 2013, **60**:433-438.

25. Spruit MA, Sillen MJ, Groenen MT, Wouters EF, Franssen FM: **New normative values for handgrip strength: results from the UK Biobank.** *J Am Med Dir Assoc* 2013, **14**:775.e5-11.

26. Birnie K, Cooper R, Martin RM, Kuh D, Sayer AA, Alvarado BE; HALCyon study team: **Childhood socioeconomic position and objectively measured physical capability levels in adulthood: a systematic review and meta-analysis.** *PLoS One* 2011, **6**:e15564.

27. Moura-Dos-Santos M, Wellington-Barros J, Brito-Almeida M, Manhães-de-Castro R, Maia J, Góis Leandro C: **Permanent deficits in handgrip strength and running speed performance in low birth weight children.** *Am J Hum Biol* 2013, **25**:58-62.

28. España-Romero V, Ortega FB, Vicente-Rodríguez G, Artero EG, Rey JP, Ruiz JR: **Elbow position affects handgrip strength in adolescents: validity and reliability of Jamar, DynEx, and TKK dynamometers***. J Strength Cond Res* 2010, **24**:272-277.

29. The NHANES muscle strength http://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/Muscle_Strength_Proc_Manual.pdf

30. Klidjian AM, Foster KJ, Kammerling RM, Cooper A, Karran SJ: **Relation of anthropometric and dynamometric variables to serious postoperative complications.** *BMJ* 1980, **281**:899e901.

31. Cheung CL, Nguyen US, Au E, Tan KC, Kung A: **Association of handgrip strength with chronic diseases and multimorbidity: a cross-sectional study.** Age (Dordr) 2012, [Epub ahead of print].

32. Artero EG, Lee DC, Ruiz JR: **A prospective study of muscular strength and all-cause mortality in men with hypertension.** J Am Coll Cardiol 2011, **57**:1831-1837.

33. Montalcini T, Migliaccio V, Yvelise F, Rotundo S, Mazza E, Liberato A, Pujia A: **Reference values for handgrip strength in young people of both sexes.** Endocrine. 2013;43:342-345.