Normative Reference Values for Handgrip Strength in Colombian Schoolchildren: The FUPRECOL Study

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[1]*Center of Studies in Physical Activity Measurements, School of Medicine and Health Sciences, University of Rosario, Bogotá, Colombia;* [2]*Hubert Department of Global Health, Rollins School of Public Health, Emory University, Atlanta, Georgia; and* [3]*Department of Health Sciences, Public University of Navarre, Navarra, Spain*

Abstract

Ramírez-Vélez, R, Morales, O, Peña-Ibagon, JC, Palacios-López, A, Prieto-Benavides, DH, Vivas, A, Correa-Bautista, JE, Lobelo, F, Alonso-Martínez, AM, and Izquierdo, M. Normative reference values for handgrip strength in Colombian schoolchildren: the FUPRECOL study. *J Strength Cond Res* 31(1): 217–226, 2017—The primary aim of this study was to generate normative handgrip (HG) strength data for 10 to 17.9 year olds. The secondary aim was to determine the relative proportion of Colombian children and adolescents that fall into established Health Benefit Zones (HBZ). This cross-sectional study enrolled 7,268 schoolchildren (boys $n = 3,129$ and girls $n = 4,139$, age 12.7 [2.4] years). Handgrip was measured using a hand dynamometer with an adjustable grip. Five HBZs (Needs Improvement, Fair, Good, Very Good, and Excellent) have been established that correspond to combined HG. Centile smoothed curves, percentile, and tables for the third, 10th, 25th, 50th, 75th, 90th, and 97th percentile were calculated using Cole's LMS method. Handgrip peaked in the sample at 22.2 (8.9) kg in boys and 18.5 (5.5) kg in girls. The increase in HG was greater for boys than for girls, but the peak HG was lower in girls than in boys. The HBZ data indicated that a higher overall percentage of boys than girls at each age group fell into the "Needs Improvement" zone, with differences particularly pronounced during adolescence. Our results provide, for the first time, sex- and age-specific HG reference standards for Colombian schoolchildren aged 9–17.9 years.

Key Words grip, percentile, normative data, muscle strength

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Introduction

Low muscular fitness (MF), as determined with a handgrip dynamometer, is recognized as a marker of poor metabolic profile during adolescence (11) and is associated with disease and mortality in adulthood (12,24,28). Most current studies support an inverse relationship between MF and cardiovascular disease risk factors in youth, generally expressing muscular strength in relative terms (14,23). For example, Ruiz et al. (23) reported in a systematic review the relationship between MF and health outcomes, particularly in overweight and obese children. Ortega et al. (11) indicated that lower-body MF was inversely related to abdominal adiposity and that a composite strength score (with handgrip, standing broad jump, and an indicator of muscle endurance) was related to a positive lipid profile and improved glucose levels in female adolescents. Steene-Johannessen et al. (30) reported that independent of adiposity and cardiorespiratory fitness, higher MF was associated with lower levels of chronic inflammation markers, such as C reactive protein, leptin, and TNF-α, that promote systemic low-grade inflammation (3,4).

The clinical examination as well as MF and handgrip (HG) measurements are described in detail by Ruiz et al. (23) and Ortega et al. (10), respectively. The term "MF" has been used to represent muscular strength, local muscular endurance, and muscular power (16). Typically, HG strength can be measured using relatively inexpensive, portable, and easy-to-use dynamometers and is a reliable and valid method for strength assessment (4,19,29). Collective MF can be assessed using various strength performance tests such as HG, explosive lower-limb power (jumps), and muscular endurance (sit-ups)

Table 1. Characteristics of population (mean [*SD*] or frequencies [%]).*

Sex	*n*	Body mass (kg)	Height (cm)	BMI ($kg \cdot m^{-2}$)	Handgrip strength (kg)	Normalized grip strength
Boys						
9–9.9	217	32.1 (7.5)	133.5 (6.5)	17.8 (3.1)	13.4 (3.8)†	0.41 (0.12)†
10–10.9	403	34.5 (8.5)	137.3 (7.4)‡	18.1 (3.3)	14.5 (4.1)†	0.42 (0.11)†
11–11.9	412	37.2 (8.8)‡	141.9 (8.2)‡	18.3 (3.2)	15.9 (3.9)†	0.43 (0.10)†
12–12.9	374	41.3 (9.1)‡	147.1 (8.2)‡	18.9 (3.2)	18.1 (4.8)†	0.44 (0.09)†
13–13.9	388	46.0 (9.8)‡	153.5 (9.3)‡	19.4 (3.3)†	22.2 (5.9)†	0.47 (0.10)†
14–14.9	415	50.0 (9.7)‡	158.9 (9.1)†	19.7 (3.0)†	24.5 (6.9)†	0.47 (0.10)†
15–15.9	374	54.4 (9.7)‡	163.3 (8.9)†	20.3 (3.0)†	28.8 (8.2)†	0.54 (0.12)†
16–16.9	319	57.7 (8.7)†	166.7 (7.2)†	20.8 (2.9)†	31.1 (8.0)†	0.55 (0.11)†
17–17.9	227	60.8 (10.3)†	168.1 (7.4)†	21.5 (3.3)†	32.7 (7.0)†	0.55 (0.11)†
Total	3,129	45.5 (13.0)‡	151.9 (14.1)†	19.4 (3.3)†	22.2 (9.0)†	0.48 (0.12)†
Girls						
9–9.9	277	32.1 (7.4)	134.6 (7.6)	17.6 (3.0)	13.0 (3.9)	0.39 (0.09)
10–10.9	618	35.0 (7.9)	138.4 (7.6)	18.1 (3.0)	13.9 (3.6)	0.38 (0.09)
11–11.9	620	38.3 (7.9)	143.7 (7.5)	18.4 (2.9)	15.6 (3.7)	0.41 (0.09)
12–12.9	491	42.8 (8.6)	148.5 (7.3)	19.3 (3.0)	18.3 (4.3)	0.42 (0.08)
13–13.9	457	47.4 (9.0)	152.4 (6.3)	20.3 (3.2)	19.8 (4.7)	0.42 (0.09)
14–14.9	592	51.0 (8.9)	154.6 (6.5)	21.3 (3.3)	21.6 (4.8)	0.42 (0.09)
15–15.9	441	52.7 (8.6)	155.7 (6.8)	21.7 (3.1)	22.1 (5.3)	0.42 (0.09)
16–16.9	393	53.9 (8.6)	156.4 (5.8)	22.0 (3.1)	22.9 (5.1)	0.42 (0.08)
17–17.9	250	55.1 (9.3)	156.8 (6.5)	22.4 (3.6)	23.9 (5.3)	0.43 (0.10)
Total	4,139	44.8 (11.5)	148.7 (10.1)	20.0 (3.5)	18.5 (5.6)	0.41 (0.09)

*BMI = body mass index.
†Significant between-sex differences by a 2-way analysis of variance (ANOVA) test $p < 0.01$.
‡Significant between-sex differences by a 2-way ANOVA test $p < 0.001$.

(3,4). However, Sex-age-specific normative values for HG in young people have been published (1,10,13,14,25,26). However, the majority of published HG reference values are for schoolchildren from high income countries in North America (14) and Europe (4,9). In contrast, there is a scarcity of reference values for children using harmonized measures of fitness in Latin America and other low-middle income countries (LMICs) undergoing nutritional transitions, making it impossible to evaluate secular trends within these regions (24).

From a public health perspective, the inclusion of HG in health surveillance systems is therefore clearly justifiable, and schools may be an ideal setting for monitoring youth fitness to identify those with poor strength (17,20,24). There are no such data available for school-aged Colombian adolescents and children. Therefore, the primary aim of this study was to generate normative handgrip strength (HG) data for 10 to 17.9 year olds. The secondary aim was to determine the relative proportion of Colombian children and adolescents that fall into established Health Benefit Zones (HBZ).

Methods

Experimental Approach to the Problem

This is a secondary analysis of a cross-sectional study, published elsewhere (17,20,24). Briefly, this study aimed to examine relationships between physical fitness levels in children and adolescents with cardiometabolic risk factors and (un)healthy habits. During the 2014–2015 school year, we conducted a cross-sectional component of the FUPRECOL study (17,20,24).

Subjects

The sample comprised 7,268 healthy Colombian schoolchildren (boys $n = 3{,}129$ and girls $n = 4{,}139$, mean ± [*SD*], age 12.7 [2.4] years, weight 44.5 [12.3] kg, height 1.49 [0.1] m, body mass index [BMI] 19.7 [3.6] $kg \cdot m^{-2}$). The schoolchildren were of low-middle socioeconomic status (1–3 defined by the Colombian government) and enrolled in public elementary and high schools (grades 5 and 11) in the capital district of Bogota in a municipality in the Cundinamarca Department in the Andean region. A convenience sample of volunteers was included and grouped by sex and age with 1-year increments (a total of 9 groups). Power calculations were based on the mean of HG from the first 150 participants in the ongoing data collection (range, 25–35 kg), with a group *SD* of approximately 9.9 kg. The significance level was set to 0.05, and the required power was set to at least 0.80. The sample size was estimated to be approximately 150–200 participants per group. Exclusion factors

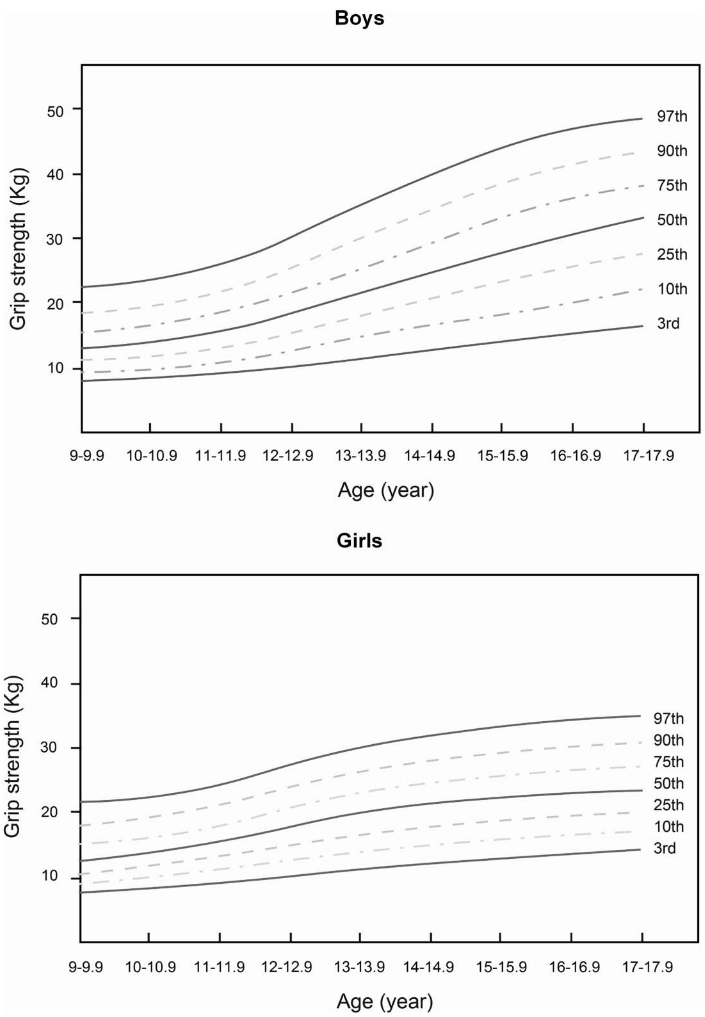

Figure 1. Centile curves for handgrip strength (kg) in Colombian children and adolescents by sex and age.

were a clinical diagnosis of cardiovascular disease, diabetes mellitus 1 and 2, pregnancy, the use of alcohol or drugs, and, in general, the presence of any disease not directly associated with nutrition. Exclusion from the study was made effective a posteriori, without the students being aware of it, to avoid any undesired situations.

The study was approved by the institutional review board for use of human subject research in addition to the Rosario University Board (Code No. CEI-ABN026-000262). Potential subjects and their parents or guardian (s) were informed of the purpose, benefits, and potential risks of the study, and then provided written informed consent to participate. The protocol was in accordance with the latest revision of the Declaration of Helsinki (as revised in Hong Kong in 1989 and in Edinburgh, Scotland, in 2000) and current Colombian laws governing clinical research on human subjects (Resolution 008430/1993 Ministry of health).

Procedures

Anthropometrics variables were measured by a level 2 anthropometrist certified by the International Society for the Advancement of Kinanthropometry (ISAK), in accordance with the ISAK guidelines (8), in the morning after an overnight fast, at the same time (7:00–10:00 AM). Body weight of subjects in underwear and with no shoes were measured using electronic scales (Tanita BF-689; Tanita Corporation, Tokyo, Japan) with a low technical error of measurement (TEM = 0.510%). Height was measured using a mechanical stadiometer platform (TEM = 0.019%, Seca 274; Hamburg, Germany). The BMI was calculated as the body weight in kilograms divided by the square of height in meters. Waist circumference was measured at the midpoint between the last rib and the iliac crest using a tape measure (TEM = 0.086%, Ohaus 8004-MA; Ohaus Corporation, Parsippany, NJ, USA) (24). The data were recorded on paper by the FUPRECOL evaluators (17).

Handgrip was measured using a standard adjustable handle Takei Digital Grip Strength Dynamometer Model T.K.K.540 (Takei Scientific Instruments Co., Ltd, Niigata, Japan). Pupils were given a brief demonstration and verbal instructions for the test, and, if necessary, the dynamometer was adjusted to the child's hand size according to predetermined protocols (17). Handgrip was measured with the subject in a standing position with the shoulder adducted and neutrally rotated and arms parallel but not in contact with the body. The participants were asked to squeeze the handle for a maximum of 3–5 seconds, and no verbal encouragement was given during the test. Two trials were allowed in each limb and the average score recorded the peak grip strength (kg). Thus, the HG values presented here

Table 2. Mean, *SD*, and percentile distribution of handgrip strength (kg) in Colombian children and adolescents by sex and age.

	n	Mean	*SD*	3rd	10th	25th	50th	70th	90th	97th
Boys										
9–9.9	217	13.4	3.8	7.9	9.4	11.1	12.9	15.1	17.3	20.1
10–10.9	403	14.5	4.1	8.3	10.1	11.7	14.1	16.5	18.9	22.6
11–11.9	412	15.9	3.9	9.4	11.1	13.2	15.6	18.3	21.1	25.0
12–12.9	374	18.1	4.8	9.8	12.8	15.0	17.5	20.8	24.6	28.1
13–13.9	388	22.2	5.9	13.2	15.6	18.2	21.1	25.2	30.6	36.6
14–14.9	415	24.5	6.9	12.8	16.3	19.4	23.8	29.0	33.4	40.7
15–15.9	374	28.8	8.2	12.3	18.3	23.1	28.5	34.7	39.5	42.8
16–16.9	319	31.1	8.0	16.5	20.1	24.9	31.1	36.1	41.5	47.3
17–17.9	227	32.7	7.0	16.7	22.4	28.8	33.5	37.2	41.1	45.7
Total	3,129	22.2	9.0	9.8	11.9	15.2	20.2	28.6	35.5	41.4
Girls										
9–9.9	277	13.0	3.9	7.4	8.7	10.6	12.7	15.2	17.1	20.6
10–10.9	618	13.9	3.6	8.1	9.8	11.6	13.4	15.8	18.6	21.9
11–11.9	620	15.6	3.7	9.5	10.9	12.9	15.3	17.7	20.5	23.6
12–12.9	491	18.3	4.3	10.7	12.7	15.4	18.1	21.1	23.5	26.0
13–13.9	457	19.8	4.7	10.4	13.7	16.6	19.5	23.3	25.7	28.6
14–14.9	592	21.6	4.8	12.8	15.5	18.2	21.9	24.5	27.3	30.7
15–15.9	441	22.1	5.3	12.1	16.3	18.7	21.5	25.2	28.8	33.5
16–16.9	393	22.9	5.1	13.6	17.1	19.6	22.7	25.9	28.5	33.4
17–17.9	250	23.9	5.3	14.5	17.9	20.8	23.3	26.4	30.9	36.9
Total	4,139	18.5	5.6	9.5	11.5	14.3	18.2	22.3	25.5	29.1

Maximal contraction on each hand (over 2 trials each) was summed to yield combined handgrip (kg) used to identify the age and sex.

combine the results of left- and right-handed subjects, without consideration for hand dominance. Because there is substantial covariance between strength capacity and body mass–and, moreover, the links between muscle strength and both physical function and chronic health are mediated by the proportion of strength relative to body mass–grip strength was normalized as strength per body mass (i.e., [grip strength in kg]/[body mass in kg]). All of the personnel were trained in testing and calibration procedures, and a calibration log was maintained. The systematic error when the HG assessments were performed twice was 0.508 (95% confidence interval = −3.078 to 4.094%; $n = 207$) (17).

Five HBZs (Needs Improvement, Fair, Good, Very Good, and Excellent) have been established that correspond to combined-hand grip strength for boys and girls aged 9–17.9 years (1,9,13). Health Benefit Zones reflect the combination of quintiles derived from European approaches based on the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) (9), Australians normative health-related fitness values for children (1), and NHANES (National Health and Nutrition Examination Survey) 2011–2012 (13,14) studies and estimate benefits associated with achieving a specified HG strength relative to sex and age. Criteria underpinning specific HBZ cut points were not provided (9). Recently, Perna et al. (9) reported that increased health risks are reportedly associated with musculoskeletal strength in the "Needs improvement" zone, both risks and benefits for scores in the "Fair" zone, benefits in the "Good" zone, and considerable or optimal benefits for grip strength in the "Very Good" and "Excellent" zones. For example, Perna et al. (9) indicated that an HG < 21 kg has been associated with an 8-fold risk of developing muscular disabilities as an older adult, and poor grip strength has been associated with adverse weight gain among women and mortality among men. In young people, movement from the first 2 zones into the "Good" zone is inversely associated with cardiometabolic risk factors, such as the Homeostasis Model Assessment (HOMA) index, triglycerides, blood pressure, and inflammatory markers such as C reactive protein and TNF-α (7,16,30).

Statistical Analyses

We used SPSS V. 21.0 software for Windows (SPSS, Chicago, IL, USA) for all but LMS method calculations. Anthropometric and HG characteristics from the study sample are presented as the mean with *SD*. Normality for selected variables was verified using histograms and Q-Q plots. Differences were analyzed by 2-way analysis of variance (ANOVA) or chi-square test to compare sex and age differences. The LMS method assumes that the outcome variable has a normal distribution after a Box-Cox power transformation is applied, using the LMS method implemented in the LMSChartMaker Pro Version 2.54 (Medical Research Council, London, United Kingdom, http://www.healthforallchildren.com/shop-base/software/lmschartmaker-light/). Smoothed and specific curves for each age were obtained through a penalized maximum likelihood with the following abbreviations: (1) M (median), (2) L (Box-Cox transformation), and (3) S (coefficient of variation) (5). The appropriate number of degrees of freedom was selected on the basis of the deviance, Q-tests, and worm plots, following the suggestions of Royston and Wright (22). The third, 10th, 25th, 50th, 75th, 90th, and 97th smoothing centiles were chosen as age- and sex-specific reference values. Statistical significance was set at $p \leq 0.05$.

Results

Descriptive statistics for each sex are shown in Table 1. All of the anthropometric variables, except the BMI (aged 9–12.9 years), were higher in boys than in girls ($p < 0.01$). The 2-way ANOVA tests showed that the HG (kg) and normalized grip strength were higher in boys than in girls ($p < 0.01$). Post hoc analyses within sexes showed yearly increases in HG and strength relative to body mass scores in all ages.

Centile Curves and Reference Values

Smoothed LMS curves (third, 10th, 25th, 50th, 75th, 90th, and 97th percentile) for boys and girls HG (kg) are given in Figure 1. The equivalent numerical values are available in Table 2. Together, these data show that boys performed better on the test at all ages compared with girls. In boys, the HG 50th percentile ranged from 12.9 to 33.5 kg. In girls, the 50th percentile ranged from 12.7 to 23.3 kg. In boys, there was an improvement in muscle strength across the age range, with performance improving most rapidly between 13 and 16 years. In girls, performance increased between the ages of 11 and 15 years, although this increase was more modest. In boys, there was increase in normalized strength throughout all ages. For girls, the HG increased yearly from 9 to 11.9 years before reaching a plateau aged 12–17.9 years. Table 3 provides growth charts of normalized values for boys and girls separately.

Health Benefit Zones

The HG (kg) HBZ for boys and girls are given in Figure 2. Overall, among children aged 9–19.9 years, significantly more boys (49.1%) than girls (37.7%) were in the "Needs Improvement" category, and more girls (5.0%) than boys (3.8%) were in the "Excellent" category ($p < 0.001$). Among children aged 10–10.9 years, significantly more boys (29.5%) than girls (11.3%) were in the "Needs Improvement"

Table 3. Mean, *SD*, and percentile distribution of normalized grip strength in Colombian children and adolescents by sex and age.

	n	Mean	*SD*	3rd	10th	25th	50th	70th	90th	97th
Boys										
9–9.9	217	0.41	0.12	0.24	0.30	0.34	0.41	0.46	0.54	0.67
10–10.9	403	0.42	0.11	0.25	0.30	0.35	0.41	0.47	0.56	0.64
11–11.9	412	0.43	0.10	0.26	0.31	0.37	0.43	0.48	0.57	0.62
12–12.9	374	0.44	0.09	0.26	0.32	0.38	0.45	0.50	0.56	0.64
13–13.9	388	0.47	0.10	0.29	0.35	0.41	0.48	0.53	0.61	0.68
14–14.9	415	0.47	0.10	0.28	0.35	0.42	0.50	0.55	0.65	0.71
15–15.9	374	0.54	0.12	0.29	0.39	0.45	0.55	0.60	0.69	0.76
16–16.9	319	0.55	0.11	0.32	0.38	0.48	0.56	0.62	0.70	0.77
17–17.9	227	0.55	0.11	0.32	0.39	0.49	0.56	0.61	0.69	0.77
Total	3,129	0.48	0.12	0.27	0.33	0.40	0.48	0.54	0.64	0.71
Girls										
9–9.9	277	0.39	0.09	0.24	0.29	0.33	0.38	0.43	0.51	0.58
10–10.9	618	0.38	0.09	0.23	0.29	0.34	0.40	0.44	0.51	0.56
11–11.9	620	0.41	0.09	0.25	0.30	0.35	0.42	0.46	0.52	0.57
12–12.9	491	0.42	0.08	0.28	0.32	0.37	0.42	0.47	0.54	0.59
13–13.9	457	0.42	0.09	0.23	0.30	0.36	0.42	0.47	0.54	0.59
14–14.9	592	0.42	0.09	0.26	0.31	0.36	0.42	0.47	0.53	0.60
15–15.9	441	0.42	0.09	0.25	0.31	0.35	0.42	0.47	0.53	0.60
16–16.9	393	0.42	0.08	0.26	0.32	0.37	0.43	0.46	0.54	0.60
17–17.9	250	0.43	0.10	0.27	0.31	0.37	0.42	0.49	0.55	0.62
Total	4,139	0.41	0.09	0.25	0.31	0.35	0.42	0.46	0.53	0.59

Handgrip strength was normalized as strength per body mass (i.e., [HG in kg]/[body mass in kg]).

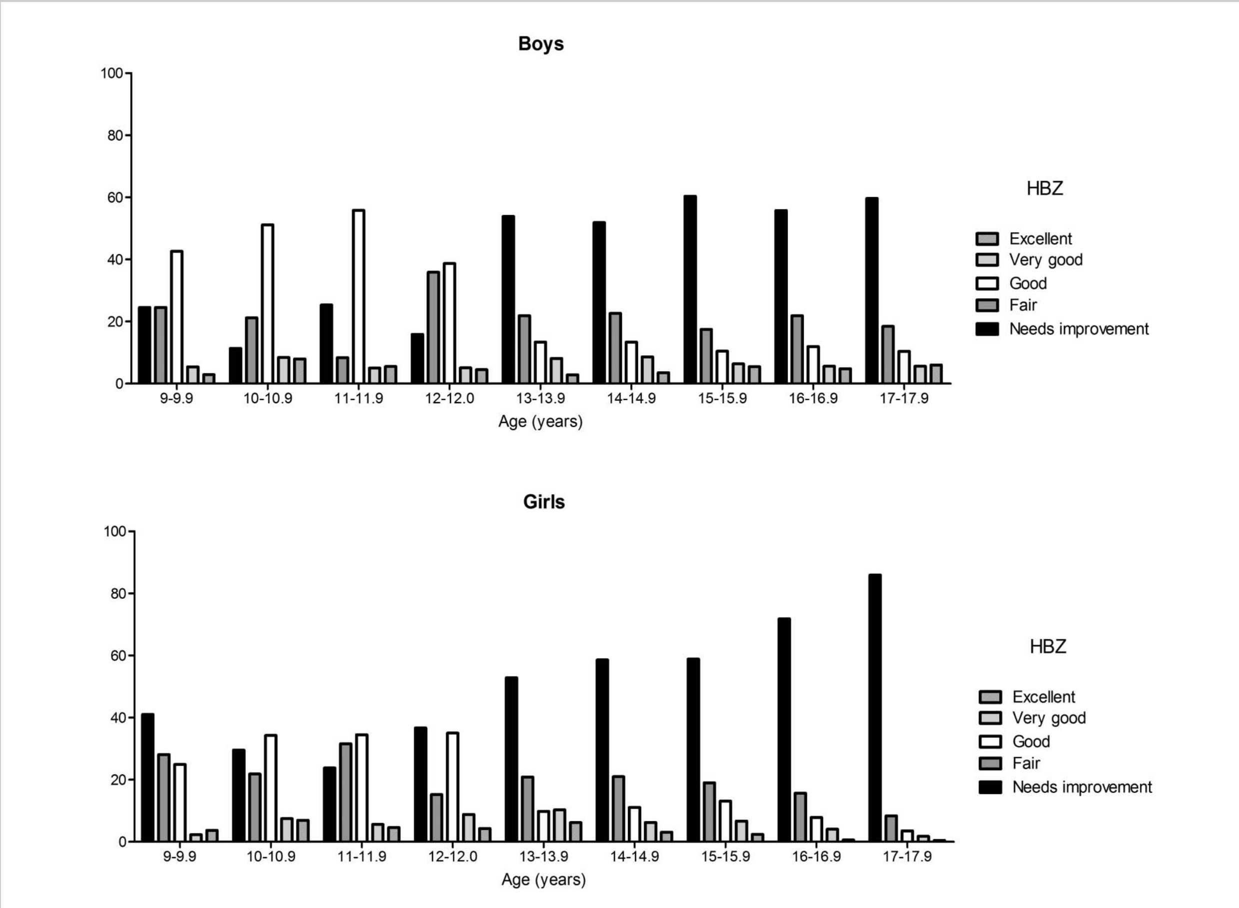

Figure 2. Percent of children and adolescents by handgrip strength health benefit zone (HBZ) by sex and age.

category ($p < 0.001$). Among adolescents aged 15–15.9 years, significantly more boys (58.8%) than girls (60.3%) were in the "Needs Improvement" category ($p < 0.001$).

Hand Grip Differences: Comparisons With Previous Research

Finally, comparisons between the 50th percentile and/or mean values for HG (kg) from this study are presented in Table 4. We found that Colombian schoolchildren have lower values than children and adolescents from the USA, United Kingdom, the European Union (EU), Hungary, Latvia, and Australia.

Discussion

This study had the following aims: (1) to generate reference values and centile curves for 9–17.9-year-old Colombian schoolchildren that can be used to assess HG strength in similar populations (13–18) and (2) to determine the relative proportion of children and adolescents falling into established HBZs. We have shown that HG strength increases in early life, however, HG was greater for boys than for girls. Our study shows that the HG strength of boys and girls is similar in children (aged 9–12.9 years); after this point, boys began to gain strength more rapidly to a higher peak mean of 33.5 kg between ages 17 and 17.9 compared with the peak girls' mean grip of 23.3 kg at the same age. In contrast, HBZ data indicate that a higher percentage of boys than girls at each age group fell into the "Needs Improvement" zone, with differences particularly pronounced during adolescence. This is important to assess, particularly in the context of an LMIC setting such as Latin American schoolchildren because normative data for MF throughout life will inform clinical interpretations of HG strength measurements (17).

Age- and sex-related MF developmental patterns have been well studied in nonrepresentative samples (1,6,10,13,14,25,26). These are the first published normative HG data in Colombian schoolchildren aged 9–17.9 years (Figure 1 and Tables 2–3). By providing centile curves for HG, it is now possible to identify Colombian children and adolescents with low or high HG with respect to their age and sex. Most current studies support an inverse association between MF and cardiovascular disease risk factors in youth,

TABLE 4. Reference values (50th percentile or mean) for handgrip (HG) (kg) from cited studies.*

Sex	FUPRECOL study†,[1] (*n* = 7,268)	Australia (1)‡,[2] (*n* = 3,707)	Canada (31)†,[3] (*n* = 2,074)	EU (9)‡,[4] (*n* = 3,428)	USA (13)‡,[5] (*n* = 1,224)	Hungarian (25)‡,[6] (*n* = 1,086)	Latvian (26)†,[7] (*n* = 4,359)	United Kingdom (4)‡,[8] (*n* = 7,147)
Boys								
9–9.9	12.9	16.4	25.0	–	20.6	–	14.4	–
10–10.9	14.1	19.0	–	–		–	16.4	16.6
11–11.9	15.6	21.2	48.0	–	27.8	21.4	18.5	19.6
12–12.9	17.5	22.7	51.0	–		21.7	21.8	22.6
13–13.9	21.1	25.8	–	26.2	34.1	25.0	26.0	27.2
14–14.9	23.8	30.7	–	32.2		30.0	31.3	32.5
15–15.9	28.5	36.5	–	37.7	39.3	35.4	36.4	39.0
16–16.9	31.1	–	–	41.8		40.0	40.5	–
17–17.9	33.5	–	–	45.1	43.4	42.6	41.0	–
Girls								
9–9.9	12.7	14.4	23.0	–	18.6	–	12.8	–
10–10.9	13.4	17.1	–	–		–	14.8	15.5
11–11.9	15.3	18.8	40.8	–	22.9	20.0	17.2	18.7
12–12.9	18.1	21.4	42.0	–		19.5	19.9	21.2
13–13.9	19.5	23.6	–	23.6	26.1	19.6	23.1	23.5
14–14.9	21.9	25.4		25.2		20.3	26.1	25.8
15–15.9	21.5	27.7	27.4	26.2	28.3	21.6	27.0	26.9
16–16.9	22.7	–	–	26.6		23.5	27.8	–
17–17.9	23.3	–	–	27.6	29.7	26.1	28.5	–

*EU: from 10 European cities in Austria, Belgium, France, Germany, Greece (an inland city and an island city), Hungary, Italy, Spain, and Sweden.
†Mean.
‡50th percentile.
Grip strength testing protocol:
[1]Two trials were allowed in each limb and the average score recorded the peak grip strength (kg). HG values presented here combine the results of left- and right-handed subjects, without consideration for hand dominance.
[2]Maximal contraction values as the mean of both hands (kg).
[3]Maximal contraction twice on each hand (alternating) and combining the maximum score for each hand (kg).
[4,5]Maximal contraction on each hand (over 3 trials separated by 60 seconds and alternating hands) was summed to yield the final combined-hand grip strength value (kg converted to lbs). In this table, the HG mean is presented in kg.
[6]The maximal isometric contraction was set to last 2 seconds and participants completed 2 trials with a break in between. The assessment was done for both hands, and handgrip strength obtained from the preferred hand was rounded to the nearest 1 kg and the higher of the 2 trials was recorded and used for analysis.
[7]The maximal isometric force that can be generated mainly in the forehand muscle (kg).
[8]Two trials were allowed in the dominant limb and the highest score recorded as peak grip strength (kg).

generally expressing muscular strength in relative terms (7,10–12,30). For example, Chan et al. (2) reported that HG strength is an independent predictor of bone mass among children and adolescents after controlling for weight, height, pubertal development, weight-bearing activities, and calcium intake. This effect seems, independent of the associations between metabolic health, sexual maturation, and/or low CRF. Additionally, the Pan-European HELENA study showed that poor performance on the MF test is associated with elevated metabolic and cardiovascular risk factors in youth (9). This and other studies have shown that overweight and obese adolescents have better metabolic profiles if they also have adequate MF (3,16).

Our data (Table 2 and Table 3) confirm the previously observed sexual dimorphism in HG for children and adolescents in this range age (1,10,13,14,25,26), with significantly higher HG in boys than in girls at every age. In English schoolchildren, Cohen et al. (4) confirmed linear increases in HG in both sexes with age that are parallel up to age 12–13, after which point the development of HG accelerates in boys in a pattern similar to that in this study. Sherriff et al. (27) and Rauch et al. (18) suggest that sex differences in HG partly contribute to the increased development of major HG determinants in boys, muscle mass, total body mass, and stature. Similarly, Round et al. (21) reported that knee extensor muscle strength in boys is influenced not only by body size but also by testosterone level, which becomes an indicator of maturation. Additionally, serum testosterone levels are positively related to maximal muscle strength in adolescent boys.

Consistent with other studies, absolute HG strength and the ascent of strength from childhood to young adulthood was greater in males than in females (3,7,13,14). There were also age and sex differences in the HBZ categories (9,13,14). For all ages, the percentage of children and adolescents in the "Needs Improvement" zone steadily lessened with each increasing age and sex group. However, the age and sex group-associated increase in mean HG strength was not necessarily associated with an improvement in the HBZ category. For example, in adolescents (aged 17–17.9 years), the percentage of boys with HG strength in the "Needs Improvement" category was exceedingly high (85.9%), higher than has been reported for English (4) or Pan-European schoolchildren (9), and higher than similarly aged Colombian girls (59.6%) who were on par with their Australian (1) and Hungarian counterparts (25). In contrast, the percentage of girls aged 10–10.9 years in the "Needs Improvement" zone was low (11.3%), remained relatively steady, was accompanied by increasing percentages of girls in the "Excellent" HG strength category (7.9%), and decreased from age 13 to 17. Our findings are consistent with previously reports (1,6,7,10,13,14,25,26,31) that indicate that girls lose upper extremity strength at a lower rate than lower extremity strength, whereas boys experience a parallel decline in upper and lower-body strength. For example, Flanagan et al. (7) in 568 subjects from schools in the Chambersburg, USA, indicated that boys demonstrated greater grip strength than girls. Comparing MF performance allows us to establish that this sample of Colombian children and adolescents has one of the lowest HG strengths of all of the countries examined (1,6,7,10,14,25,26,31). Our data are based on samples of 200–600 schoolchildren of each sex by age group and thus may better describe the patterns of HG in both sexes. Pan-European HELENA (9), United Kingdom (4), USA (6,14), Canada (31), Hungarian (25), Latvian (26), and Australia (1) studies have used large samples, comprising 3,428 (age 12–17 years), 7,147 (age 10–16 years), 4,652 (age 9–17 years), 2,074 (age 9–13 years), 1,086 (age 11–18 years), 4,359 (age 9–17 years), and 3,707 subjects (age 9–15 years), respectively, but contain no data regarding Colombian children and adolescents. We observed moderate but significant differences (8%) between the sexes in 15 to 16.9 year olds, which increased to 10% by ages 17–17.9. In adolescents (aged 15 to 17.9 years), the latter magnitude of between-sex differences is similar to subjects from Latvia (9–13%) but lower than other European samples (i.e., EU 12–18% and Hungary 14–17%). In children (aged 9–12.9 years), we observed small but not significant differences (1–2%), similar to findings reported in European schoolchildren (i.e., United Kingdom 1%, Latvia 2%, and Hungary 2%) and Australian schoolchildren (2%). Only partial use was made of data reported in a Canadian study by Tremblay and colleagues (31). International comparisons with grip strength results from NHANES (13) and National Health and Nutrition Examination Survey National Youth Fitness Survey (31) show some similarities and some differences. In Canadian mean grip strength (based on the combined maximum score from both hands) among youth aged 6 to 10, 11 to 14, and 15 to 19 years was greater in boys than girls. For example, among 11 to 14 year olds, mean grip strength was 51 kg in boys and 42 kg in girls (11). The reference range grip strength for 12.5–17.5 year olds in European HELENA (9) is 31.2 kg, compared with range 15.7 to 27.6 kg in boys and range 16.3–19.4 kg in girls in the United States (13).

In this study, there were 3 groups of children, one of which was composed of Old Order Mennonite children who lived a lifestyle described as "representative of life in Canada 3–4 generations ago." In addition, the age- and sex-matched mean normalized grip strength values from the Colombian children and adolescents are lower than US samples (14). The differences may reflect higher aerobic fitness among international samples, fundamental differences in testing protocols, dynamometer used, or some combination of explanations.

This study had some limitations. First, this study includes participants from only a single region in Colombia; therefore, inferences to all Colombian children and adolescents should be made cautiously. Second, we have not considered the potential impact of recognized determinants to HG strength such as height on the centile values presented. However, because our study is cross-sectional, a cohort effect may have occurred, and as a consequence, our estimations of muscle strength levels could not be extrapolated from previous cohorts. Third, we did not measure important variables associated with blood lipids, such as levels of physical activity, sex hormone levels, sexual maturation, and familial health background. Another limitation is the lack of nationally representative samples. Thus, it might be questioned whether the present findings truly characterize the entire population of children and adolescents living in the Colombia. This is an area for future research. However, such limitations do not compromise the results obtained when validating our results.

Practical Applications

In summary, this study provides age- and sex-specific reference values for HG strength that can be used for the following: i) to generate reference values and centile curves for 9–17.9-year-old Colombian schoolchildren that can be used to assess HG strength in similar populations; ii) to determine the relative proportion of children and adolescents falling into established HBZs; and iii) to compare these data with existing reference values for this age range collected in international studies (1,6,10,13,25,26,31). These values are especially important in public health and educational settings and suggest consideration for HBZ information in conjunction with muscular strength to improve surveillance intervention planning among Latin American schoolchildren.

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