

Geographical Distribution, Socioeconomic Status and Health-Related Physical Fitness in Adolescents From a Large Population-based Sample From Bogotá, Colombia: The SER Study

By

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A thesis submitted to the School of Medicine and Health Science of Rosario University
in partial fulfillment of the requirements for the degree of Master of Physical Activity
2016

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Abstract

Background: The negative gradient between socio-economic status and prevalence of non-communicable disease in adulthood has prompted investigation of potential foundations based in childhood. The objective of the present study is to examine the influence of socio-geographical variations and socioeconomic status on health-related physical fitness in adolescents from a large population-based sample of Colombian ninth graders.

Methods: During the 2014–2015 school years, we examined a cross-sectional component of the SER Study is a cross-sectional Body mass, height, muscular fitness (standing broad jump and handgrip tests) and cardiorespiratory fitness (20 m shuttle-run) were measured in n=52,204 14–16-year-olds. Area-level socioeconomic status was categorized from 1 to 6. A model was built by means of a step-by-step process and gradient maps were created to show physical fitness in the quartiles and the trend of physical fitness across disaggregated in Zonal Planning Units (in Spanish UPZ) in Bogotá, for each of the five health-related physical fitness variables.

Results: Socioeconomic status was used as the only group-level variable and this had a significant effect on the models for all health-related physical fitness parameters except for handgrip. Cardiorespiratory fitness, standing broad jump, and body mass index increased 6.31, 2.69, and 1.45 times, respectively, on average with the maximum increase in socioeconomic status categories, when we compared two random individuals in each stratum.

Conclusions: Our results suggest a significant association between health-related physical fitness variables and socio-geographical location in ninth grade adolescents from Bogotá, using a multilevel methodological approach.

Key words: Socioeconomic status, Muscular strength, Cardiorespiratory fitness, Schoolchildren, Epidemiology.

Background

Physical fitness (PF) can be defined as a set of attributes that gives the ability to perform physical activity (1). In this context, PF has two close meanings: a health-related meaning regarding the condition of health and well-being, and a skill-related meaning which is more task-oriented based on the ability to perform specific aspects of sports or occupations (2). Health-related components of PF include body composition, flexibility, cardiorespiratory fitness (CRF), musculoskeletal strength (e.g., muscle endurance, muscle strength, muscle power), and endurance (3). Agility, balance, coordination, power, reaction time, and speed are components of neuromotor skill-related fitness (4).

Substantial evidence indicates that adolescents' low PF levels are markers of their lifestyles (5) and cardio-metabolic health profiles and also a predictor of the future risk of chronic diseases (6). Excess adiposity, and low CRF or musculoskeletal fitness in particular, are independently associated with poor cardio-metabolic health in youth (7). An excess of adiposity results from an imbalance between energy intake (diet) and expenditure (physical activity—PA); but PF is primarily the product of the type and quantity of habitual PA, modulated by genetic and early life (epigenetic) influences (8). According to several studies, compared with PA, PF is a more potent indicator of cardio-metabolic health status (5, 6), which also tracks more strongly from childhood into adulthood (8). Moreover, in many of these studies the results are not presented independently from the adiposity parameters such as body mass index (BMI), body fat mass, etc., potentially confounding variables of the relationship between PF—even the variable socioeconomic status (SES). However, it is not entirely clear whether such factors can affect aspects of body composition and, therefore, PF (9).

The distribution of health-related PF across the population is not homogenous and has been found to differ, for example, according to gender, SES, and ethnicity, as well as area of residence (2). For example, Petroski et al. (10) examined differences in multi-component fitness score according to SES in Brazilian children. Compared with mid-SES and high-SES groups, children from low-SES families were

40% less likely to meet fitness standard criteria. In addition, several studies examining differences in PA, PF, and overweight among rural and urban children show that children from rural areas and small cities were more active than urban children (2, 11, 12).

Latin-America, like many other regions of the world, has experienced an epidemiological transition characterized by a decreasing burden of malnutrition and infectious diseases and a corresponding increasing burden of non-communicable diseases related to shifts in diet and lifestyle (13). This change has been especially profound in Colombia, due to a rapidly developing high middle income country fast-adopting ‘westernized’ dietary habits and lifestyles, including increased consumption of energy-dense foods, increased sedentary time, and lower levels of physical activity (14).

Information about the regional distribution of health-related PF status is necessary in order to tailor public health interventions, because a number of behavioral health risks have been established in late childhood and early adolescence, including sedentary behavior and lack of strenuous exercise (1, 2, 15). On the other hand, in high income countries, low-SES is a recognized risk factor for childhood and adult obesity. In transitional countries, westernized lifestyles are more likely to be adopted in urban areas; these also contain more high-SES neighborhoods (13, 16). The objective of the present study is to examine the influence of socio-geographical variations on health-related physical fitness in adolescents from a large population-based sample of Colombian ninth graders.

Methods

Study sample and design

This cross-sectional study was based on a representative sample of Bogotá, Colombia ninth grade students (median [IQR range] age 15 [14–16] years) sampled in the 2015 40x40 Curriculum and The SER Study (17) administered by the District Secretary of Education in November 2015. In 2012, the “Bogotá Humana”, a developmental policy (2012–2016) aimed at improving the life of citizens in Bogotá (Colombia) with a strong focus on early life, was introduced (17). One of the strategies in place is the

40x40 Curriculum. The 40x40 Curriculum strategy seeks to progressively extend regular school time to 40 hours a week, 40 weeks a year (18). The main objective of The SER Study strategy is to use the school as a setting to promote equity in terms of education and health access among low SES adolescents living in Bogotá. The second objective of The SER Study is to establish the general prevalence of cardiovascular risk factors (including CRF, musculoskeletal strength, and body composition) in the study population (ninth grade students) living in Bogotá, Colombia. Data was collected in 498 schools across 20 districts and full details are provided in Table 1.

Data was collected beginning in September 2015 in $n=20$ research groupings. The researchers ($n=6$ researchers per group) involved are each specialized in a specific area of knowledge: (a) Center of Studies in Physical Activity Measurements, School of Medicine and Health Sciences, University of Rosario and (b) District Education Secretary (DES), Bogotá, DC. In total $n=55,915$ students were considered for PF evaluation from 20 districts (“*localidades*”) of Bogotá, Colombia. Due to erroneous data entry, student disability, student temporary illness or injury, student chronic illness, or student absenteeism, DES limited the sample to $n=52,204$ students. All adolescents were SES 1 (lower) to SES 6 (higher; as determined by a scale by the Colombian government) and enrolled in public or private high schools in the capital district of Bogotá, Cundinamarca Department, in the Andean region. This region is located at approximately $4^{\circ}35'56''\text{N}$ $74^{\circ}04'51''\text{W}$ and at an elevation of approximately 2,625 m (range 2,500–3,250 m) above sea level. Bogotá is considered an urban area, with approximately 7,862,277 inhabitants (19). Between 70% and 75% of the capital district of Bogotá ninth-grade-age students are enrolled in school. 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.

Valid cases were considered to be those with valid data for standing broad jump (SBJ), handgrip (HG), and accompanying anthropometric and demographic information. We removed $n=437$ cases due

to missing HG; n=1,758 due to missing or invalid horizontal SBJ data. We removed n=22 participants for which neither an age nor a valid date of birth had been recorded for them and we also removed n=61 participants over the age of 18 years. Either height or weight was missing in n=168 cases. A further n=1,265 duplicate cases (identical school roll number and name) were also removed. The final sample comprised n=52,204 participants aged 15 (± 1) years of whom 51% (n=26,630) were males.

Geographical Distribution

The Territorial Zoning Plans establish units of territorial division at the municipal and district level with the purpose of defining and specifying precisely the planning and use of urban land. Such divisions have different names which vary according to the zoning plan of each municipality or district. The regulations established in the UPZ (Zonal Planning Units) have a lower regulatory hierarchy than the Territorial Zoning Plans. The UPZs (name adopted for Bogotá) seek to respond to the dynamics of the municipality or district and its insertion in the regional context, involving the social actors in the definition of different aspects of zoning and control. In this study, we created gradient maps to show the PF in each quartile and their trend across UPZ, for each of the five health-related PF variables.

Physical fitness

These parameters were measured as described previously and specific aspects regarding validity (20) and reliability (15) have been reported elsewhere in the assessment of three dimensions of physical fitness: the 20 m shuttle run test (20mSRT) to estimate peak oxygen consumption ($\dot{V}O_{2peak}$, ml·kg⁻¹·min⁻¹), SBJ, HG, and BMI, to assess body composition. CRF was assessed by the 20mSRT, as described by Leger et al. (21); participants ran in a straight line between two lines 20 m apart in time with pre-recorded signals. The initial speed of 8.5 km·h⁻¹ increased by 0.5 km·h⁻¹ each minute and the test was terminated when participants failed to reach the end lines (i.e., keep pace) on two consecutive occasions or when the subject stopped due to volitional fatigue. The protocol tends to elicit a maximal response in children and

adolescents, irrespective of which criterion results in the termination of the test (21). Results were recorded to the nearest stage (minute) completed. In the SBJ, students jumped as far as possible, standing with feet shoulder-width apart. The student was encouraged to flex and extend their knees, ankles, and hips and jump with a simultaneous oscillation of the arms. The farthest of two scores was recorded as the distance between toes at take-off and heels at landing, or whichever body part landed nearest to take-off. Maximal HG was assessed using an adjustable analogue handgrip dynamometer, the T-18 TKK SMEDLY III® (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 according to the child's hand size according to predetermined protocols (22, 23).

Morphological component

Variables were collected at the same time in the morning, between 7:00–10:00 a.m., following an overnight fast. During the anthropometric measurements, students wore light clothing and were barefoot. During weight measurement, the student stood on the scale for 5 seconds with feet hip-width apart. Weight was measured to the nearest 0.1 kg. During standing height measurement, the student stood with heels together and heels touching the base of the stadiometer and head positioned in the Frankfort plane with eyes looking straight ahead. Height was measured to the nearest 0.1 cm. BMI was calculated as the body weight in kilograms, divided by the square of the height in meters. Weight status was defined as having a BMI above or below the age and sex-specific thresholds of the International Obesity Task Force (IOTF) (24) and expressed as z-scores based on the CDC global reference data (25). Waist circumference (WC) was measured with the patient in the standing position without clothing at the midpoint level of the mid-axillary line between the 12th rib head and the superior anterior iliac spine, using a tape measure.

Data collection, ethical, and legal aspects

Prior to carrying out the assessments of the study, researchers and field practitioners performed six theoretical and practical sessions to standardize the evaluation process and to minimize inter-observer variability. The Review Committee for Research on Human Subjects at the University of Rosario (Code N° CEI-ABN026-000262) approved the study. A comprehensive verbal description of the nature and purpose of the study was given to the adolescents and their parents/guardians. However, the participants and their parents were informed that the information could be accessed by the Colombian Health Authorities under the Law of Data Protection (Resolution 8430/93). All participants and their parents/legal guardians provided written informed consent before partaking in the study. The study was conducted according to the ethical standards established in the 1961 Declaration of Helsinki (as revised in Hong Kong in 1989 and in Edinburgh, Scotland, in 2000). All assessments were performed by trained staff.

Statistical analysis

Health-related PF characteristics of the study sample are presented as means, standard deviations (SD), or frequencies. Normality of selected variables was assessed using histograms and Q-Q plots. Differences were analyzed by two-way analysis of variance (ANOVA) or Chi-square test (χ^2) to explore sex and age differences. With the aim of studying the effects of neighborhoods on PF and anthropometric outcomes, we conducted a multilevel model design and used multiple data sources. This examined the association between neighborhood markers and CRF, muscular fitness, sex, and age, controlled by SES strata at a community level. Statistically, the model was built by means of a step-by-step process. In addition, we created gradient maps to show the PF in each quartile and their trend across UPZ (26), for each of the five health-related PF variables. A median *odd ratio* (MOR) was also calculated as a measure of heterogeneity in PF markers across UPZs. This measure can be understood as the MOR obtained by

choosing 2 random persons with the same covariates but from different UPZs and computing the OR between them (27).

Results

Descriptive statistics for each sex are shown in Table 1. Mean values for body mass were close to reference values in both sexes, but stature was below expected both in boys ($z=-0.42$) and girls ($z=-0.76$). Girls were more likely to be overweight or obese than boys, but fewer girls were underweight. As expected, boys performed better on all the tests of muscular fitness (SBJ and HG) when performance was expressed in absolute values. These differences persisted when SBJ and HG were expressed as z-scores. Boys also scored higher on our test of CRF (20 m shuttle-run) but conversion of running speed to z-scores eliminated the between-sex difference in performance.

Table 1. Socio-geographic and physiological characteristics of ninth grade students from Bogotá.

Characteristics	Boys, n=25,562	Girls, n=26,625
	Mean <i>or</i> % SD <i>or</i> (n)	Mean <i>or</i> % SD <i>or</i> (n)
Morphological component		
Age	15.1 \pm 1.01	14.9 \pm 0.94
Stature (cm)	165.7 \pm 7.23	156.4 \pm 5.78
Stature (z-score)	-0.42 \pm 0.94	-0.76 \pm 0.90
Mass (kg)	56.0 \pm 9.6	53.5 \pm 8.6
Mass (z-score)	-0.15 \pm 0.94	0.06 \pm 0.85
BMI (kg·m ⁻²)	20.3 \pm 2.85	21.8 \pm 3.16
BMI (z-score)	-0.02 \pm 0.91	0.43 \pm 0.78
Underweight (-3, -2, -1)	6.9% (1,759)	4.0% (1,062)
Normal Weight (0)	80.1% (20,464)	72.9% (19,433)
Overweight/Obese (1,2)	13.0% (3,339)	23.1% (6,130)
Waist circumference	69.5 (6.9)	68.7 (7.1)
Muscular Fitness		
Standing broad jump (cm)	177.2 \pm 26.0	128.1 \pm 20.6
Standing broad jump (z-score)	-0.17 \pm 0.88	-0.39 \pm 0.77
Handgrip (kg)	33.6 \pm 6.85	24.9 \pm 4.29

Handgrip (z-score)	-0.50 ± 0.90	-0.32 ± 0.92
Cardiorespiratory Fitness		
Total Shuttles (n)	47.0 ± 17.8	24.2 ± 11.4
Speed (km/h)	11.07 ± 0.97	9.78 ± 0.68
Speed (z-score)	-0.54 ± 0.72	-0.53 ± 0.65

Legend: BMI z-scores calculated using the WHO/CDC reference values; Underweight, Normal Weight Overweight, and Obese classified using the International Obesity Task Force criteria. Standing broad jump: best from two attempts, z-scores according to predetermined protocols [25, 26].

Geographical variation by physical fitness and body composition

Figures 1–3 show quartile distribution for health-related PF data by sex and geographical areas (UPZ distribution). With regard to BMI, boys were more likely to have elevated BMI classified as quartile 4 (12.3% boys vs. 1.0% girls) while the prevalence of lower BMI (quartiles 1 and 2) was more prevalent in girls (Figure 1). Colombian ninth graders with abdominal obesity (quartiles 3 and 4) are more likely to be girls than boys (16% vs 6%, $p < 0.001$). Girls were more likely to have a HG, SBJ, and CRF classified as quartile 1 or 2 while the prevalence of higher muscular strength (quartiles 3 and 4) was more prevalent in boys.

Figure 1. Quartile distribution for body mass index and waist circumference among Colombian ninth grade students by UPZ areas in Bogotá.

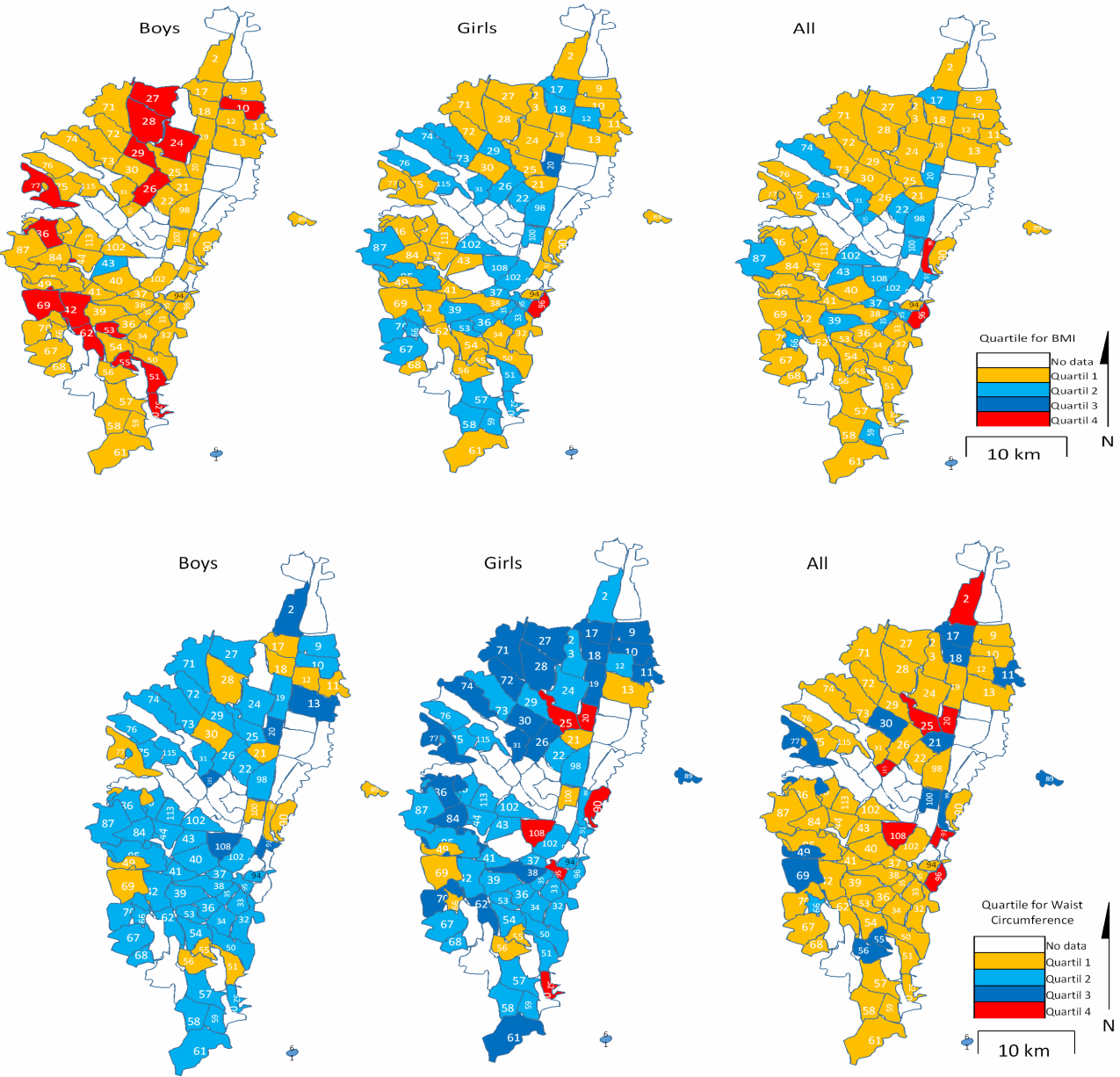


Figure 2. Quartile distribution for muscular fitness among Colombian ninth grade students by UPZ areas in Bogotá.

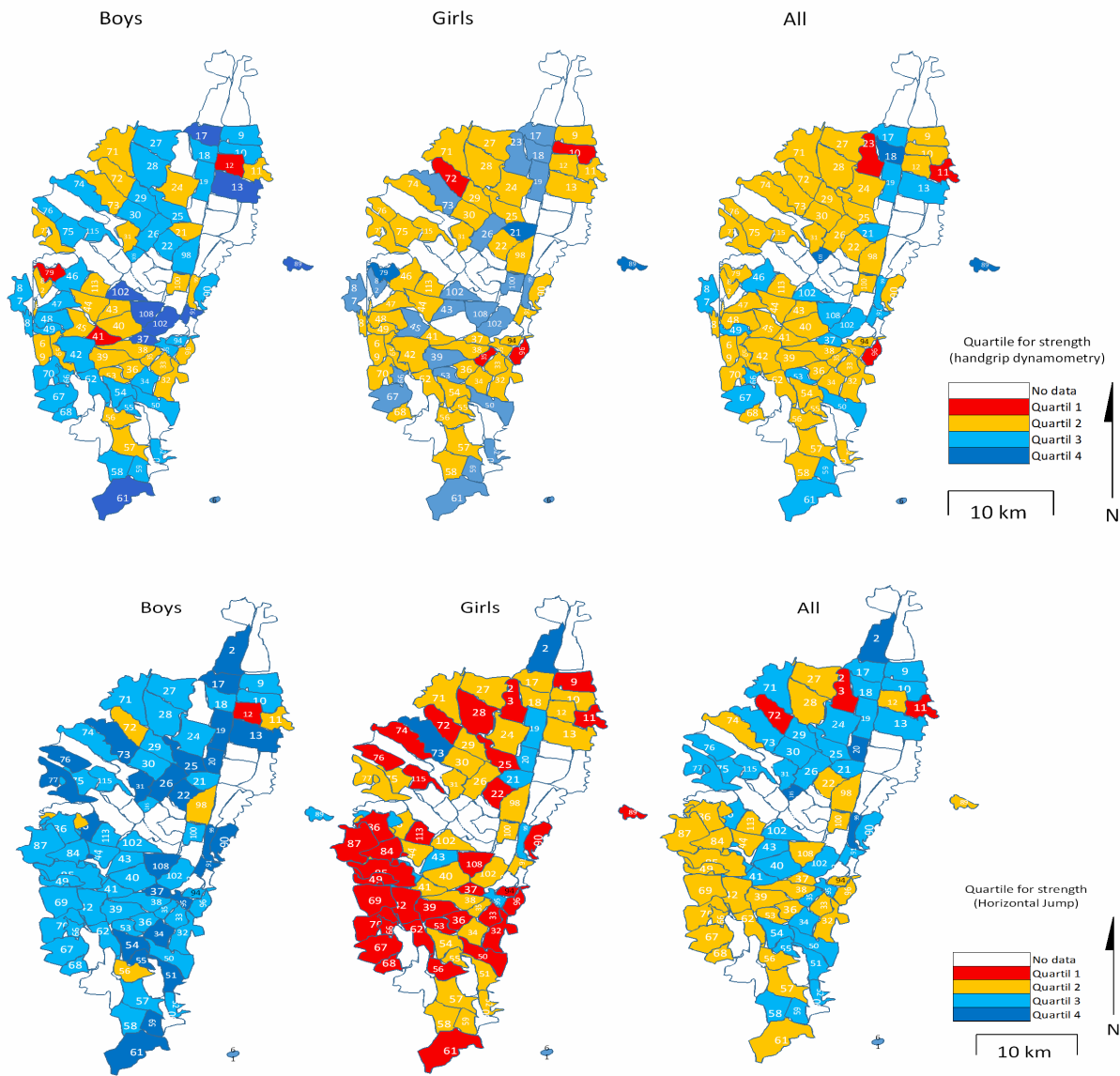
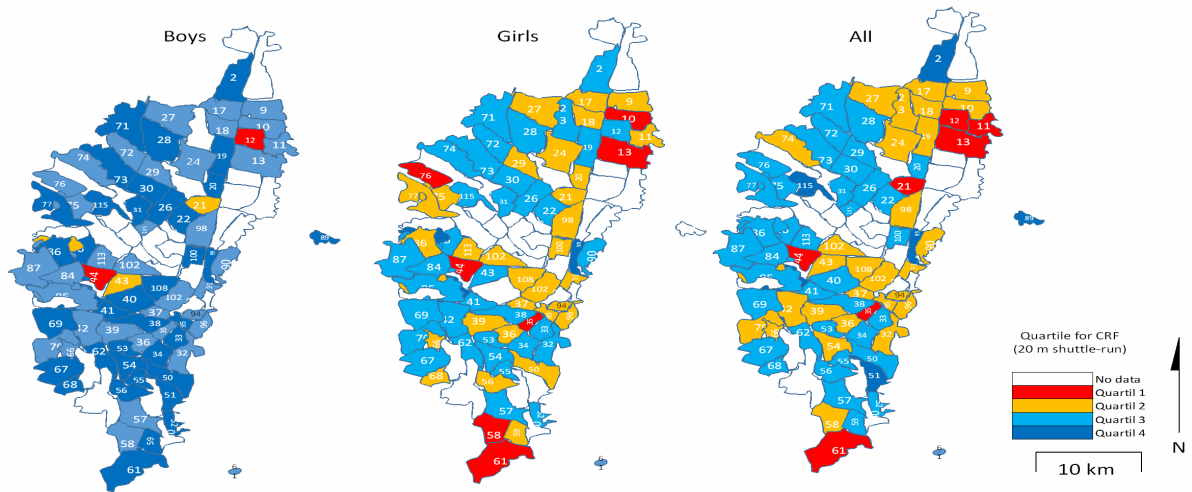


Figure 3. Quartile distribution for cardiorespiratory fitness among Colombian ninth grade students by UPZ areas in Bogotá.



Multilevel model by physical fitness and socio-geographical factors

Table 2 shows the adjusted analysis by sex and age for each PF measured variable. SES, which was used as the only group-level variable, had a significant effect for all models except for handgrip. The estimates show that the multilevel MOR of CRF increased 6.31 times on average with the maximum increase among SES categories, considering from the comparison two random individuals in each stratum. In addition, the group-level variables which had significant participation were BMI 1.45 and WC 0.58. With regard to the inclusion of cross-level interaction terms, these had minimal effects on the contribution of individual-level and regional-level variables and were very limited because of the small sample sizes in the first-level analysis. Furthermore, the inclusion of the first-level (UPZ-level) variables had minimal effect on the MOR estimated for individual-level variables. This supports the nonexistence of cross-level interactions in the model and also the independent effect of the UPZ-level effect with variations in the prevalence of PF across the studied zones of Bogotá.

Table 2. Combined associations between physical fitness and socio-geographical factors among Colombian ninth grade students from Bogotá.

Predictor variables	Sex		Age		Constant		Random – Effects Strata	
	β	CI 95%	β	CI 95%	β	CI 95%	β	CI 95%
Cardiorespiratory Fitness (Shuttles)	6.85 p<0.001	6.42 to 7.27	- 1.26 p=0.01	-2.03 to 5.01	53.25 p<0.001	41.05 to 65.46	6.31 p<0.001	5.18 to 7.69
Standing Broad Jump (cm)	47.02 p<0.001	45.20 to 48.85	3.70 p=0.014	0.75 to 6.64	62.00 p=0.009	15.33 to 108.66	2.69 p<0.001	1.50 to 4.81
BMI (z-score)	- 1.35 p<0.001	-1.46 to 1.23	0.250 p=0.005	0.08 to 0.43	17.83 p=0.009	15.03 to 20.63	1.45 p<0.001	1.10 to 1.93
Waist Circumference (cm)	1.33 p< 0.001	1.00 to 1.66	0.87 p=0.002	0.33 to 1.41	54.39 p=0.009	45.84 to 62.94	0.58 p<0.001	0.34 to 1.00
Handgrip (kg)	1.00 p=0.991	0.74 to 1.33	0.98 p=0.94	0.62 to 1.55	1.03 p=0.71	0.84 to 1.22	1.33 p=0.99	0.00 to 1.78

Legend: Analyses adjusted by age, sex, socioeconomic status, and type of school. β , standardized coefficients; CI, Confidence Interval; BMI, Body Mass Index.

Discussion

We used data from more than 50,000 adolescents from Bogotá, Colombia to examine the influence of socio-geographical and SES variations on health-related PF. Our results suggest a significant association between the levels of PF variables at an individual level and SES through a multilevel approach methodology. Specifically, findings indicate that variables such as CRF, BMI, and SBJ are positively associated with higher levels of SES; by contrast, a worse performance was indicated by the model with regard to WC.

Rapid adoption of a westernized lifestyle in middle-income countries is a major public health concern as chronic diseases such as diabetes are increasing more rapidly compared with high-income countries (28). Area-level SES provides information about the inhabitants, as well as their history, class, accumulation of capital, and other aspects shaping health. SES and PF are important determinants of health, which in high-income countries are also positively correlated with one another (29). The scarce data available from low-to-middle-income countries is more heterogeneous, suggesting that youth from

either mid- (20) or high-SES (10, 30) families may be fitter than low-SES groups. To date, studies from low-to-middle-income countries have not attempted to disentangle the complex web of geographical and anthropometric factors, which may interact with SES as a determinant of health-related PF. Our findings support those of previous studies, highlighting geographical variations and SES in PF and body composition of youth (31-36); however, the scientific evidence for this is conflicting (10, 37). Discrepancies among studies could be due to the specific social and cultural contexts of each country, together with the different methodologies used to assess PF and SES levels.

Youth PF is influenced at different levels by a range of individual and social factors, as well as community, environmental, and policy-level factors (38). In our multilevel analysis, the study shows that the variation in the levels of selected PF variables might be partly explained by the SES composition of the populations and, in particular, according to the SES measures in the city. This result was consistent with previous findings in studies of PA in different populations (39, 40). In our case, the biggest effect was associated with CRF, indicating that the effect of area-level SES on CRF may be mediated only partly by individual SES, as assessed by UPZs. Studies in adult populations confirm our results; Lakka et al. (41) showed an inverse relationship between CRF and individual-level SES (education, income, and occupation), using an incremental ergometer cycle test. Similarly, Shishenbor et al. (42) showed a strong relationship between low neighborhood SES and impaired CRF in 2,505 healthy adults aged 25 to 42 years old, as measured through a symptom-limited graded treadmill incremental exercise test. Scientific evidence on these matters is conflicting and provides mixed results. The Pan-European Healthy Lifestyle in Europe by Nutrition in Adolescence Study (10) shows large differences between high-SES and low-SES for both sexes, while more modest differences were reported in the Food and Assessment of the Nutritional Status of Adolescents Study in girls, using parental profession rather than parental level of education as an SES level (37). In contrast, the Madeira Growth Study (36) analyzed 507 subjects of 5 cohorts and reported no difference between SES (parental occupation, education, income, and housing)

in CRF. A possible explanation for this could be that differences in area-level SES can provide walkability, which is a measure of the PA-promoting ability of the local environment, known to be correlated with CRF, regardless of area level SES (43). Also, youth in these areas may be more dependent on, or responsive to, facilitated PA (e.g., reliant on parents as drivers to access team sport facilities) rather than unassisted active play (44). In this regard, previous studies have also found that low-SES area residents have less positive perceptions of their physical environment (44). In summary, these findings support studies that used PF measurements suggesting an SES gradient such as community health status indicators.

With regard to muscular strength, several studies have analyzed its relationship with SES level. In Bogotá, we found no significant association between the variation of handgrip and SES level, but unlike SBJ. In contrast, the Pan-European Healthy Lifestyle in Europe by Nutrition in Adolescence Study (34) found slightly better handgrip in mid- and high-SES children compared to low-SES. Petroski et al. (10) found lower SES children were less likely to meet the criteria of strength and PF standards than those in mid-SES and high-SES groups. However, in relation to lower body muscular strength (SBJ), the Food and Assessment of the Nutritional Status of Adolescents Study and the Madeira Growth Study reported a positive association between SES and lower-SBJ in boys (37) and girls (36), respectively. Therefore, it can be suggested that area-level SES is a stronger moderator of Colombian adolescents' fitness.

This study also has various strong points that should be highlighted. First, a strength of this study is the large sample size. Second, was the measurement of PF using standardized tests. The data is representative of school students in Bogotá, Colombia. However, given schools were sampled from only public schools the generalizability of the findings to other school systems, or other jurisdictions is limited. The SER Study was deployed in collaboration with the Bogotá District Education Department, which only has jurisdiction among public schools. Another limitation is the cross-sectional design prevented us from

making cause–effect inferences. Finally, socio-geographical area may influence the PA of adolescents, but was not analyzed in this study.

Conclusion

Our results suggest a significant association between the levels of selected PF variables at an individual level in ninth grade students in Bogotá and SES through a multilevel approach methodology. The findings of the current study may enhance our understanding of PF in the adolescent population and the role of ecological variables in its development. This information can be used to help set policies and provide programs aimed at improving fitness and decreasing obesity risk among low-income children. Such information could be useful in targeted obesity prevention initiatives; for example, in setting priorities and ascertaining in which countries or contexts public health messages (e.g., “take electronic media out of the bedroom”) may have more impact. Further research is needed in order to better understand the mechanisms that underlie these variations and to identify other factors that contribute to the variation in individual PF levels, especially in developing countries where knowledge about the phenomenon is sparse.

Competing Interests

The authors declare that they have no competing interests.

Funding

The “SER Study” was possible given the financial support provided by Secretaria de Educacion Distrital (Code 300-2014). The content of this paper reflects the author’s views alone, and the Colombian Community or the Universidad del Rosario is not liable for any use that may be made of the information contained herein.

Acknowledgements

The authors are grateful to the Bogota District Education Department for supporting data collection for this study. The authors also thank the participating Bogota District students, teachers, schools, and staff.

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