NORMATIVE REFERENCE VALUES FOR HANDGRIP STRENGTH IN COLOMBIAN SCHOOLCHILDREN: THE FUPRECOL STUDY.

Running title: Handgrip among Colombian schoolchildren

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ABSTRACT

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). This cross-sectional study is enrolling 7268 schoolchildren (boys n=3129 and girls n=4139, age 12.7 (2.4) years old. HG 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 3rd, 10th, 25th, 50th, 75th, 90th and 97th percentile were calculated using Cole's LMS method. HG 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.

Keywords: grip; strength; percentile; normative data.

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 (12,23,28). Most current studies support an inverse relationship between MF and cardiovascular disease risk factors in youth, generally expressing muscular strength in relative terms (14,24). For example, Ruiz et al. (24) 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 (7).

The clinical examination as well as MF and handgrip (HG) measurements are described in detail by Ruiz et al. (24) 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) (3,4). On the other hand, Sex–age specific normative values for HG in young people have been published (1,10,14,13,25,26). 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 (23).

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 (17,20,23). 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

Participants and Study Design

This is a secondary analysis of a cross-sectional study, published elsewhere (17,20,23). Briefly, this study aimed to examine relationships between physical fitness levels in children and adolescents with cardiometabolic risk factors and (un)healthy habits. A subset of participants with asthma who completed HG scans was included in the current analysis. The During the 2014–2015 school year, we conducted a cross-sectional component of the FUPRECOL study (*in Spanish,* ASOCIACIÓN DE LA **FU**ERZA **PRE**NSIL CON MANIFESTACIONES DE RIESGO CARDIOVASCULAR TEMPRANAS EN NIÑOS Y ADOLESCENTES **COL**OMBIANOS) (17,20,23). The sample comprised 7268 healthy Colombian schoolchildren (boys n=3129 and girls n=4139, means ± standard deviations (SD) age 12.7 (2.4) y, weight 44.5 (12.3) kg, height 1.49 (0.1) m, BMI 19.7 (3.6) kg/m^2). The schoolchildren were of low-middle socioeconomic status (SES, 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 handgrip strength 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 to 200 participants per group. Exclusion factors included 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 Review Committee for Research on Human Subjects at the University of Rosario (Code Nº CEI-ABN026-000262) approved all of the study procedures. A comprehensive verbal description of the nature and purpose of the study, as well as on the experimental risks, was given to the children and adolescents, their parents/guardians, and their teachers. This information was also sent to parents/guardians by regular mail, and written informed consent was obtained from the parents and participants before participation. 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 following an overnight fast, at the same time (7:00-10:00 a.m.). Body weight was measured in the subjects' underwear and with no shoes, using electronic scales (Tanita® BC544, Tokyo, Japan) with a low technical error of measurement (TEM = 0.510%). Height was measured using a mechanical stadiometer platform (Seca® 274, Hamburg, Germany; TEM = 0.019%). 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 (Ohaus® 8004-MA, New Jersey, USA; TEM = 0.086%) (23). The data were recorded on paper by the FUPRECOL evaluators (17).

HG 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). HG 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 combine the results of left- and right-handed subjects, without consideration for hand dominance. Since 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% CI= -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). HBZs 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 HOMA index, triglycerides, blood pressure and inflammatory markers such as CRP and TNF-α (7, 16,30).

Statistical analysis

We used SPSS V. 21.0 software for Windows (SPSS, Chicago, Illinois, USA) for all but the LMS method calculations. Anthropometric and HG characteristics from the study sample are presented as the mean with standard deviation (SD). Normality for selected variables was verified using histograms and Q-Q plots. Differences were analyzed by one-way analysis of variance (ANOVA) or Chi-square test (X_2) 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, UK, http://www.healthforallchildren.com/shop-base/software/lmschartmaker-light/). Smoothed and specific curves for each age were obtained via 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 & Wright (22). The 3rd, 10th, 25th, 50th, 75th, 90th and 97th smoothing centiles were chosen as age- and gender-specific reference values. Statistical significance was set at $p<0.05$.

RESULTS

Descriptive statistics for each sex are shown in Table 1. All of the anthropometric variables, except the BMI (aged 9 to 12.9 years old), were higher in boys than in girls (p<0.01). The one-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.

**** Insert Table 1 ****

Centile curves and reference values

Smoothed LMS curves (3rd, 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 to 17.9 years old. Table 3, provide growth charts of normalized values for boys and girls separately.

**** Insert Table 2 and 3****

**** Insert Figure 1 ****

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" 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).

**** Insert Figure 2 ****

Hand grip differences: comparisons with previous research

Finally, comparisons between the 50_{th} 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 EE.UU, UK, the European Union (EU), Hungary, Latvia and Australia.

**** Insert Table 4 ****

DISCUSSION

The present study had the following aims: (1) to generate reference values and centile curves for 9-17.9-year-old Colombian school-children 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 (9-12.9 years old); 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 a 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 non-representative samples (1,6,10,13,14,25,26). These are the first published normative HG data in Colombian schoolchildren aged 9–17.9 years (see Figure 1 and Table 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, 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 appears, 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 (see 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 genders 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 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 (3,13,14). 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 (17-17.9-year-olds), 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 (1,6,10,13,14,25,26,31) that indicate that girls lose upper extremity strength at a lower rate than lower extremity strength while boys experience a parallel decline in upper and lower body strength.

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 (1,6,10,14,25,26,31). 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 genders. Pan-European HELENA (9), UK (4), EE.UU (6,14), Canada (31), Hungarian (25), Latvian (26) and Australia (1) studies have used large samples, comprising 3428 (12– 17 years old), 7147 (10-16 years old), 4652(9-17 years old), 2074 (9-13 years old), 1086 (11–18-year-olds), 4359 (9-17 years old) and 3707 subjects (9-15 years old), 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-years-olds, which increased to 10% by ages 17-17.9. In adolescents (aged 15- to 17.9-years-old), the latter magnitude of between-gender differences is similar to subjects from Latvia (9 to 13%) but lower than other European samples (i.e., EU 12 to 18% and Hungary 14 to 17%). In children (aged 9 to 12.9 years old), we observed small but not significant differences (1 to 2%), similar to findings reported in European schoolchildren (i.e., UK 1%, Latvia 2% and Hungry 2%) and Australian schoolchildren (2%). Only partial use was made of data reported in a Canadian study by Tremblay and colleagues (31). In this study, there were three groups of children, one of which was composed of Old Order Mennonite children who lived a lifestyle described as "representative of life in Canada three to four 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.

In summary, this study provides age- and sex-specific reference values for HG strength that can be used for the following: (1) to generate reference values and centile curves for 9-17.9-year-old Colombian school-children that can be used to assess HG strength in similar populations (2) to determine the relative proportion of children and adolescents falling into established HBZs; and (3) 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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CONFLICT OF INTEREST

The authors declare that there is no conflict of interests.

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

Sex	n	Body mass (kg)	Height (cm)	BMI (kg/m2)	Handgrip strength (kg)	Normalized grip strength
Boys						
9 to 9.9	217	32.1 (7.5)	133.5 (6.5)	17.8 (3.1)	13.4 (3.8)**	0.41 (0.12)**
10 to 10.9	403	34.5 (8.5)	137.3 (7.4)*	18.1 (3.3)	14.5 (4.1)**	0.42 (0.11)**
11 to 11.9	412	37.2 (8.8)*	141.9 (8.2)*	18.3 (3.2)	15.9 (3.9)**	0.43 (0.10)**
12 to 12.9	374	41.3 (9.1)*	147.1 (8.2)*	18.9 (3.2)	18.1 (4.8)**	0.44 (0.09)**
13 to 13.9	388	46.0 (9.8)*	153.5 (9.3)*	19.4 (3.3)**	22.2 (5.9)**	0.47 (0.10)**
14 to 14.9	415	50.0 (9.7)*	158.9 (9.1)**	19.7 (3.0)**	24.5 (6.9)**	0.47 (0.10)**
15 to 15.9	374	54.4 (9.7)*	163.3 (8.9)**	20.3 (3.0)**	28.8 (8.2)**	0.54 (0.12)**
16 to 16.9	319	57.7 (8.7)**	166.7 (7.2)**	20.8 (2.9)**	31.1 (8.0)**	0.55 (0.11)**
17 to 17.9	227	60.8 (10.3)**	168.1 (7.4)**	21.5 (3.3)**	32.7 (7.0)**	0.55 (0.11)**
Total	*3129*	*45.5 (13.0)**	*151.9 (14.1)***	*19.4 (3.3)***	*22.2 (9.0)***	*0.48 (0.12)***
Girls						
9 to 9.9	277	32.1 (7.4)	134.6 (7.6)	17.6 (3.0)	13.0 (3.9)	0.39 (0.09)
10 to 10.9	618	35.0 (7.9)	138.4 (7.6)	18.1 (3.0)	13.9 (3.6)	0.38 (0.09)
11 to 11.9	620	38.3 (7.9)	143.7 (7.5)	18.4 (2.9)	15.6 (3.7)	0.41 (0.09)
12 to 12.9	491	42.8 (8.6)	148.5 (7.3)	19.3 (3.0)	18.3 (4.3)	0.42 (0.08)
13 to 13.9	457	47.4 (9.0)	152.4 (6.3)	20.3 (3.2)	19.8 (4.7)	0.42 (0.09)
14 to 14.9	592	51.0 (8.9)	154.6 (6.5)	21.3 (3.3)	21.6 (4.8)	0.42 (0.09)
15 to 15.9	441	52.7 (8.6)	155.7 (6.8)	21.7 (3.1)	22.1 (5.3)	0.42 (0.09)
16 to 16.9	393	53.9 (8.6)	156.4 (5.8)	22.0 (3.1)	22.9 (5.1)	0.42 (0.08)
17 to 17.9	250	55.1 (9.3)	156.8 (6.5)	22.4 (3.6)	23.9 (5.3)	0.43 (0.10)
Total	*4139*	*44.8 (11.5)*	*148.7 (10.1)*	*20.0 (3.5)*	*18.5 (5.6)*	*0.41 (0.09)*

Note: Significant between-sex differences by Anova one way test *p<0.001; **p<0.01

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

	n	M	SD	3th	10th	25th	50th	70th	90th	97th
Boys										
9 to 9.9	217	13.4	3.8	7.9	9.4	11.1	12.9	15.1	17.3	20.1
10 to 10.9	403	14.5	4.1	8.3	10.1	11.7	14.1	16.5	18.9	22.6
11 to 11.9	412	15.9	3.9	9.4	11.1	13.2	15.6	18.3	21.1	25.0
12 to 12.9	374	18.1	4.8	9.8	12.8	15.0	17.5	20.8	24.6	28.1
13 to 13.9	388	22.2	5.9	13.2	15.6	18.2	21.1	25.2	30.6	36.6
14 to 14.9	415	24.5	6.9	12.8	16.3	19.4	23.8	29.0	33.4	40.7
15 to 15.9	374	28.8	8.2	12.3	18.3	23.1	28.5	34.7	39.5	42.8
16 to 16.9	319	31.1	8.0	16.5	20.1	24.9	31.1	36.1	41.5	47.3
17 to 17.9	227	32.7	7.0	16.7	22.4	28.8	33.5	37.2	41.1	45.7
Total	*3129*	*22.2*	*9.0*	*9.8*	*11.9*	*15.2*	*20.2*	*28.6*	*35.5*	*41.4*
Girls										
9 to 9.9	277	13.0	3.9	7.4	8.7	10.6	12.7	15.2	17.1	20.6
10 to 10.9	618	13.9	3.6	8.1	9.8	11.6	13.4	15.8	18.6	21.9
11 to 11.9	620	15.6	3.7	9.5	10.9	12.9	15.3	17.7	20.5	23.6
12 to 12.9	491	18.3	4.3	10.7	12.7	15.4	18.1	21.1	23.5	26.0
13 to 13.9	457	19.8	4.7	10.4	13.7	16.6	19.5	23.3	25.7	28.6
14 to 14.9	592	21.6	4.8	12.8	15.5	18.2	21.9	24.5	27.3	30.7
15 to 15.9	441	22.1	5.3	12.1	16.3	18.7	21.5	25.2	28.8	33.5
16 to 16.9	393	22.9	5.1	13.6	17.1	19.6	22.7	25.9	28.5	33.4
17 to 17.9	250	23.9	5.3	14.5	17.9	20.8	23.3	26.4	30.9	36.9
Total	*4139*	*18.5*	*5.6*	*9.5*	*11.5*	*14.3*	*18.2*	*22.3*	*25.5*	*29.1*

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

Table 3. Mean (M), standard deviation (SD), and percentile distribution of normalized grip strength in Colombian children and adolescents by sex and age

	n	M	SD	3th	10th	25th	50th	70th	90th	97th
Boys										
9 to 9.9	217	0.41	0.12	0.24	0.30	0.34	0.41	0.46	0.54	0.67
10 to 10.9	403	0.42	0.11	0.25	0.30	0.35	0.41	0.47	0.56	0.64
11 to 11.9	412	0.43	0.10	0.26	0.31	0.37	0.43	0.48	0.57	0.62
12 to 12.9	374	0.44	0.09	0.26	0.32	0.38	0.45	0.50	0.56	0.64
13 to 13.9	388	0.47	0.10	0.29	0.35	0.41	0.48	0.53	0.61	0.68
14 to 14.9	415	0.47	0.10	0.28	0.35	0.42	0.50	0.55	0.65	0.71
15 to 15.9	374	0.54	0.12	0.29	0.39	0.45	0.55	0.60	0.69	0.76
16 to 16.9	319	0.55	0.11	0.32	0.38	0.48	0.56	0.62	0.70	0.77
17 to 17.9	227	0.55	0.11	0.32	0.39	0.49	0.56	0.61	0.69	0.77
Total	*3129*	*0.48*	*0.12*	*0.27*	*0.33*	*0.40*	*0.48*	*0.54*	*0.64*	*0.71*
Girls										
9 to 9.9	277	0.39	0.09	0.24	0.29	0.33	0.38	0.43	0.51	0.58
10 to 10.9	618	0.38	0.09	0.23	0.29	0.34	0.40	0.44	0.51	0.56
11 to 11.9	620	0.41	0.09	0.25	0.30	0.35	0.42	0.46	0.52	0.57
12 to 12.9	491	0.42	0.08	0.28	0.32	0.37	0.42	0.47	0.54	0.59
13 to 13.9	457	0.42	0.09	0.23	0.30	0.36	0.42	0.47	0.54	0.59
14 to 14.9	592	0.42	0.09	0.26	0.31	0.36	0.42	0.47	0.53	0.60
15 to 15.9	441	0.42	0.09	0.25	0.31	0.35	0.42	0.47	0.53	0.60
16 to 16.9	393	0.42	0.08	0.26	0.32	0.37	0.43	0.46	0.54	0.60
17 to 17.9	250	0.43	0.10	0.27	0.31	0.37	0.42	0.49	0.55	0.62
Total	*4139*	*0.41*	*0.09*	*0.25*	*0.31*	*0.35*	*0.42*	*0.46*	*0.53*	*0.59*

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

Table 3. Reference values (50th percentile *or* mean) for HG (kg) from cited studies

Sex	FUPRECOL Study[a] n = 7268	Australia (1)[b] n = 3707	Canada (31)[a] n= 2074	EU (9)[b] n = 3428	EE.UU (14)[b] n = 1224	Hungarian (25)[b] n = 1086	Latvian (26)[a] n = 4359	UK (4)[b] n = 7147
Boys								
9 to 9.9	12.9	16.4	25.0	-	20.6	-	14.4	-
10 to 10.9	14.1	19.0	-	-		-	16.4	16.6
11 to 11.9	15.6	21.2	48.0	-	27.8	21.4	18.5	19.6
12 to 12.9	17.5	22.7	51.0	-		21.7	21.8	22.6
13 to 13.9	21.1	25.8	-	26.2	34.1	25.0	26.0	27.2
14 to 14.9	23.8	30.7	-	32.2		30.0	31.3	32.5
15 to 15.9	28.5	36.5	-	37.7	39.3	35.4	36.4	39.0
16 to 16.9	31.1	-	-	41.8		40.0	40.5	-
17 to 17.9	33.5	-	-	45.1	43.4	42.6	41.0	-
Girls								
9 to 9.9	12.7	14.4	23.0	-	18.6	-	12.8	-
10 to 10.9	13.4	17.1	-	-		-	14.8	15.5
11 to 11.9	15.3	18.8	40.8	-	22.9	20.0	17.2	18.7
12 to 12.9	18.1	21.4	42.0	-		19.5	19.9	21.2
13 to 13.9	19.5	23.6	-	23.6	26.1	19.6	23.1	23.5
14 to 14.9	21.9	25.4		25.2		20.3	26.1	25.8
15 to 15.9	21.5		27.4	26.2	28.3	21.6	27.0	26.9

16 to 16.9	22.7	-	26.6		23.5	27.8	-
17 to 17.9	23.3	-	27.6	29.7	26.1	28.5	-

Note: [a] Mean, [b] 50^{th} percentile
EU: from 10 European cities in Austria, Belgium, France, Germany, Greece (an inland city and an island city), Hungary, Italy, Spain and Sweden.

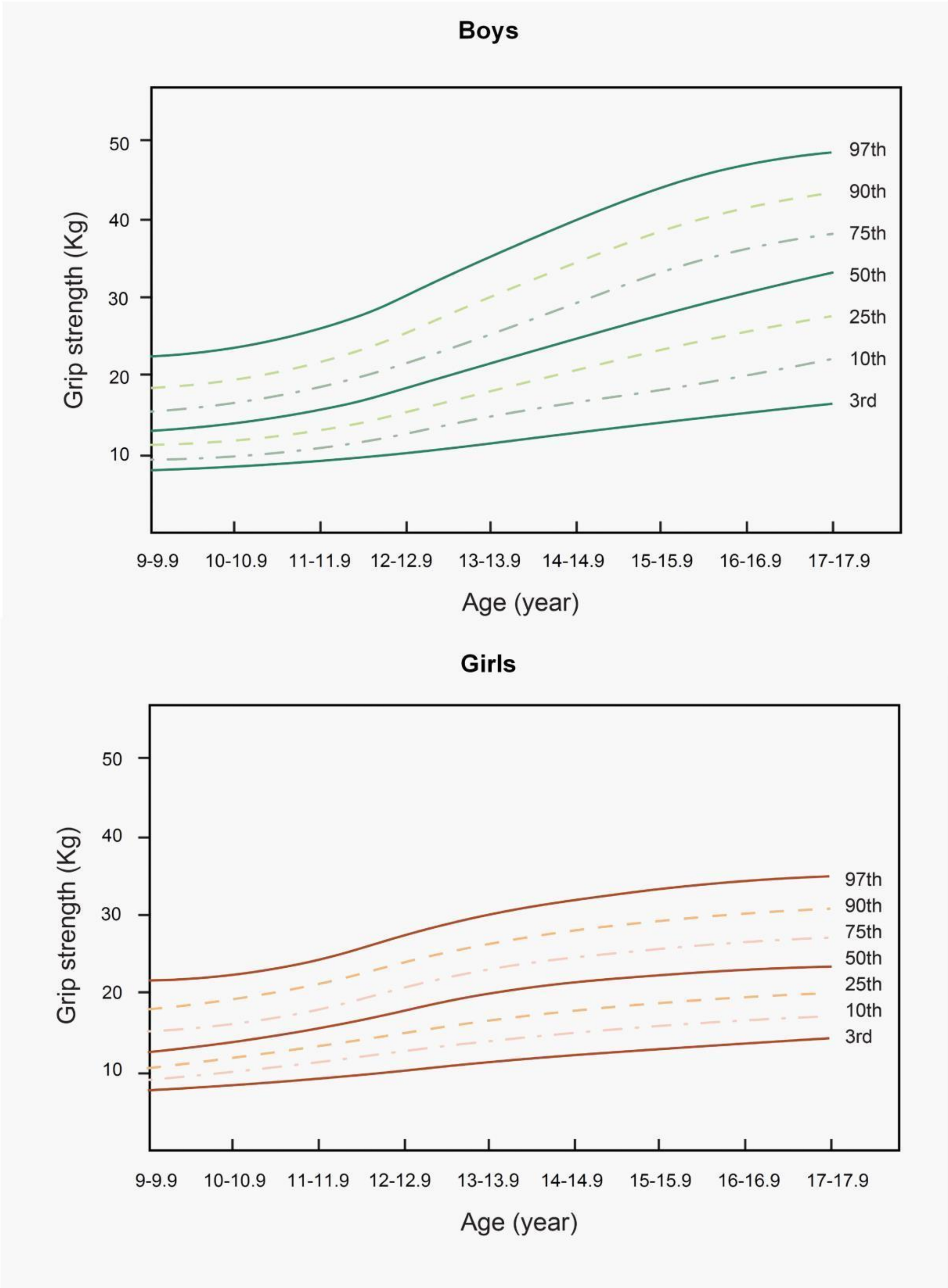

Figure 1. Percentile curves for handgrip strength (kg) in Colombian children and adolescents by sex and age

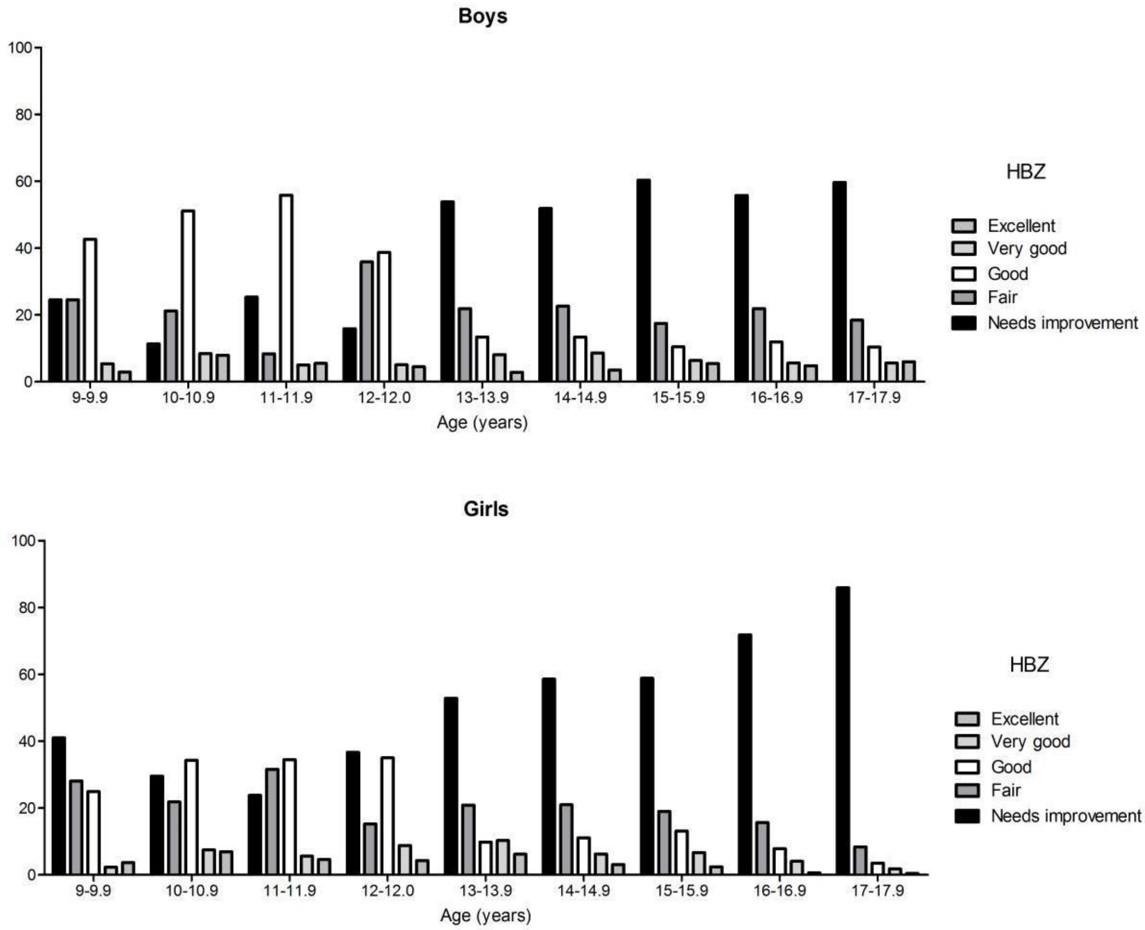

Figure 2. Percent of children and adolescents by handgrip strength Health Benefit Zone (HBZ) by sex and age