Handgrip strength cut-off for cardiometabolic risk index among Colombian children and adolescents: The FUPRECOL Study

Handgrip Strength Thresholds in Youths

By
Jonathan Peña
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Robinson Ramírez-Vélez, Ph.D (MsC advisor)
Jorge Enrique Correa-Bautista, Ph.D (MsC co-advisor)

Master in Physical Health Program
Center of Studies in Physical Activity Measurements (CEMA)
School of Medicine and Heatlh Science
Rosario University
Bogotá, D.C
Colombia

Abstract

Objective: Evidence shows an association between muscular strength (MS) and health among youth, however low muscular strength cut-points for the detection of high metabolic risk in Latin-American populations are scarce. The aim of this study was two-fold: to explore potential age- and sex-specific thresholds of MS, for optimal cardiometabolic risk categorization among Colombian children and adolescents; and to investigate if cardiometabolic risk differed by MS group by applying the receiver operating characteristic curve (ROC) cut point.

Methods: This is a secondary analysis of a cross-sectional study (the FUPRECOL study), published elsewhere. The FUPRECOL study assessments were conducted during the 2014–2015 school year. MS was estimated by a handle dynamometer on 1,950 children and adolescents from Colombia, using the MS relative to weight (handgrip strength/body mass). A metabolic risk score was computed from the following components: waist circumference, triglycerides, HDL-c, glucose, systolic and diastolic blood pressure. ROC analysis showed a significant discriminatory accuracy of MS in identifying the low/high metabolic risk in children and adolescents and both gender.

Results: In children, handgrip strength/body mass level for a low metabolic risk were 0.359 and 0.376 in girls and boys, respectively. In adolescents, these points were 0.440 and 0.447 in girls and boys, respectively.

Conclusion: In conclusion, the results suggest a hypothetical MS level relative to weight for having a low metabolic risk, which could be used to identify youths at risk.

Key words: Muscular strength; Thresholds; Metabolic Syndrome; Receiver operating characteristic curve.

Introduction

Poor muscular strength (MS), as determined with a handgrip (HG) dynamometer, is recognized as a marker of poor metabolic profile during adolescence[1] and is associated with disease and mortality in adulthood [2, 3]. Most current studies support an inverse relationship between low MS and cardiovascular disease risk factors in youth, generally expressing muscular strength in relative terms. Our group[4] and others researchers[5-7] have shown an independent and inverse association between low strength and cardiometabolic risk clustering among adolescents and adults. In addition, Ruiz et al. [8] and Ortega et al. [1] reported in a systematic review the relationship between MS and health outcomes such as lipid profile and glucose levels, particularly in overweight and obese children, respectively.

The HG strength test is a quick and easy-to-perform muscular fitness test that provides useful information about overall MS, and it could potentially be used in the clinical setting [9, 10]. Clinical examination as well as HG measurements are described in detail by Artero et al. [5], Smith et al. [11] and Ortega et al. [12], respectively. The contribution of low MS to progression of secondary sedentary behavior with aging and/or cardiometabolic risk factors (e.g. obesity, systemic low-grade inflammation, insulin resistance) is equally unequivocal, and recent national efforts to identify cut points or thresholds for Lambda-Mu-Sigma (MLS) among youth[13, 14] will aid clinicians to screen individuals with greatest risk [15].

Previous studies have shown there is a relationship between MS and cardiometabolic risk factors in young and adult populations. However there is no consensus regarding the minimum MS level associated with a clustered cardiometabolic risk among youth in Latin

America. Therefore, from a public health perspective, the inclusion of HG in health surveillance systems is therefore clearly justifiable; schools also may be an ideal setting for monitoring youth fitness to identify those with poor MS [16, 17]. In order to identify children and adolescents in whom low MS is a potential contributor to cardiometabolic risk factors, it is necessary to determine what constitutes a clinically relevant reiterating the need for early and improved clinical screening strategies across populations. Thus, the aim of this study was two-fold: to explore potential age- and sex-specific thresholds of MS, for optimal cardiometabolic risk categorization among Colombian children and adolescents aged 9- to 17.9-year-olds; and to investigate if cardiometabolic risk differed by MS group by applying the receiver operating characteristic curve (ROC) cut point.

Methods

Participants and Study Design

This is a secondary analysis of a cross-sectional study (the FUPRECOL study), published elsewhere [18, 19]. The FUPRECOL study assessments were conducted during the 2014–2015 school year. The sample consisted of children and adolescents (boys n = 4,000 and girls n = 4,000) ages 9–17.9 years. In a subgroup of 2,775 schoolchildren, biomarkers parameters were also assessed and a more exhaustive health and lifestyle assessment was carried out. From this subgroup 1,950 schoolchildren (64.5% adolescents) showed valid data from the HG, anthropometric and blood parameter assessments, and were consequently used in this study. The schoolchildren were of low-middle socioeconomic status (SES, 1–3 defined by the Colombian government) from 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 80 to 100 participants by sex age 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 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 [20], in the morning following an overnight fast, at the same time (7:00-10:00 a.m.). Body weight and height were measured in the subjects' underwear and

with no shoes, using electronic scales (Tanita® BC544, Tokyo, Japan; TEM = 0.510%) and a mechanical stadiometer platform (Seca® 274, Hamburg, Germany; TEM = 0.01%), respectively. The average of the two readings of weight and height was used to calculate body mass index (BMI) as weight (kg) divided by height squared (m^2). Weight status were defined as having a BMI above the age and sex-specific thresholds of the International Obesity Task Force (IOTF) [21]. Waist circumference was measured with the patient in the standing position without clothing at the midpoint level of the mid-axillary line between the 12^{th} rib head and the superior anterior iliac spine using a tape measure (Ohaus® 8004-MA, New Jersey, USA; TEM = 0.86%). Hip circumference was taken at the largest point at the level of the greater trochanters, and thigh circumference was measured mid-way between the hip and knee (Ohaus® 8004-MA, New Jersey, USA; TEM = 0.91%). All circumference measures were calculated as the average of three measurements.

In addition, percentage of body fat was assessed by bioelectrical impedance using a bipolar device TANITA® BF-689 floor scale (Arlington Heights, IL 60005, USA), with and the results were expressed as percentage of body weight. Briefly, the subject stood with the feet slightly separated, the instrument records impedance from foot to foot and subsequently calculates %body fat to the nearest 0.1% based on age, gender, height and weight. TEM was 0.63 and the repeatability coefficient, 0.98%. According to Kasvis et al. [22] the bipolar BIA equipment has demonstrated to be reliable and valid because it includes prediction equations to estimate body fat percentage adjusted by age and gender in 5-17 year-old children. Validation tests and equations are available from the manufacturer's website (http://www.tanita.com/en/bf-689/) or from the study conducted by Kasvis et al. [22]

Sexual maturation was classified based on Tanner staging [23], which uses self-reported puberty status to classify participants into stages I to V [24]. Each volunteer entered an isolated room where they categorized the development of their own genitalia (for boys), breasts (for girls), armpits (for boys) and pubic hair (for both genders) using a set of images exemplifying the various stages of sexual maturation. The reproducibility of our data reached R=0.78.

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). According to predetermined protocols [22], the dynamometer grip opening was adjusted to the subject's hand size. Study participants had previously received brief instructions (verbal and demonstration) regarding measurement procedures. 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. Two trials were allowed in each limb and the average score recorded as 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. Several studies suggest that links between MS and both physical function and health status is directly mediated by the proportion of MS relative to body weight. Also there is substantial covariance between MS capacity and body weight. Therefore, to avoid the potential biasing effect of body weight on the estimation of MS, HG was adjusted for body weight in line with standard assumptions about morphologic effects as previous studies[25, 26] have suggested [i.e. (HG strength in kg)/(body weight in kg)]. This methodology was recently used in a similar large study in American adolescents[27]. HG measurements in a subsample (n=229, similar in demographics and biological characteristics to the whole sample) were recorded to ensure reproducibility on the day of the study. The reproducibility of our data was R=0.96. Intra-

rater reliability was assessed by determining the intraclass correlation coefficient (0.98, CI 95% 0.97 to 0.99).

Biochemical assessments

Blood samples were collected between 6:00 and 8:00 am by two experienced paediatric phlebotomists after at least 12 hours fasting. Before the extraction, fasting condition was confirmed by the child and parents. Blood samples were obtained from an antecubital vein, and analyses were subsequently completed within 1 day from collection. The levels of triglycerides (TG), total cholesterol (TC), cholesterol linked to high-density lipoproteins (HDL-c) and glucose were measured using colorimetric enzymatic methods using a Cardiocheck analyzer. The fraction of cholesterol linked to low-density lipoproteins (LDL-c) was calculated using the Friedewald formula [28]. The precision performance of these assays was within the manufacturer's specifications.

Cardiometabolic risk assessment

We calculated a cardiometabolic risk index (CMRI) as the sum of the age-sex standardized scores of WC, TG, HDL-c, glucose, systolic and diastolic blood pressure. The HDL-c value was then multiplied by -1 as this is inversely related to cardiovascular risk. An age adjusted continuous cardiometabolic risk score (composite z-score) was calculated for each participant as follows:

Composite z-score= z-WC+z-triglycerides+z-HDL-C+z-glucose+z-SBP+zDBP

The components of the score were selected on the basis of the International Diabetes Federation [29] and the modified De Ferranti et al. [30] definitions of metabolic syndrome. High risk was defined as ≥1 SD of this score. The higher the value in the CMRI, the higher the cardiovascular risk. All cut-off values were based on data international school children [31-33].

Statistical analysis

Anthropometric, biochemical profile and MS characteristics of the study sample are presented as means and standard deviations (SD). Normality of selected variables was verified using histograms and Q-Q plots. Differences were analyzed by two-way analysis of variance (ANOVA) *or* Chi-square test (X^2) to explore sex and age differences. Cut-off values were derived mathematically from the ROC curves, using the point on the ROC curve with the lowest value for the formula: $(1\text{-sensitivity})^2 + (1\text{-specificity})^2$. The positive likelihood ratio LR (+) and the negative likelihood ratio LR (-) were used to analyse the potential diagnostic accuracy of the HG (kg)/body mass (kg) to discriminate between low and high CMRI. The area under the curve (AUC) and 95% confidence interval (CI) were calculated. The AUC represents the ability of the test to correctly classify children and adolescents having a low/high CMRI. The AUC values can range between 1 (perfect test) and 0.5 (worthless test). Finally, an ANOVA was used to investigate if cardiometabolic risk differed by MS group by applying the ROC cut point in both gender and age group. Data were analyzed with SPSS for Windows (SPSS, Chicago, Illinois, USA). A *p* value under 0.05 denoted statistical significance.

Results

The 1,950 scholars included 691 boys (54.7% girls 9 to 12.9 years old) and 1,259 girls (56.6% girls 13.0 to 17.9 years old). Their mean age was 12.9±2.3 years. Overall, boys had higher levels of hip circumference, body fat, and triglycerides than girls ($p< 0.001$), whereas girls had lower HG and normalized as strength per body mass ($p < 0.05$). In children girls, the prevalence of overweight and obesity were 26.3% and 9.8%, and 22.7% and 5.5%

in adolescents, respectively ($p < 0.05$), according to the IOTF criteria (Table 1). In children boys, the prevalence of overweight and obesity were 18.3% and 10.9%, and 10.8% and 5.7% in adolescents, respectively ($p < 0.05$).

Table 1. Characteristics of children and adolescents with anthropometric, biochemical profile and muscular strength

	Children n=691			Adolescents n=1259		
	Girls n= 378	Boys n=313	*p value*	Girls n=713	Boys n=546	*p value*
Age (years)	10.1 (0.7)	10.0 (0.8)	0.377	13.14 (0.8)	13.15 (0.8)	0.138
Height (cm)	139.4 (8.5)	138.5 (8.4)	<0.001	152.8 (6.7)	156.18 (9.9)	<0.001
Body mass (kg)	35.5 (8.0)	35.1 (8.2)	0.006	47.4 (8.6)	47.18 (10.0)	<0.001
Body mass index (kg/m^2)	18.0 (2.7)	18.1 (2.8)	0.540	20.2 (2.8)	19.19 (2.8)	<0.001
Weight status n(%) [a]						
Underweight	69 (18.3)	24 (7.7)		101 (14.2)	90 (16.5)	
Normal	173 (45.6)	198 (63.1)	0.027	411 (57.6)	366 (67.0)	<0.001
Overweight	99 (26.3)	57 (18.3)		162 (22.7)	59 (10.8)	
Obesity	37 (9.8)	34 (10.9)		39 (5.5)	31 (5.7)	
Waist circumference (cm)	59.0 (6.8)	61.2 (7.3)	<0.001	64.0 (6.9)	65.32 (6.8)	0.605
Hip circumference (cm)	74.3 (7.7)	73.1 (7.7)	<0.001	85.0 (7.9)	81.41 (7.9)	<0.001
Body fat BIA (%)	24.6 (6.1)	16.2 (6.1)	<0.001	22.7 (6.2)	18.5 (6.6)	<0.001
Tanner stage n(%) [a]						
Pre-puberty	64 (16.9)	69 (22.1)		12 (1.7)	11 (2.0)	
Puberty	312 (82.5)	239 (76.3)	0.001	672 (94.2)	498 (91.2)	0.002
Post-puberty	2 (0.5)	5 (1.6)		29 (4.1)	37 (6.8)	
SBP (mmHg)	109.8 (14.0)	111.2 (13.7)	0.881	109.4 (12.2)	111.5 (14.1)	0,011
DBP (mmHg)	66.6 (8.4)	67.0 (87.9)	0.655	68.2 (8.3)	66.9 (9.0)	0.622
Total cholesterol (mg/dl)	153.7 (30.5)	153.9 (30.0)	0.632	147.7 (28.7)	138.8 (29.6)	<0.001
HDL cholesterol (mg/dl)	48.6 (13.2)	52.1 (12.5)	<0.001	47.5 (11.9)	46.6 (12.3)	0.003
LDL cholesterol (mg/dl)	88.2 (27.0)	86.8 (29.8)	0.908	84.2 (27.1)	82.6 (33.4)	0.006
Triglycerides (mg/dl)	97.4 (67.7)	85.8 (41.8)	0.006	93.9 (50.8)	84.1 (38.8)	0.001
Glucose (mg/dl)	83.3 (14.9)	85.4 (14.7)	0.144	81.5 (15.4)	81.5 (15.4)	0.028
CMRI	0.028 (0.52)	-0.027 (0.48)	0.198	-0.041 (0.48)	-0.018 (0.53)	0.216
Handgrip (kg)	14.9 (3.7)	15.3 (3.6)	0.001	21.1 (4.2)	24.2 (6.9)	<0.001
Handgrip (kg)/body mass (kg)	0.439 (0.08)	0.441 (0.08)	<0.001	0.453 (0.08)	0.521 (0.10)	<0.001

CMRI, cardiometabolic risk index

ROC analyses showed a significant discriminatory accuracy for the identifying the low/high CMRI in both gender and age group (AUC=0.83 (95%CI: 0.71-0.95), $p< 0.001$; boys AUC= 0.84 (95%CI: 0.74-0.94), $p< 0.001$; adolescents girls AUC=0.79 (95%CI: 0.70-0.89), $p< 0.001$; boys AUC= 0.88 (95%CI: 0.68-0.92), $p< 0.001$). In children (9 to 12.9 years

old), handgrip strength (kg)/body mass (kg) values at these points were 0.359 and 0.376 in girls and boys, respectively. In adolescents (13.0 to 17.9 years old), these points were 0.440 and 0.447 in girls and boys, respectively (Table 2).

Table 2. Cut-off between sensitivity and specificity for the normalized grip strength [measured as (grip strength in kg)/(body mass in kg)] to screen for CMRI by sex and group aged

	Children n=691		Adolescents n=1259	
	Girls n= 378	Boys n=713	Girls n=713	Boys n=546
AUC	0.83 (0.71-0.95)	0.84 (0.74-0.94)	0.79 (0.70-0.89)	0.80 (0.68-0.92)
Cut-off	0.359	0.376	0.440	0.447
J-Youden	0.61	0.62	0.48	0.56
Sensitivity	78.6	80.0	92.9	78.9
Specificity	81.9	81.5	55.1	77.0
Positive likelihood ratio	4.34	4.32	2.07	3.43
Negative likelihood ratio	0.26	0.25	0.13	0.27

Thresholds were determined as the corresponding normalized strength at the low/high CMRI, per sex and group categories. Group- and sex-specific thresholds for high strength and low strength are provided in children (Table 3) and adolescents (Table 4), with corresponding anthropometric and biochemical profile differences. In both groups, thresholds may, therefore, be used to categorize individuals into two categories of risk (i.e. low and high risk) on the combined basis of sex and age group and combined grip strength capacity. In children and adolescents, ANOVA showed that there were differences in BMI, all circumferences (waist, hip and mid-upper-arm), adiposity (body fat), and biochemical profile.

Table 3. Sex thresholds for high and low normalized grip strength [measured as (grip strength in kg)/(body mass in kg)], with anthropometric, biochemical profile and CMRI among Colombian children 9 to 12.9 years old.

	Children					
	Girls (n=378)			Boys (n=313)		
	<0.359	≥0.359	*p value*	<0.376	≥0.376	*p value*
Body mass index (kg/m^2)	20.4 (3.5)	17.9 (2.6)	<0.0001	21.0 (4.1)	17.7 (2.6)	<0.0001
Waist circumference (cm)	65.1 (7.7)	60.5 (6.5)	<0.0001	67.7 (9.5)	61.5 (6.6)	<0.0001
Hip circumference (cm)	79.2 (8.6)	75.4 (8.3)	<0.0001	78.4 (9.2)	73.4 (7.7)	<0.0001
Body fat BIA (%)	27.4 (6.5)	21.9 (5.6)	<0.0001	31.3 (8.2)	23.9 (7.4)	<0.0001
Systolic blood pressure (mmHg)	109.7 (14.8)	107.8 (14.5)	0.028	108.5 (13.4)	108.2 (15.5)	0.762
Diastolic blood pressure (mmHg)	66.2 (10.1)	66.4 (10.6)	0.759	66.7 (10.6)	66.6 (11.0)	0.882
Total cholesterol (mg/dl)	154.0 (28.5)	152.1 (29.4)	0.588	150.9 (28.5)	154.2 (30.8)	0.386
HDL cholesterol (mg/dl)	47.0 (12.6)	49.4 (13.3)	0.114	46.9 (11.3)	53.1 (13.2)	<0.0001
LDL cholesterol (mg/dl)	89.5 (27.6)	85.0 (26.2)	0.145	84.6 (25.4)	86.1 (29.8)	0.670
Triglycerides (mg/dl)	103.1 (52.1)	92.7 (41.0)	0.038	100.1 (51.7)	84.0 (42.8)	0.005
Glucose (mg/dl)	86.1 (15.6)	84.0 (15.1)	0.223	89.0 (16.7)	85.1 (16.5)	0.066

Table 4. Sex thresholds for high and low normalized grip strength [measured as (grip strength in kg)/(body mass in kg)], with anthropometric, biochemical profile and CMRI among Colombian adolescents 12.9 to 17.9 years old.

	Adolescents					
	Girls (n=713)			Boys (n=546)		
	<0.440	≥0.440	*p value*	<0.447	≥0.447	*p value*
Body index mass (kg/m^2)	22.8 (3.4)	20.3 (2.6)	<0.0001	22.9 (4.1)	19.7 (2.6)	<0.0001
Waist circumference (cm)	70.1 (7.9)	65.2 (6.4)	<0.0001	72.7 (9.5)	67.7 (6.7)	<0.0001
Hip circumference (cm)	90.3 (8.3)	86.5 (6.8)	<0.0001	88.2 (9.8)	84.5 (8.4)	<0.0001
Body fat BIA (%)	27.4 (6.4)	23.5 (6.1)	<0.0001	21.0 (8.0)	13.8 (5.3)	<0.0001
Systolic blood pressure (mmHg)	111.9 (12.3)	109.7 (13.2)	<0.0001	115.1 (14.4)	113.9 (14.8)	0.176
Diastolic blood pressure (mmHg)	69.5 (9.8)	68.5 (9.7)	0.008	70.4 (9.1)	69.1 (10.8)	0.046
Total cholesterol (mg/dl)	150.2 (31.3)	147.1 (30.4)	0.131	141.8 (35.0)	131.3 (30.0)	0.001
HDL cholesterol (mg/dl)	45.6 (11.2)	48.0 (11.9)	<0.002	42.7 (12.5)	44.3 (10.9)	0.192
LDL cholesterol (mg/dl)	86.1 (27.5)	83.5 (31.6)	0.210	83.5 (35.2)	76.2 (35.1)	0.049
Triglycerides (mg/dl)	105.1 (64.1)	88.7 (35.5)	<0.0001	94.0 (45.5)	82.8 (33.0)	0.003
Glucose (mg/dl)	80.6 (16.4)	81.2 (16.8)	0.554	85.0 (13.5)	82.6 (16.0)	0.151

Discussion

The present study builds on earlier findings about the relationship between MS and cardiovascular disease by examining the predictive ability of different cut-offs for MS in detecting children and adolescents at risk. Thus, our results describe pragmatic MS cut-points reflecting differences in several cardiometabolic risk factors between youth above the thresholds (adequate/high level of MS) and those who did not (low level of MS).

Our results show that among children (9 to 12 years old), cut-offs for handgrip strength/body mass level associated with low metabolic risk were 0.359 and 0.376 in girls and boys, respectively. In adolescents (13 to 17 years old), these cut-points were 0.440 and 0.447 in girls and boys, respectively. The objectives of this study were similar to those of another recent study to determine thresholds of muscular weakness for prediction of cardiometabolic risk factors in a large cohort (n=1,326) of adolescents [27]. In this study, Peterson et al, reported a high-risk threshold for boys (≤0.33) and girls (≤0.28), as well as an intermediate threshold (boys, >0.33 and ≤0.45; girls, >0.28 and ≤0.36). Our results are in agreement with those of Pederson et al, which included a composite score of normalized strength. Although absolute strength testing is certainly more specific to inform exercise prescription, it is not readily viable as a screening tool for a clinical setting.

The ROC curves generated for this study showed acceptable AUC and 95% confidence interval limits, suggesting that the resultant cut-points were not due to chance (all AUC ≥0.79) and distinguished between children and adolescents at high cardiometabolic risk on the basis of HG relative to body weight. Our findings underscore the need for public health interventions to promote MS as a potentially effective strategy for lowering cardiovascular disease risk in later life. As suggested by the World Health Organization physical activity

recommendations [34], MS activities to enhance muscular fitness should be included at least three days a week.

The role of MS has been increasingly recognized in the prevention of chronic disease in adults [3]. Low MS in children and adolescence associated with poorer current cardio-metabolic health, predicts higher cardiovascular risk in adulthood [35] and mortality from total and cardiovascular disease in adulthood [3]. Previous studies have shown that MS is inversely associated with metabolic risk [7], principally in high income countries and largely in Caucasian cohorts [25]. In Colombian schoolchildren of similar social status as the present sample from Bucaramanga city, Cohen et al. [7] showed that poorer HG/body mass was associated with a worse metabolic risk profile, specifically youth in the lowest strength quartile were at three times as likely to have elevated metabolic risk than those in the highest strength quartile. In the present study, youths classified as "low level of MS", displayed significantly higher clustered cardiometabolic risk scores, than those who reached the MS threshold. The exact mechanisms that explain the protective effect of MS on cardio-metabolic risk in young population were not yet established. Steene-Johannessen et al. [6] hypothesized that the apparent protective effect of MS in children and adolescents could be a function of puberty, however these authors reported an association also in prepubertal children and both sexes.

There are some limitations to this study. The cross-sectional design prevents us from establishing a causal relationship. Also, the ROC analysis does not enable adjustments for potential confounders within the model, and data were not adjusted prior to ROC analysis. The thresholds were not applied to a different cohort of youths from the population that the ROC curves were originally generated to determine the usefulness of these. Finally, study

participants were teenagers and hand size can be influenced by height, which could have an effect in MS values. However, we applied a standard protocol to avoid measurement errors. However, the inclusion of a large number of subjects of the same age and the objective measurement of MS and biochemical parameters are notable strengths of this study. Also, the HG strength test is a simple, low cost method of assessing MS its use is urged at a population level.

Conclusion

Our study identifies MS cut-points associated with high cardiometabolic risk in youth. These cut-points are the first to be based on the widely used HG assessment and provide a highly useful tool for classifying young population at risk of cardiometabolic disease. Longitudinal studies are needed to establish the incidence of cardiovascular and metabolic diseases later in life based on MS levels during childhood and adolescence, especially in low-middle income countries.

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