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Handgrip Strength and Ideal Cardiovascular Health among Colombian Children and Adolescents

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Objective To evaluate the association between handgrip strength and ideal cardiovascular health (CVH) in Colombian children and adolescents.

Study design During the 2014-2015 school years, we examined a cross-sectional component of the FUPRECOL (Association for Muscular Strength with Early Manifestation of Cardiovascular Disease Risk Factors among Colombian Children and Adolescents) study. Participants included 1199 (n = 627 boys) youths from Bogota (Colombia). Handgrip strength was measured with a standard adjustable hand held dynamometer and expressed relative to body mass (handgrip/body mass) and as absolute values in kilograms. Ideal CVH, as defined by the American Heart Association, was determined as meeting ideal levels of the following components: 4 behaviors (smoking status, body mass index, cardiorespiratory fitness, and diet) and 3 factors (total cholesterol, blood pressure, and glucose).

Results Higher levels of handgrip strength (both absolute and relative values) were associated with a higher frequency of ideal CVH metrics in both sexes (P for trend ≤ .001). Also, higher levels of handgrip strength were associated with a greater number of ideal health behaviors (P for trend < .001 in both boys and girls), and with a higher number of ideal health factors in boys (P for trend < .001). Finally, levels of handgrip strength were similar between ideal versus nonideal glucose or total cholesterol groups in girls.

Conclusions Handgrip strength was strongly associated with ideal CVH in Colombian children and adolescents, and thus supports the relevance of early targeted interventions to promote strength adaptation and preservation as part of primordial prevention. *(J Pediatr 2016;■■:■■-■■).*

See related article, p •••

Low muscular strength, as determined by handgrip dynamometry, is a recognized marker of poor health during adolescence,[1,2] and is associated with disease and mortality in adulthood.[3-5] Numerous studies support an inverse relationship between muscular strength and cardiovascular disease (CVD) risk factors in young populations, and generally express muscular strength relative to body mass.[1,6] Epidemiological studies indicate that muscle weakness has been associated with a higher frequency of adverse health consequences including obesity, systemic low-grade inflammation, and insulin resistance.[7-10] CVD events occur most frequently during or after the fifth decade of life, and yet the precursors of disease originate in childhood and adolescence.[1,11]

In response to the increasing burden of CVD risk factors, the American Heart Association established several strategic goals.[12] In 2010, the American Heart Association released a set of cardiovascular health metrics for adults and children that were intended to prioritize cardiovascular health, as opposed to CVD.[12] Population-representative studies have shown a low prevalence of ideal cardiovascular health (CVH) metrics in US children and adolescents, particularly for achieving physical activity recommendations and dietary intake.[13,14] Data from the Cardiovascular Risk in Young Finns Study and The Healthy Lifestyle in Europe by Nutrition also demonstrated that children and adolescence with a higher number of ideal CVH components had a reduced risk for hypercholesterolemia, hypertension, and elevated blood glucose.[15] Increases in ideal CVH are directly associated with aortic elasticity[16] and healthier levels of cardiorespiratory fitness (CRF) in adolescents.[17] Among adults, a recent systematic review[18] reported an inverse association between number of ideal CVH metrics and early all-cause and CVD-related mortality. Improved understanding of the health risks associated with muscle weakness will help to inform the development of targeted interventions for different phenotypes.

BMI	Body mass index
CRF	Cardiorespiratory fitness
CVD	Cardiovascular disease
CVH	Cardiovascular health

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Obesity and physical inactivity are leading CVD risk factors among Hispanic/Latino adults, raising concerns about whether an increased risk of these conditions also is manifested at younger ages.[19] Previous research has demonstrated an independent association between muscle weakness and increased cardiometabolic risk factors.[20,21]

In Colombia, a region that has undergone a well-documented epidemiologic transition and epidemic of CVD,[19-22] relatively little research on physical activity[22] and physical fitness exists.[23,24] Therefore, describing the magnitude of these risk factors in youth is important for prioritizing prevention and public health efforts.[19] Nevertheless, there have been no studies to date to determine the association between handgrip strength and ideal CVH in Latin American youth. Therefore, the objective of the present study was to investigate the relationship between handgrip strength and ideal CVH among Colombian children and adolescents.

Methods

This study aimed to examine the relationships between physical fitness levels, healthy and unhealthy behaviors, and cardiometabolic risk factors in Colombian children and adolescents. During the 2014-2015 school years, we examined a cross-sectional component of the FUPRECOL (Association for Muscular Strength with Early Manifestation of Cardiovascular Disease Risk Factors among Colombian Children and Adolescents) study[25-27] (in Spanish, Asociación de la FUerza PREnsil con Manifestaciones de Riesgo Cardiovascular Tempranas en Niños y Adolescentes COLombianos). The sample consisted of children and adolescents (boys n = 4000 and girls n = 4000) aged 9-17.9 years. Blood sampling was randomly performed in one-third of the recruited subjects (n = 2775). From this subgroup, 1199 schoolchildren (52.2% boys) had valid data muscular strength and all components included in the ideal CVH concept. There were no differences in the study key characteristics (ie, age, sex distribution, body mass index [BMI], and muscular strength) between the current study sample and the original FUPRECOL (Association for Muscular Strength with Early Manifestation of Cardiovascular Disease Risk Factors among Colombian Children and Adolescents) study sample (n = 8000; all $P > .100$). The children and adolescents were of low to middle socioeconomic status (1-3 defined by the Colombian government), enrolled in public elementary and high schools (grades 5-11), and from 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).

Measurements

Handgrip Strength Assessment. Consistent with recommendations,[28,29] we restricted our analysis to the following health-related[30] field-based tests that have demonstrated adequate levels of criterion-related validity, and reliability[27-29] in the assessment of 2 dimensions of muscular strength: handgrip strength and normalized handgrip strength in kg/body mass in kg.[31-33] Handgrip was measured using a standard adjustable hand held dynamometer (Takei Digital Grip Strength Dynamometer Model T.K.K. 540, Takei Scientific Instruments Co, Ltd, Niigata, Japan). Participants were given a brief demonstration and verbal instructions for the test and, if necessary, the dynamometer was adjusted to the participant's hand size according to predetermined protocols.[27] Handgrip strength 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 as hard as possible for a maximum of 3-5 seconds, and no verbal encouragement was given during the test. Handgrip strength performance was recorded as the best score from either hand, 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 [ie, (grip strength in kg)/(body mass in kg)]. Handgrip measurements in a subsample (n = 229; median age: 12.8 ± 2.4 years; 46.2 ± 12.4 kg; 1.50 ± 0.1 m; 19.9 ± 3.1 kg/m^2) were recorded to ensure reproducibility on the day of the study. The reproducibility of our data was R = 0.96. Intrarater reliability was assessed by determining the intraclass correlation coefficient (0.98; 95% CI, 0.97-0.99). Monthly, each dynamometer was tested using a standardized calibration procedure that showed that the device was within 1 kg of accuracy over the whole measuring range (from 0 to 100 kg), and with a 100-g sensitivity.

Anthropometric Measurements. 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 (technical error of measurement = 0.510%). Height was measured using a mechanical stadiometer platform (Seca 274, Hamburg, Germany; technical error of measurement = 0.01%). BMI was calculated as the body weight in kilograms divided by the square of height in meters (kg/m^2). Obesity status was defined as having a BMI above the age- and sex-specific thresholds of the International Obesity Task Force.[34] Participants who had a BMI < 85th percentile were categorized as meeting the ideal CVH criteria for BMI.

Biochemical Determinations. Blood samples were collected between 6:00 a.m. and 8:00 a.m. by 2 experienced pediatric phlebotomists after ≥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. In children and adolescence, levels of total cholesterol have been defined as "ideal" < 4.40 mmol/L (<170 mg/dL), or "nonideal" ≥ 4.40 mmol/L (≥170 mg/dL). Fasting serum glucose concentrations were analyzed enzymatically and also classified as ideal < 5.6 mmol/L (<100 mg/ dL), or nonideal ≥ 5.6 mmol/L (≥100 mg/dL). Interassay reproducibility (coefficient of variation) was determined from 80 replicate analyses of 8 plasma pools over 15 days, and shown to be 2.6% for total

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cholesterol and 1.5% for serum glucose. None of the study youths were on any drug treatments.

Resting Blood Pressure. Blood pressure was measured using an electronic oscillometric device (Riester Ri-Champion model, Jungingen, Germany) after being seated in a quiet room for 10 minutes with their back supported and feet on the ground. Two blood pressure readings were taken with a 10-minute interval of quiet rest. Before blood pressure session monitoring, the accuracy of the device was tested against a standard mercury sphygmomanometer in a random subsample (n = 25) to ensure that there was no consistent difference of >10 mm Hg in measured blood pressure; interobserver variability was R = 0.96. Mean systolic blood pressure was defined as ideal (<90th percentile and mean diastolic blood pressure of <90th percentile), or nonideal (systolic blood pressure ≥ 90th percentile or diastolic blood pressure ≥ 90th percentile). All percentile-based threshold limits were sex and age specific, and selected on the basis of the International Diabetes Federation[35] and the modified De Ferranti et al[36] definitions of the metabolic syndrome.

Dietary Assessment. Dietary intake and food consumption was assessed by the Kidmed questionnaire.[37] This tool consists of 16 questions related to the principles of Mediterranean dietary patterns. The score ranges from −4 to 12 points, because questions with negative connotations with respect to the Mediterranean diet are assigned a value of −1 (frequent intake of fast food, increased consumption of sweets, skipping breakfast, frequent intake of pastries for breakfast). Variables with positive connotations are assigned +1 point (eg, takes a fruit or fruit juice every day, consumes fish regularly [≥2-3 times/week]), as indicated previously.[37] As suggested by Serra-Majem et al,[37] the total score was divided into 3 categories of Mediterranean diet quality: (1) ≤ 3 points = poor diet quality, (2) 4-7 points = average diet quality, and (3) ≥8 points = good diet quality (optimal Mediterranean diet style). Participants who had ≥8 points were categorized as having an ideal healthy diet, whereas children and adolescents with <7 points were classified as having a nonideal healthy diet.

Cardiorespiratory Fitness. Although the American Heart Association relied on physical activity to determine active habits, we used estimated CRF owing to its robust association with cardiovascular risk factors,[38] and ideal CVH[12,17] in this population. We estimated CRF with the 20-meter shuttle run test, as previously described by Leger et al.[39] Participants ran in a straight line between 2 lines 20 meters apart, while keeping pace with prerecorded audio signals. The initial speed was 8.5 km/h and increased by 0.5 km/h each minute. The test was finished when the participant failed to reach the end lines, keeping pace with the audio signals on 2 consecutive occasions, or when the subject stopped because of fatigue. Results were recorded to the nearest stage (minute) completed. Healthy CRF was defined by using either the cutoff by sex and age (shuttle-runs or estimated peak rate of oxygen consumption) listed in the healthy fitness zone (needs improvement and health risk). The FITNESSGRAM[40] has been shown to have cardiometabolic health predictive value,[41] and peak rate of oxygen consumption cutoff points were validated against the presence of metabolic syndrome using nationally representative US data.[41,42]

Smoking Habits. Data on smoking were collected via self-reported questionnaires (number of cigarettes smoked per day). Students who reported that they had never smoked were categorized as having an ideal smoking status and those who reported having smoked one or more cigarettes were categorized as presenting a nonideal smoking status.

Sexual Maturation. Sexual maturation was classified based on Tanner staging,[43] which uses self-reported puberty status to classify participants into stages I-V.[44] 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 sexes) using a set of images exemplifying the various stages of sexual maturation. The reproducibility of our data reached R = 0.78.

Ideal CVH

The metrics for ideal CVH in children and adolescents defined by the American Heart Association[12] were followed as precisely as possible (**Table I**; available at www.jpeds.com). Finally, each participants was categorized into 5 health levels based on the number of ideal CVH metrics in the ideal range: the healthiest level (favorable ideal CVH score) was defined as having ≥5 metrics, the intermediate levels as 2 to 4 metrics in the ideal range, and the unfavorable level as having 0-1 ideal CVH metrics. We collapsed 0 with 1 and 5 with 7 ideal metrics owing to relatively few youths who had 0 (2% of total cohort) or 6 (8% of total cohort) and 7 (2% of total cohort) ideal CVH metrics.

Ethics Statement. The Review Committee for Research on Human Subjects at the University of Rosario (Code N° CEI-ABN026-000262) approved all of the study procedures. A comprehensive verbal description of the nature and purpose of the study and its experimental risks was given to the participants and their parents/guardians. Written informed consent was obtained from parents and subjects before participation in the study. The protocol was in accordance with the latest revision of the Declaration of Helsinki and current Colombian laws governing clinical research on human subjects (Resolution 008430/1993 Ministry of Health).

Statistical Analyses

Data are presented as mean values, standard deviations, and percentages. The *t* test was used to compare unadjusted means by sex. Differences on handgrip strength (both absolute and normalized handgrip strength in kg/body mass in kg) between ideal and nonideal CVH components were assessed by ANCOVA, with handgrip strength as a dependent variable, the CVH component (ideal vs nonideal) entered as a fixed factor, age as a covariate, and sexual maturation as a random factor. The association between handgrip strength and ideal CVH metrics, as well as with ideal CVH behaviors and factors separately, was assessed by ANCOVA, as discussed. Analyses were

Table II. Characteristics of children and adolescents in Bogota, Colombia (mean [SD] or frequencies), by sex

	Girls (n = 572)	Boys (n = 627)	All (n = 1199)
Age (y)	12.9 (2.2)	13.3 (2.2)	13.1 (2.2)
Body mass (kg)	42.1 (9.0)	45.8 (11.3)	44.0 (10.4)
Height (cm)	149.3 (10.2)	155.7 (13.7)†	152.6 (12.5)
BMI (kg/m^2)	18.6 (2.3)	18.5 (2.0)	18.6 (2.2)
Tanner stage prepuberty/ puberty/postpuberty, (%)	7/89/4	6/84/10	6/86/8
Resting blood pressure (mm Hg)			
Systolic	106.4 (11.1)	109.6 (12.4)	108.0 (11.9)
Diastolic	66.3 (7.7)	66.0 (8.0)	66.1 (7.8)
Glucose (mg/dL)	78.3 (13.3)	79.7 (12.9)	79.1 (13.1)
Total cholesterol (mg/dL)	140.9 (21.9)	133.3 (24.6)†	136.9 (23.6)
Mediterranean diet adherence (–4 to 12 points)	7.1 (2.0)	7.0 (1.8)	7.0 (2.1)
CRF (mL/kg/min)	41.1 (3.9)	45.6 (4.7)†	43.5 (4.9)
Muscular strength			
Handgrip strength (kg)	19.6 (5.4)	25.3 (9.2)†	22.6 (8.2)
Normalized grip strength*	0.47 (0.08)	0.54 (0.11)†	0.51 (0.10)

*Handgrip strength/body mass.
†The *t*-test was applied to compare unadjusted means by sex ($P < .001$).

conducted for boys and girls separately. The associations between normalized handgrip strength in kg/body mass in kg and 4 behaviors (smoking status [number of cigarettes smoked per day], BMI, CRF [shuttle-runs], and diet [score ranges from –4 to 12 points]) and 3 factors (total cholesterol, blood pressure, and glucose) were tested by means of Pearson correlation coefficients. All analyses were performed using the Statistical Package for Social Sciences (v. 22.0 for Windows, Chicago, Illinois), and the level of significance was set to .05.

Results

The 1199 subjects included 627 boys, and mean age was 13.1 (2.2) years. Boys had lower levels of total cholesterol than girls ($P < .001$), and girls had lower CRF, handgrip strength, and normalized handgrip strength ($P < .001$) (**Table II**). Higher levels of handgrip and normalized handgrip strength were associated with an higher number of ideal CVH components in both boys (P for trend < .001) and girls (P for trend < .001) (**Figure 1**). Higher levels of handgrip strength were associated with a higher number of ideal health behaviors (P for trend < .001 in both boys and girls), and with a higher number of ideal health factors in boys (P for trend < .001) (**Figure 2**).

Levels of handgrip strength (both handgrip and normalized handgrip strength) were different between ideal versus nonideal components except for glucose or total cholesterol groups in girls (**Table III**). Overall, similar results were observed when we included physical activity instead of CRF (data not

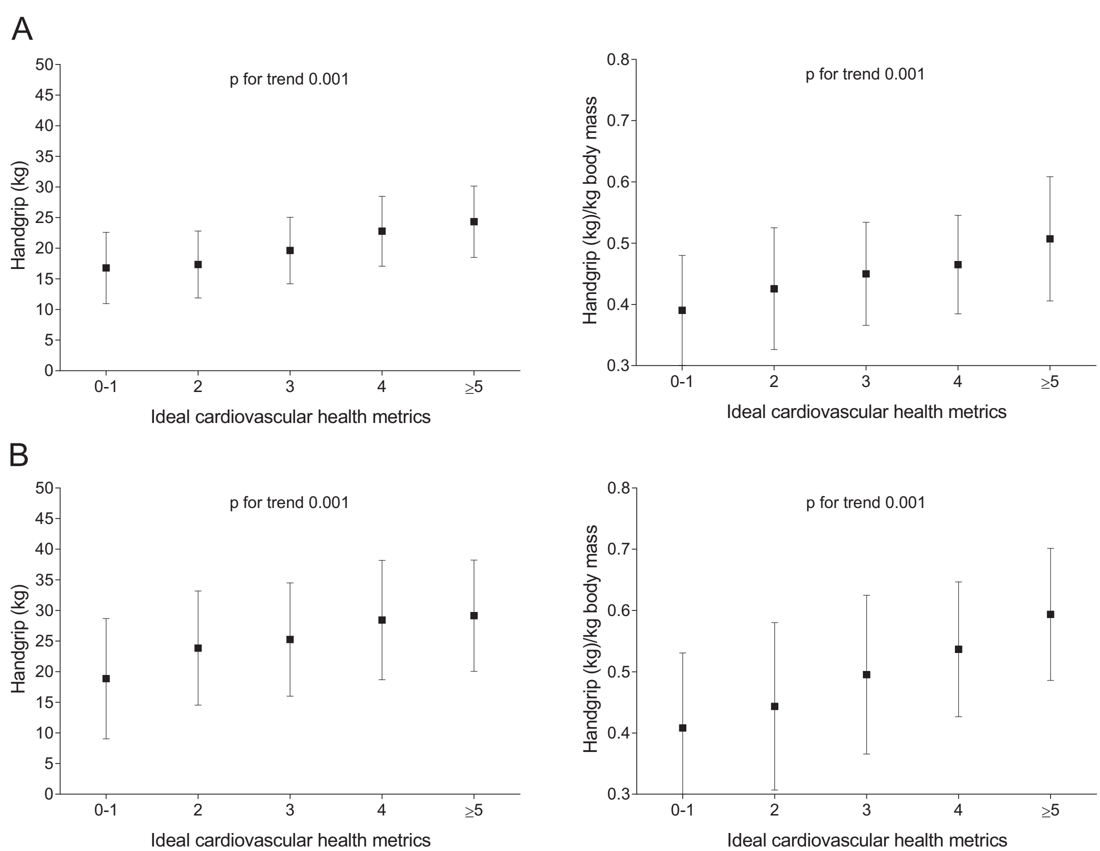

Figure 1. Association between handgrip strength and normalized grip strength (measured as grip strength in kg/body mass in kg) across ideal CVH metrics in schoolchildren. **A,** Boys and **B**, girls.

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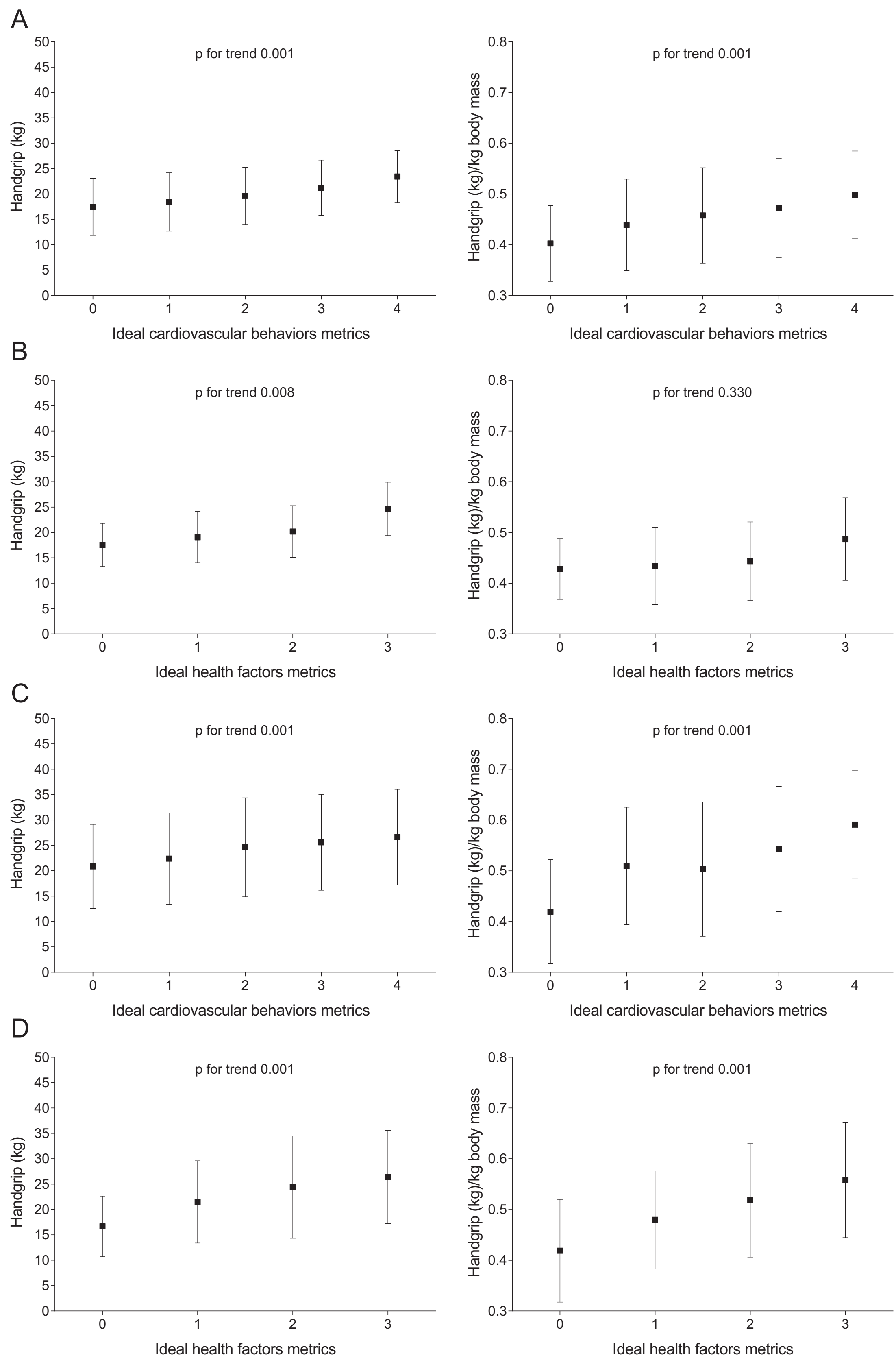

Figure 2. Levels of handgrip strength and normalized grip strength (measured as grip strength in kg/body mass in kg) across ideal CVH behaviors (smoking, BMI, CRF, and Mediterranean diet adherence) and ideal health factors (total cholesterol, blood pressure, and plasma glucose) in schoolchildren; **A, B**, Boys and **C, D,** girls.

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Table III. Handgrip (kg) and normalized grip strength (measured as handgrip strength/body mass) mean and SE estimates by ideal CVH metrics, by sex

	Girls (n = 572)								Boys (n = 627)							
	Ideal	Mean (SE)		Nonideal	Mean (SE)		*P* value*		Ideal	Mean (SE)		Nonideal	Mean (SE)		*P* value*	
	N/%	HG	HG/BM	N/%	HG	HG/BM	HG	HG/BM	N/%	HG	HG/BM	N/%	HG	HG/BM	HG	HG/BM
Health behaviors																
Smoking	217/38	19.6 (0.3)	0.461 (0.004)	355/62	18.7 (0.4)	0.472 (0.005)	.001	.001	307/49	25.8 (0.5)	0.534 (0.006)	320/51	24.7 (0.5)	0.554 (0.006)	.001	.001
BMI	538/94	19.6 (0.2)	0.469 (0.003)	34/6	19.7 (0.8)	0.397 (0.011)	.123	.022	609/97	25.3 (0.3)	0.546 (0.004)	18/3	22.9 (2.2)	0.449 (0.021)	.001	.001
CRF	440/77	20.6 (0.4)	0.465 (0.006)	132/23	19.4 (0.3)	0.469 (0.003)	.001	.001	545/87	26.0 (0.9)	0.545 (0.011)	82/13	25.2 (0.4)	0.544 (0.004)	.001	.001
Mediterranean diet adherence	103/18	19.9 (0.2)	0.465 (0.004)	469/82	18.4 (0.5)	0.464 (0.008)	.001	.001	94/15	25.8 (0.4)	0.548 (0.005)	533/85	22.4 (0.9)	0.518 (0.011)	.001	.001
Health factors																
Blood pressure	532/93	19.7 (0.2)	0.465 (0.003)	40/7	18.0 (0.7)	0.460 (0.011)	.001	.001	577/92	25.2 (0.4)	0.545 (0.004)	50/8	23.9 (1.7)	0.513 (0.017)	.001	.001
Glucose	561/98	20.6 (1.8)	0.482 (0.027)	11/2	19.8 (0.2)	0.464 (0.003)	.498	.090	602/96	25.6 (0.4)	0.545 (0.004)	25/4	23.0 (1.9)	0.540 (0.019)	.001	.001
Total cholesterol	538/94	19.9 (0.2)	0.464 (0.003)	34/6	19.2 (0.9)	0.471 (0.013)	.594	.298	596/95	25.9 (0.4)	0.547 (0.004)	31/5	18.3 (1.1)	0.492 (0.016)	.001	.001

HG, handgrip (kg); *HG/BM*, normalized grip strength (measured as handgrip strength/body mass).
*From analysis of covariance with age as covariate and Tanner stage as random factor.

shown). Finally, in both sexes, we found an inverse correlation between normalized grip strength and number cigarettes smoked per day (r = −0.356; $P < .01$), BMI (r = −0.604; $P < .01$), CRF (r = −0.424; $P < .01$), diet score (r = −0.104; $P = .45$), total cholesterol (r = −0.238; $P < .01$), blood pressure (r = −0.220; $P < .05$), and glucose (r = −.016; $P < .01$).

Discussion

The findings of the present study indicate that handgrip strength is associated positively with the ideal CVH index among Colombian children and adolescents. The importance of muscular strength is recognized in most current recommendations for maintaining and improving health status, and preventing chronic diseases.[45] A recent meta-analysis highlights the importance of developing muscular strength in youth for a number of health-related benefits in young population.[32] Also, our study suggests a positive link between ideal CVH metrics and handgrip (for both absolute and relative values). Although there are very few studies on this topic, Ruiz et al[17] showed that higher levels of CRF were associated with a higher number of ideal CVH components in both boys and girls. These findings together with our results confirm that physical fitness should be considered a hallmark factor for meeting ideal CVH components.

Several studies have showed the relationship between individual components included in the ideal CVH and handgrip strength in children and adolescents. Because the American College of Sports Medicine recently recommended the incorporation of grip strength testing as a component of musculoskeletal fitness assessment in children,[46] it is important to not only understand the link between variability in this measured outcome and that of health risks, but also from the context of translating meaningful risk stratification information to clinical and public health audiences. Moreover, a recent systematic review and meta-analysis revealed strong evidence for an inverse association between musculoskeletal fitness and cardiometabolic risk factors among adolescents.[32]

Regarding health behaviors, there is a well-established link between BMI, physical activity, CRF, and muscular strength.[47] However, there is less evidence pertaining to the relationship between handgrip strength and healthy dietary adherence in younger populations. Therefore, considering the limited number of studies that have previously examined these associations, it is difficult to compare our results. A cross-sectional study in Spanish adolescents showed that there was no relationship between handgrip strength and ideal diet; the authors hypothesized that results seemed to be more associated with physical activity levels and aerobic capacity at these ages.[48] Regarding smoking habits, the small number of available studies has shown inconsistent results. A previous study reported that smoking habits were not related with handgrip strength[48]; however, another Spanish study in children and adolescents suggests that those who had muscle weakness had a significantly higher odds ratio of reporting smoking tobacco sometimes.[49] In our study, we found an inverse correlation between normalized grip strength and number cigarettes smoked per day (r = −0.356; $P < .01$). Cross-sectional and longitudinal studies showed that

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smoking affects the body through, for example, increased oxidative stress, which negatively influences the muscles.[3,5,50] Circulating cigarette smoke constituents seem to play an important role in the underlying molecular mechanisms of muscle damage, such as reduced oxygen delivery and impair mitochondrial function.[51]

These findings are particularly important from a public health perspective, given the well-known negative consequences of smoking and the fact that this behavior starts already at young ages. Regarding health factors, the role of muscular strength in prevention of CVD has become increasingly recognized.[39] Our results show higher values of handgrip strength in children and adolescents who had ideal health factors as compared with peers who did not meet that ideal condition. The exception for this was for total cholesterol and glucose in girls, which could be explained by the small number of youth with nonideal factors (2% and 6%, respectively).

The present findings lend strong support to the growing body of literature revealing a link between muscle weakness and increased cardiometabolic risk factors[7-10]; and yet, the mechanisms underlying this association are still to be determined. It has been hypothesized that a possible mechanism by which healthy muscular strength exerts favorable health effects may be its capacity to reduce chronic low-grade inflammation. In the Pan-American HELENA study (Healthy Lifestyle in Europe by Nutrition in Adolescents), Artero et al[9] found an inverse association between muscular strength with lower levels of markers of chronic inflammation such as C-reactive protein, complement factors C3 and C4, leptin, and white blood cell counts in adolescents, even after adjusting for sex, age, CRF, maturation, and socioeconomic status. In addition, Steene-Johannessen et al,[7] Cohen et al,[8] and Peterson et al[52] reported strong evidence of the inverse associations between muscular strength and cardiometabolic risk factors such as Homeostasis Model Assessment index, triglycerides, and blood pressure, positive associations with markers of endothelial function, and lower arterial stiffness. Differences in body distribution of excess adiposity could be another explanation; studies suggest that muscular strength is a stronger influence on cardiometabolic abnormalities.[17,19,31,33] However, further research is needed to confirm these mechanisms, especially in the pediatric population.

The observations of our study are limited by the descriptive and cross-sectional design; therefore, direction of causality cannot be determined. Another limitation was that adherence to the Mediterranean diet was measured by a self-administered questionnaire, so some of the questions may have been misinterpreted deliberately or unintentionally by some participants. Future research is needed to better describe the age- and sex-specific trajectories of strength as a predictor of comorbidities across the lifespan and, perhaps just as important, to apply robust analyses that can compartmentalize risk into hierarchical categories.[52] Finally, it should also be noted that the formation of the ideal CVH metrics relies on the use of binary variables and on the assumption that all health behaviors and factors contained in this index contribute the same to the final score.[17]

The findings of this study indicate that handgrip strength is positively associated with ideal CVH metrics in Colombian youths. These results provide an important public health message that children and adolescents do not necessarily have to reach all 7 metrics to gain CVH benefits. Moreover, the data suggest that preventive efforts should be focused on those with few ideal health behaviors or factors, and should target early development of handgrip strength to reduce the risk of premature health problems. ■

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Table I. Definition of the ideal cardiovascular health metrics (<20 years of age) as defined by the American Heart Association and the criteria used in this study

	Ideal metric, American Heart Association definition	Ideal metric, definition in this study
Health behaviors		
Smoking	Never tried; never smoked whole cigarette	Never smoked a cigarette
BMI	<85th percentile	<85th percentile
Physical activity	≥60 min of moderate- or vigorous-intensity activity every day	Healthy CRF was defined by using either the cut-off by sex- and age (shuttle-runs or estimated VO_{2peak}) listed in the healthy fitness zone
Diet	4-5 components:	Mediterranean diet quality
	Fruit and vegetables: ≥ 4.5 cups/d	Participants who had ≥8 points were categorized as having an ideal healthy diet
	Fish: 2 or more 3.5-oz[‡] servings/wk	
	Fiber-rich whole grains: 3 or more 1-oz-equivalent servings/d	
	Sodium: < 1500 mg/d	
	Sugar-sweetened beverages: ≤ 450 kcal (36 oz)/wk	
Health factors		
Total cholesterol	<170 mg/dL (<4.40 mmol/L)	<170 mg/dL
Blood pressure	<90th percentile	<90th percentile
Plasma glucose	<100 mg/dL (<5.6 mmol/L)	<100 mg/dL

VO_{2peak}, peak rate of oxygen consumption.

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