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Association between high blood pressure and fitness and fatness in adolescents

Presión arterial alta asociada con condición física y adiposidad en adolescentes

Carlos Mario Arango-Paternina[1], **Felipe Lobelo**[2], **Diana Carolina Páez-Rubiano**[3], **José Alberto Petro-Petro**[4], **Mauricio Llano-Garcia**[5,6], **John Duperly-Sanchez**[3,7], **Diana Parra**[8]

[1] Universidad de Antioquia - Instituto Universitario de Educación Física - Medellín - Colombia.
[2] Emory University - Emory Global Diabetes Research Center - Hubert Department of Global Health - Atlanta, GA - USA.
[3] Universidad de los Andes - School of Medicine - Bogotá D.C. - Colombia.
[4] Universidad de Córdoba - Faculty of Education and Human Sciences - Department of Physical Culture - Montería - Colombia
[5] Centro Médico de los Andes - Department of Pediatrics - Bogotá D.C. - Colombia.
[6] Universidad El Bosque - School of Medicine - Department of Pediatrics - Bogotá D.C. - Colombia.
[7] Fundación Santa Fe de Bogotá - Bogotá D.C. - Colombia.
[8] Washington University in St. Louis - School of Medicine - Physical Therapy Program - St. Louis, MO - USA.
Corresponding author: Carlos Mario Arango-Paternina. Instituto Universitario de Educación Física, Universidad de Antioquia. Carrera 75 No. 65-87, Ciudadela Robledo, bloque: 45, oficina: 45-103. Teléfono: +57 5 219-9269. Correo electrónico: carlos.arangop@udea.edu.co.

Abstract

Introduction: Excess adiposity is considered the most important risk factor for high blood pressure (HBP) in children and adolescents.
Objectives: To explore the association between HBP and overweight (OW) and abdominal obesity (AO), mediated by cardiorespiratory fitness (CRF). To analyze the combined effect of excess adiposity and CRF on HBP among a sample of school-aged children from Montería, Colombia.
Materials and methods: Cross-sectional study conducted in a sample of 546 adolescents aged between 11 and 18 years from 14 randomly selected schools in Montería. Blood pressure, anthropometric, and fitness measures were evaluated by trained personnel using standardized protocols and instrumentation. The association of HBP with fitness and fatness was analyzed using logistic regression models.
Results: HBP was associated with OW, AO and low CRF. The inclusion of CRF in this model did not attenuate the association between HBP and OW and between HPB and AO. Adolescents with higher adiposity and low CRF were more likely to have HBP compared with those with lower adiposity and high CRF. Moreover, it was found that excess adiposity and low CRF had an additive effect on the risk for HBP among the sample.
Conclusion: HBP is a prevalent condition in children and adolescents from Montería, Colombia. HBP is significantly associated with OW, AO, and low CRF; therefore, it is necessary to implement initiatives to promote healthy habits aimed at this population in order to reduce the incidence rate of HBP in Colombian adolescents.
Keywords: Cardiovascular Diseases; Adiposity; Obesity (MeSH).

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Resumen

Introducción. El exceso de adiposidad es considerado como el factor de riesgo más importante para la presión arterial alta (PAA) en niños y adolescentes.
Objetivos. Explorar la asociación entre PAA y sobrepeso (SP) y obesidad abdominal (OA), mediada por condición física cardiorrespiratoria (CFC), y analizar el efecto combinado de la adiposidad excesiva y la CFC en la PAA en una muestra de escolares de Montería, Colombia.
Materiales y métodos. Estudio transversal realizado en 546 adolescentes con edades entre 11 y 18 años de 14 escuelas seleccionadas aleatoriamente en Montería. Se evaluó la presión arterial, los indicadores antropométricos y la condición física; las mediciones fueron realizadas por personal capacitado mediante el uso de protocolos e instrumentos estandarizados. La asociación de PAA con condición física y adiposidad fue analizada a través de modelos de regresión logística.
Resultados. Se encontró una asociación entre PAA y SP, OA y baja CFC. La inclusion de la CFC en el modelo no atenuó la asociación entre PAA y SP y entre PAA y OA. Los adolescentes con mayor adiposidad y baja CFC fueron más propensos a presentar PAA que aquellos con menor adiposidad y alta CFC. Además, se observó que la presencia de adiposidad excesiva y baja CFC aumenta el riesgo de desarrollar PAA.
Conclusión. La PAA es una condición prevalente en niños y adolescentes de Montería, además se encontró una asociación estádisticamente significativa entre PAA y SP, OA, y baja CFC, por lo que es necesario que en el país se implementen estrategias que promuevan hábitos saludables en escolares y permitan reducir la tasa de incidencia de PAA en esta población.
Palabras clave: Enfermedades cardiovasculares; Adiposidad; Obesidad (DeCS).

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Introduction

High blood pressure (HBP) is a critical risk factor for cardiovascular disease,[1] and it is one of the main leading causes of premature mortality in Latin America.[2] In the Americas region, the most recent estimations indicate that HBP affects 26.3% of males and 19.7% of females.[3] Specifically in Latin America, the prevalence of HBP ranges from 9 to 29%,[4] and in Colombia, 34.3% of males and 26.5% of females suffer from this condition.[3] Multiple epidemiological studies have been carried out to follow up the development of this disease from childhood into adulthood.[5]

In the last decade, the presence of HBP in children and adolescents has increased.[6] Previously considered a risk factor for adult populations, it is now reaching important proportions among teenagers. For instance, Ostchega *et al.*[7] documented an increase in HBP prevalence between 1994 (11.6%) and 2002 (13.9%) among adolescents aged 13 to 17 years. Similarly, a study conducted in León, Mexico, found a prevalence of 20.7% among adolescents aged 12 to 15 years.[8] HBP results from an interaction of genetic factors and several environmental factors[9] that appear early during childhood, including excessive sedentary behaviors (i.e., playing video games and watching television for long periods),[10] and accessibility to fast food and sugary drinks,[11] thus increasing cardiovascular risk factors.

Accelerated urbanization processes in Latin America have been associated with the high burden of non-communicable diseases.[12] In fact, the prevalence of overweight among adolescents in Colombia increased from 12.5% in 2005 to 15.5% in 2010 and 17.9% in 2015.[13] In addition, since 1998, cardiovascular disease is the main cause of death in the department of Córdoba, located in the Caribbean region of the country.[14]

Poor fitness and excess adiposity during childhood and adolescence are closely correlated to HBP in adulthood.[15,16] Actually, excess adiposity is considered a major risk factor for HBP in children and adolecents.[17] However, the independent effects of poor physical fitness and excess adiposity are masked because they often occur in combination; hence, it is unclear what condition exerts greater influence on cardiovascular risk factors.[18] In this regard, it has been documented that cardiorespiratory fitness (CRF) may attenuate the effect of excess adiposity on blood pressure.[15] This study explores the association between HBP and overweight (OW) and abdominal obesity (AO), analyzes whether these associations are mediated by CRF, and assesses the combined effect of excess adiposity and CRF on HBP among a sample of adolescents from Montería, in the department of Córdoba, Colombia.

Materials and methods

This is a school-based, cross-sectional study carried out in the city of Montería, Colombia, in 2008. Montería's population is close to 382 000 inhabitants, and some estimations show that nearly half of the population has a low socioeconomic status, 11.5% has not received a formal education, and 39.5% is below the poverty line.[19] This scenario negatively impacts children's and adolescents' health status and leads to an increased risk of developing chronic diseases.

Sampling design

The study included 546 adolescents aged 11 to 18 years from Montería, Colombia. The study design, and other design characteristics, were reported in a previous paper.[22] Based on the school records of the municipality, 14 schools were randomly selected, and considering the proportion of the size of each school for the sample frame (13 413 students registered), 578 students were randomly selected. Only the students who gave their informed assent and whose parents signed the informed consent form required to take part in the study were finally included for analysis (n=546). The study protocol was reviewed to ensure it complied with the ethical principles for medical research involving human subjects outlined by the Declaration of Helsinki,[20] and the administrative, technical and scientific standards regarding health research established by Resolution 8430 of 1993 issued by the Colombian Ministry of Health.[21] Moreover, the Central Research Committee of the Universidad de Córdoba granted its approval for the development of this research by means of the unnumbered minutes issued on August 23, 2007.

Measurements

Eight physical education teachers were trained to obtain blood pressure and anthropometric measurements (height, weight, and waist circumference), conduct the fitness test (20m shuttle run test), and administer questionnaires to the participants. To ensure reliability, each measurement was made by the same teacher.

Outcome variable

Systolic and diastolic blood pressure was measured by auscultation with a standard aneroid sphygmomanometer (Welch Allyn®) and using an upper arm cuff suitable for use in children. The blood pressure measurement protocol was followed according to the National High Blood Pressure Education Program recommendations.[23] HBP was defined as mean systolic blood pressure and diastolic blood pressure at or above the 90th percentile for sex, age, and height.[23]

Anthropometric measures

Height (SECA® stadiometer) and weight (Health-O-Meter® scale) were assessed as per standardized protocols. Body mass index (BMI) percentiles were computed using the Centers for Disease Control and Prevention (CDC) growth charts.[24] Based on the sex and age reference, overweight was identified in those students with a BMI percentile equal or greater than the 85th percentile.[24]

Waist circumference was measured following the standardized protocol with a measuring tape. The reading was taken at the end of a normal breath. The waist-to-height ratio (WHtR) was calculated as height (cm) divided by waist circumference (cm). Abdominal obesity (AO) was defined as a WHtR value above 0.5.[25]

Fitness test

Cardiorespiratory fitness (CRF) was measured using the multi-stage fitness test,[26] which is useful to estimate aerobic capacity (VO_2 max). Participants were asked to run a distance of 20m, with a progressive increase in the level of intensity marked by a sound that indicated rate increments. Participants had to run from one line to another according to the sound. The test finished when the student did not reach the 3m zone placed ahead of each 20m line at the moment of the audio signal for two consecutive times. The validity and reliability of this test have been already reported.[27] FITNESSGRAM® standards by sex and age were used to classify participants into two levels: high CRF for those who met the CRF standards for healthy fitness zone, and low CRF for those who did not.[28]

Physical activity, sedentary behaviors, and dietary intake measures

The physical activity (PA) and dietary behavior questionnaires of the Global School-based Student Health Survey (GSHS-2006) were administered to the sample of students. The GSHS was developed by the World Health Organization and has been used in Latin American countries such as Colombia, Venezuela, Peru, Ecuador, Chile, and Argentina.[29] This tool includes questions about PA, eating, and sedentary behaviors such as use of television, computers and videogames.

PA was measured with the question: During the past 7 days, on how many days were you physically active for at least 60 minutes per day? Response choices included: 0 days, 1 day, 2, 3, 4, 5, 6, and 7 days. These responses were dichotomized as physically active for those who engaged in PA during 7 days, and inactive for the rest of answers.

In addition, students reported how much time they spent watching TV during a typical school day. Seven choices were provided (I do not watch TV during school days, less than 1 h/day, 1 h/day, 2 h/day, 3 h/day, 4 h/day, 5 or more h/day). Responses were dichotomized as high TV viewing time (≥2 h/day) and low TV viewing time (<2h/day).[30]

The frequency of fruit and vegetable consumption was measured with two separate questions: During the past 30 days, how many times per day did you eat fruits/vegetables? For both questions, response options included: I did not eat fruits/vegetables during the past 30 days, less than one time per day, 1 time per day, 2, 3, 4, and 5 or more times per day. The answers to both questions were added and participants were categorized into high frequency of fruit and vegetable consumption, if the adolescent reported a frequency of combined fruit and vegetable consumption of 5 or more servings per day.[31]

Sociodemographic covariates

Information about age and sex were collected. School type, private or public, was utilized as a proxy for socioeconomic status.

Data analysis

The descriptive characteristics of the sample were analized through t-test and chi-square tests. Participants were grouped into 4 fitness categories for each adiposity measure (OW and AO) and CRF levels. The 1st category was the reference group, comprised of the participants with normal adiposity and high CRF; the 2nd category included adolescents with normal adiposity and low CRF; the 3rd category was made up of participants with high adiposity and high CRF; and the 4th category had high adiposity and low CRF.

The association between HBP and predictors was analyzed using logistic regression models. Strength of association was calculated with odds ratios (OR) and the corresponding confidence intervals (95%). All models were studied separately for OW and AO. The confounding variables included in the models were area of residence (urban and rural), type of school (public or private), sex, CRF, PA level, TV viewing time, and consumption of fruits and vegetables. The combined effect of excessive adiposity and CRF on HBP was analyzed using logistic regression models for OW and AO for the three defined categories, separately, to compare them with the reference group. Analyses were conducted with the STATA statistical software, V.10.0.

Results

Subject characteristics were stratified by sex and are presented in Table 1. Compared with girls, boys had significantly higher values in height ($t=5.4$; $p<0.001$), weight ($t=2.2$; $p<0.01$), systolic ($t=6.7$; $p<0.001$), and diastolic blood pressure ($t=3.2$; $p<0.001$), BMI ($t=-0.65$; $p<0.01$), CRF ($t=-3.8$; $p<0.001$), and number of days per week of PA ($t=0.65$; $p<0.001$). HBP was identified in 20.3% of students, being more prevalent in girls (25% vs. 15.8%, $\chi^2=7.1$; $p<0.01$). Low CRF was found in 41% of the students, being significantly more frequent in boys (61.1% vs 20.1%, $\chi^2=94.8$; $p<0.01$). OW was found in 15.2% of the adolescents, AO in 13.7%, and there were no significant differences in the prevalence of OW and AO between girls and boys. The results indicate that 92.5% of the participants are physically inactive, while 80.4% reported high TV viewing times and 47% reported low frequency of consumption of fruits and vegetables.

Table 2 shows the prevalence of HBP according to some specific characteristics and its bivariate associations. Boys (OR: 0.6; 95%CI: 0.4-0.9) and adolescents who live in rural areas (OR: 0.6; 95%CI: 0.4-1.0) were less likely to have HBP. Adolescents with OW (OR: 2.3; 95%CI: 1.4-3.9), AO (OR: 2.8; 95%CI: 1.6-4.7), and low CRF (OR: 1.5; 95%CI: 1.0-2.3) were significantly more likely to have HBP. There were no significant bivariate associations between HBP and school type, physical inactivity, TV viewing time, and fruits and vegetables consumption.

Table 1. Sample characteristics.

Variables	Overall (n=546)	Girls (n=268)	Boys (n=278)	p-value
	x̄ (σ)			
Age (years)	14.9 (1.9)	14.9 (1.9)	14.9 (1.9)	0.75
Height (cm)	157 (10.2)	154 (7.2)	159 (11.9)	0.001
Weight (kg)	49.3 (10.5)	48.2 (8.5)	50.5 (12.1)	0.01
Systolic Blood Pressure (mmHg)	109 (11.5)	106 (10.3)	112 (11.7)	0.001
Diastolic Blood Pressure (mmHg)	69 (9.1)	68 (8.5)	71 (9.3)	0.001
BMI (kg/m^2)	19.8 (2.8)	20.1 (2.9)	19.5 (2.7)	0.007
Waist circumference (cm)	70.3 (8.0)	70.3 (7.7)	70.2 (8.2)	0.89
Waist-to-height ratio	0.45 (0.05)	0.44 (0.06)	0.45 (0.05)	0.09
VO_2 max (mL^{-1}/kg^{-1}/min^{-1})	41.8 (6.6)	43.7 (6.0)	40.0 (6.5)	0.001
Physical activity (days per week)	2.9 (2.0)	2.5 (2.0)	3.2 (2.0)	0.001
TV viewing time (hours per day)	3.0 (1.6)	3.0 (1.7)	3.0 (1.6)	0.81
Variables	%			
High blood pressure (%)	20.3	25	15.8	0.008
Overweight * (%)	15.2	16.4	14	0.44
Abdominal obesity † (%)	13.7	14.9	12.6	0.43
Low CRF ‡ (%)	41	20.1	61.1	0.001
Physical inactivity **(%)	92.5	94.4	90.6	0.09
High TV viewing time †† (%)	80.4	80.6	80.2	0.91
Low frequency of consumption of fruits and vegetables ‡‡ (%)	46.9	51.1	42.8	0.05

x̄: mean; σ: standard deviation.
* Defined using the CDC 2000 CDC growth charts.[24]
† Defined using a waist-to-height ratio cutoff of 0.5.[25]
‡ Defined using the FITNESSGRAM® cutoffs values.[28]
** Being active for at least 60 minutes a day for 7 days before the survey.
†† Those who reported TV viewing times of 2 or more hours per day.
‡‡ Those who reported consuiming less than 5 portions of fruits and vegetables per day.
Source: Own elaboration.

Table 2. Prevalence of high blood pressure and bivariate associations with potential correlates (n=546).

Variables		%	High Blood Pressure		
			Prevalence (95%CI)	OR (95%CI)	p-value
Area (%)	Urban	69.8	22.6 (18.4 - 26.8)	1	0.049
	Rural	30.2	15.1 (9.6 - 20.6)	0.6 (0.4 - 1.0)	
School type	Public	84.8	20.9 (17.2 - 24.7)	1	0.396
	Private	15.2	16.9 (8.7 - 25.0)	0.8 (0.4 - 1.4)	
Sex (%)	Female	49.1	25.0 (19.8 - 30.2)	1	0.008
	Male	50.9	15.8 (11.5 - 20.1)	0.6 (0.4 - 0.9)	
Overweight *	No	84.8	17.9 (14.4 - 21.4)	1	0.001
	Yes	15.2	33.7 (23.5 - 44.0)	2.3 (1.4 - 3.9)	
Abdominal obesity†	No	86.3	17.6 (14.2 - 21.1)	1	0.001
	Yes	13.7	37.3 (26.3 - 48.4)	2.8 (1.6 - 4.7)	
Cardiorespiratory fitness ‡	High	59.0	17.4 (13.2 - 21.5)	1	0.042
	Low	41.0	24.5 (18.9 - 30.2)	1.5 (1.0 - 2.3)	
Physical activity level **	Active	7.5	17.1 (6.0 - 28.8)	1	0.591
	Inactive	92.5	20.6 (17.1 - 24.1)	1.3 (0.5 - 2.9)	
TV viewing time (%)	<2 hours	19.6	22.4 (14.5 - 30.4)	1	0.547
	≥2 hours	80.4	19.8 (16.1 - 23.6)	0.9 (0.5 - 1.4)	
Fruits and vegetables consumption	≥5 portions per day	53.1	20.0 (15.4 - 24.6)	1	0.839
	<5 portions per day	46.9	21.0 (15.7 - 25.7)	1.0 (07 - 1.6)	

OR: odds ratio; CI: confidence interval.
* Defined using the CDC 2000 Growth Charts.[24]
† Defined using a waist-to-height ratio cutoff of 0.5.[25]
‡ Defined using FITNESSGRAM® cutoffs values.[28]
** Being active for at least 60 minutes a day for 7 days before the survey.
Source: Own elaboration.

The logistic regression analysis results of the association between HBP and OW and AO, as well as other potential correlates, are depicted in Figure 1. Results show that HBP was associated with OW (adjusted odds ratio (AOR): 2.3; 95%CI: 1.4-3.9) (Model 1). Model 2 shows that HBP was associated with OW (aOR: 2.1; 95% CI: 1.3-3.6) and low CRF (AOR: 2.0; 95%CI: 1.3-3.1). Also, HBP was associated with AO in Model 1 (aOR: 2.7; 95%CI: 1.6-4.6) and in Model 2 (aOR: 2.4; 95%CI: 1.4-4.1). The inclusion of CRF in Model 2 did not attenuate the association of HBP with OW and AO.

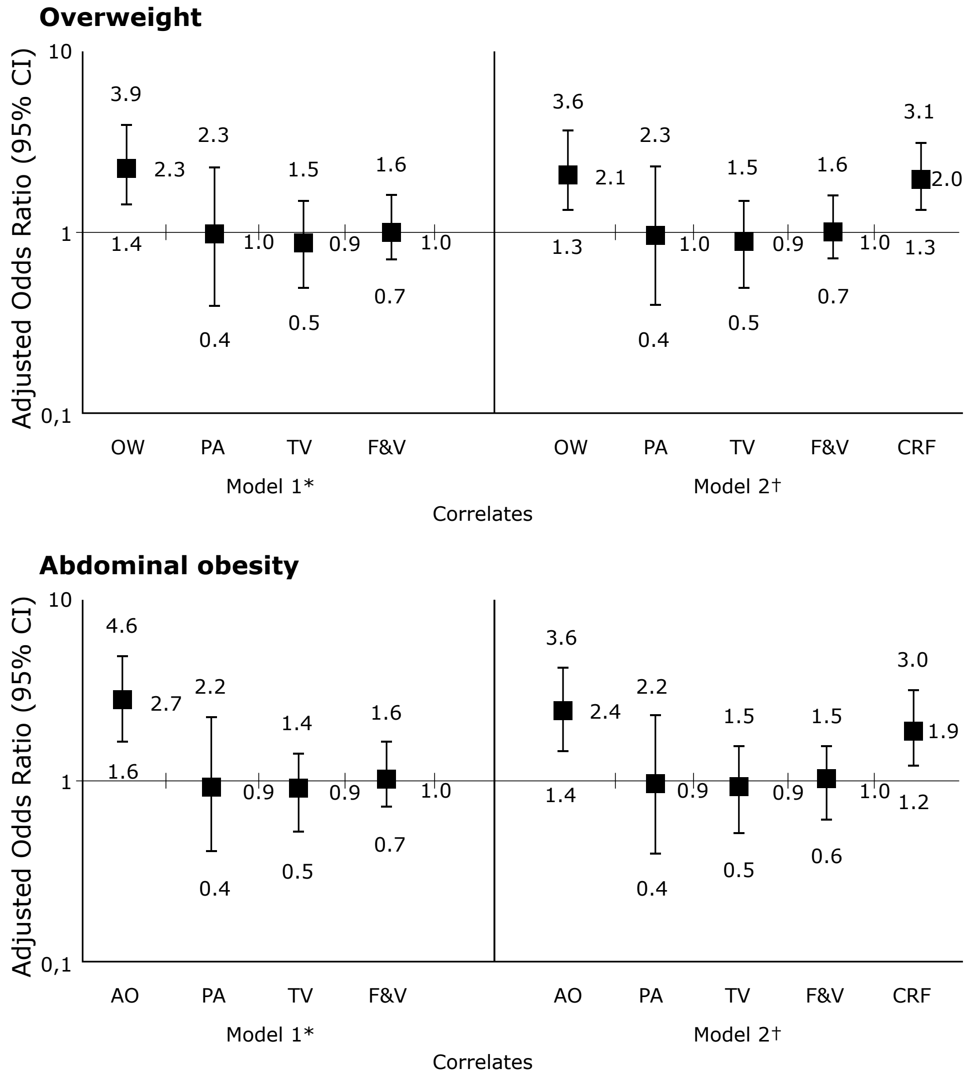

Figure 1. Logistic regression analysis of the association between high blood preassure and overweight, abdominal obesity, cardiorespiratory fitness, and other potential correlates.
OW: overweight; PA: physical activity; TV: television viewing time; F&V: fruits and vegetables consumption; CRF: cardiorespiratory fitness; AO: abdominal obesity; CI: confidence interval.
* Adjusted by residence area, school type, sex, overweight, physical activity, TV viewing time, and frequency of fruits and vegetables consumption.
† Adjusted by the correlates included in Model 1 + cardiorespiratory fitness.
Source: Own elaboration.

Figure 2 presents the results of the combined effect of adiposity and CRF. Students with normal weight and low CRF (AOR: 2.2; 95%CI: 1.2-3.7), and those with OW and low CRF (AOR: 5.6; 95%CI: 2.6-12.1) were significantly more likely to have HBP compared with the reference group, that is, those with normal weight and high CRF. Concerning AO, students with no AO and low CRF (AOR: 1.9; 95%CI: 1.2-3.3) and those with AO and low CRF (AOR: 6.2; 95%CI: 3.0-13.1) were significantly more likely to have HBP compared with the reference group. Models in Figure 2 were adjusted by residence area, school type, sex, physical activity, TV viewing time, and fruits and vegetables consumption.

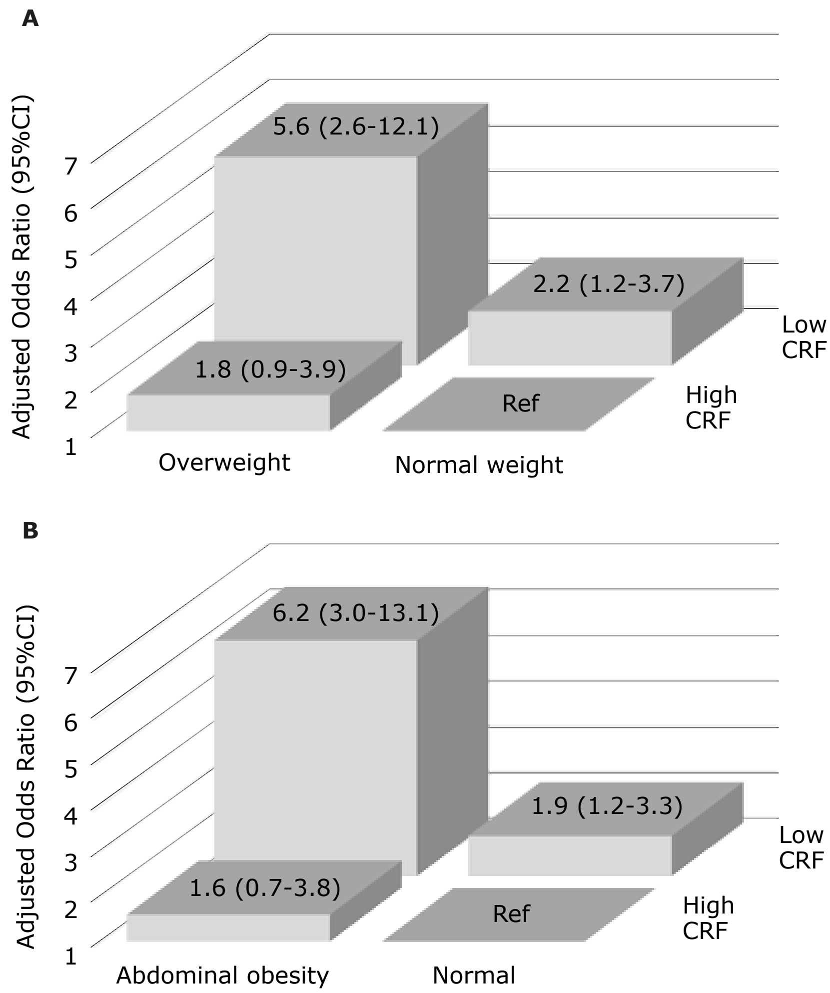

Figure 2. Logistic regression analysis of the association between high blood preassure and combined categories of adiposity and cardiorespiratory fitness. A: Combined categories of overweight and cardiorespiratory fitness; B: Combined categories of abdominal obesity and cardiorespiratory fitness.
CRF: cardiorespiratory fitness; CI: confidence interval.
Source: Own elaboration.

Discussion

This study assessed the cross-sectional associations between HBP and OW, AO, and CRF in a cohort of 546 adolescents. It was found that HPB was positively associated with OW, AO, and low CRF. Also, in this study, an additive effect of high adiposity and low CRF was found. These findings contribute to understanding the relationship between excessive adiposity and low CRF, yielding an important health-related outcome such as blood pressure level in childhood, which suggests that a high CRF may attenuate the association between excessive adiposity and blood pressure in adolescents.

In this sample, HBP is a prevalent health condition, especially among adolescents with low CRF, OW, and AO. Thus, the scope of prevention initiatives in this regard should also consider that the prevalence of HBP is partly associated with the increasing prevalence of childhood obesity.[32] The present study fount that HBP prevalence was higher compared to studies conducted in other cities from Latin America that have used similar methods (5.2% in Medellín, Colombia,[33] and 4.7% in Santiago de Cuba, Cuba),[34] and similar to the prevalence reported in León, Mexico (20.7%)[8] and in the U.S. (20.6%).[35]

It should be noted that HBP prevalence in the present sample occurs with lower prevalence of overweight (15.2%) compared to the prevalence of overweight in Mexican (22%)[8] and North American children (33%);[35] however, the latter study, the authors used a 95th percentile as a criterion for detecting HBP instead of the 90th percentile used here. This could indicate that the current population is more sensitive to excess adiposity, which has been explained by fetal programming.[36] However, the associations between HBP and OW found in this study did not have the magnitude reported previously by Rodriguez *et al.*,[37] where obese adolescents were 3.5-4 times more likely to develop HBP than non-obese adolescents.

These results are consistent with previous studies. For instance, HBP has been found to be associated with high waist circumference[38] and OW[35,39] in children and adolescents. Moreover, different studies have reported a beneficial association between CRF and blood pressure.[40] In this study, behavioral risk factors such as PA, sedentary behavior, and frequency of fruit and vegetable consumption, were not associated with HBP. Previous studies have suggested that CRF seems to relate more strongly to cardiovascular disease risk factors than to components of objectively measured PA in youth.[41]

From this perspective, it would be expected that low central adiposity and high CRF, independently, lead to a lower blood pressure level. However, in this study, HBP was more prevalent in girls than in boys, but boys had a higher prevalence of low CRF. In addition, there were no statistically significant differences in the prevalence of AO bewtween girls and boys. These findings may indicate that sex alters the interaction between fitness, fatness, and HBP. In this regard, Ruiz *et al.*[42] reported that adiposity is associated with high blood pressure only in the group of children with the lowest level of CRF. Consequently, these findings suggest a complex interdependency between sex, central adiposity, and CRF and their associations with blood pressure level.

Moreover, these findings are relevant to public health. The high prevalence of HBP points to an adverse impact on children's health due to the increased risk of short- and long-term negative health outcomes. Consequently, interventions should be focused on behavioral approaches that involve diet, sedentary behaviors and PA as main factors to reduce excess adiposity and increase CRF.

The results of this study have some limitations that should be mentioned. Firstly, the cross-sectional nature of the study does not allow establishing causal relationships between HBP, OW, AO, and CRF. However, it is not biologically plausible that HBP could lead to OW or AO. In fact, multiple intervention studies have reported the benefits of weight loss on blood pressure reduction in children .[43] Secondly, in this study, dietary sodium and family history of hypertension or cardiovascular disease were not considered; it is known that sodium is an important predictor of HBP and that heredity plays a role in high blood pressure among children.[23] Thirdly, the risk of misclassification may be of particular concern, but this risk was minimized by measuring blood pressure three times. Finally, behavioral information could be biased since it was gathered through self-report.

On the other hand, the strengths of the study include the representativeness of the sample and the inclusion of both urban and rural areas, as well as the fact that this is one of the few studies exploring these types of associations in the Colombian school population.

Conclusion

These findings show that HBP is a prevalent condition in children and adolescents from Montería. Furthermore, HBP is significantly associated with OW, AO, and CRF. These results have public health relevance, considering that, in Colombia, OW among adolescents keeps reaching unexpected proportions and, therefore, a rise of blood pressure levels is anticipated. For this reason, it is necessary to implement initiatives to promote healthy habits aimed at this population to reduce the incidence of new HBP cases in adolescents. Longitudinal and intervention studies and their translation into practice are needed in order to understand better the relationship between blood pressure and central adiposity and fitness.

Conflict of interest

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