Should they play outside? Cardiorespiratory fitness and air pollution among schoolchildren in Bogotá

¿Deberían los niños jugar al aire libre? Acondicionamiento cardiorespiratorioy contaminación del aire en Bogotá

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ABSTRACT

Objective This study was aimed at comparing cardiorespiratory fitness (CF), measured as VO_2 max, amongst school children exposed to varying levels of particulate matter (PM_{10}), and air pollution in Bogotá, Colombia.
Methods This was a cross-sectional study; it involved 1,045 children aged 7-12 attending four public schools served by different public transit routes and systems. Three schools were classified as being highly polluted (HP) and one slightly polluted (SP). The children and their parents were surveyed to collect data regarding their socio-demographic characteristics, physical activity habits and respiratory disease

background. Objective measurements of weight and height were used to calculate the body mass index. VO_2max was estimated using the 20-meter shuttle-run test, previously validated for Bogotá. Spirometry was performed on 435 children.
Results After adjustment for covariates, no difference was found inVO_2max between children attending SP or HP schools (girls SP 45.8 ml/kg/min vs HP 44.6 ml/kg/min, p=0.11;boys SP 47.2 ml/kg/min cf HP 48.2 ml/kg/min, p=0.41).
Conclusions VO_2max levels did not differ amongst children attending schools exposed to high compared to low levels of air pollution and PM. A longitudinal study assessing children's VO_2max levels in relation to exposure to highly-polluted areas is warranted.

Key Words: Physical fitness, air pollution, particulate matter, physical exertion, paediatrics (*source: MeSH, NML*).

RESUMEN

Objetivo Comparar el acondicionamiento cardiorespiratorio medido como VO_2máximo en niños escolarizados expuestos a diferentes niveles de PM_{10} en Bogotá.
Métodos Estudio de corte transversal. Se incluyeron 1045 niños de 7-12 años de 4 colegios públicos con diferentes corredores viales y sistemas de transporte público. Tres colegios tenían alta contaminación (AC) y uno baja contaminación (BC). Se aplicó una encuesta a niños y padres sobre características sociodemográficas, actividad física, antecedentes de enfermedades respiratorias y salud. Se midió objetivamente peso y talla para calcular el índice masa corporal. El VO_2 máximo se estimó con la prueba de Leger validada para Bogotá. Se realizaron espirometrìas en 435 niños.
Resultados Después de ajustar por covariables, no se encontraron diferencias significativas en el VO_2 máximo de los niños en colegios con BC ò AC. (Niñas BC: 45,8ml/kg/min vs. AC: 44,6ml/kg/min; p=0,11, niños BC: 47,2ml/kg/min vs. AC: 48,2ml/kg/min; p=0,41).
Conclusión No se encontraron diferencias en el VO_2 máximo de los niños que asistían a los colegios de AC ó BC. Se recomienda un estudio longitudinal que evalúe los niveles deVO_2 máximo en los niños expuestos a áreas altamente contaminadas.

Palabras Clave: Acondicionamiento físico, contaminación del aire; material particulado, ejercicio, pediatría (*fuente: DeCS, BIREME*).

Research has shown that exposure to high air pollutant concentrations as particulate matter (PM) is associated with respiratory symptoms, decreased pulmonary function and the development of chronic respiratory diseases (1-4). A highly-polluted environment is a threat to children's health; the highest environmental disease burden and death toll are concentrated among developing nations' children, according to the World Health Organization (3).

Evidence has shown that children whose houses or schools are close to roads having high traffic density have increased respiratory symptoms and lower pulmonary function (5-8).Increased health risks are associated with exposure to high levels of air pollutants amongst school-aged children. Specific mechanisms include on-going lung growth, an incomplete metabolic system, immature host defense, high rates of respiratory infection and outdoor activity patterns (9-10). Short- and long-term exposure to air pollution represents a risk factor for non-communicable disease (NCD) which are the main cause of disability and mortality in Latin-America (11).

Physical activity (PA) is a major protective factor against NCD, beginning in childhood (12); nonetheless, promoting outdoor PA while protecting children from contact with air pollutants such as PM_{10} continues to be a dilemma, particularly in highly-polluted urban settings (13-15) and rapidly-growing mega-cities in Latin-America, such as Mexico City, Santiago de Chile and Bogotá (16-17).

Inactivity rates and childhood obesity in these cities are growing rapidly. For example, 47.0 % of children in Chile and 44.0 % in Colombia spend 3 or more hours per day engaged in sedentary activities (18). Regarding obesity, it has been estimated that 33 % of children are overweight and 7 % obese in the Americas (19); however, a protective effect of PA while being exposed to air pollution has not been clearly established regardingVO_2 max a protetive affect of PA while being exposed to air pollution has not been clearly established (20).

Although VO_2 max in children and young people is highly influenced by genetic conditions, PA levels constitute its primary determinant (21). Despite the importance of adequate fitness levels for children and young people's health and well-being, VO_2max and pulmonary function variation due to exercising in areas having high air pollutant levels have only been documented in a few studies involving small sample sizes (21), by contrast with large bodies of evidence for adults (22-23).

To our knowledge, no studies in Latin-America have dealt with an association between children'sVO_2max and air pollution despite the fact that the region contains three of the most polluted urban center in the world (the aforementioned Santiago de Chile, Sao Paulo and Bogotá), transportation being the leading cause of PM air pollution in all of them (16,17,24).

Bogotá provides a useful setting for evaluating PM_{10} air pollution and VO_2max in children for the first time in Latin-America because it has several PA-promoting urban programs and also intends to introduce changes in its transport system (17,25). This study was aimed at assessing whether VO_2max values differed amongst children exposed to different levels of PM_{10} air pollution due to varying levels of traffic density.

METHODS

Study population and school setting

A cross-sectional study was conducted during 2006–2007 in Colombia's capital, Bogotá, located about 2,640 meters above sea level. Bogotá has around 7 million inhabitants, 1.8 million of whom are less than 18 years old. This city has no seasons. Bogotá is one of the most polluted cities in Latin-America (26), PM_{10} being the main pollutant (26).

The study population was formed by 1,045 children aged 7 to 12 years attending four public schools in Bogotá. Twenty-three of the 737 public schools in the city were selected because they were located less than 100 meters from the main motorized transport corridors. All the schools were served by an old public transport system (OPTS) with or without a rapid bus transit system (known as TransMilenio). Only four of these 23 schools met the inclusion criteria, i.e. being located 2 to 5 meters from a busy street (transport corridor), having boys and girls, having elementary and middle school and having agreed to participate in the study for at least five years.

School 1 acted as control as it was located in a semi-rural area next to a transport corridor having an OPTS, had low traffic density, did not have TransMilenio and had the lowest PM air pollution levels in Bogotá. School 2 was served by an OPTS with no plans for conversion to TransMilenio. School 3 was served by an OPTS which had plans for conversion to TransMilenio in the next few years. School 4 had mixed traffic that included both an OPTS and TransMilenio.

Data collection

Data was collected from 7-12 year-old children and their parents using face-to-face questionnaires after written informed consent had been obtained. All protocols and questionnaires were reviewed and approved by the Universidad de los Andes and Fundación Santa Fe de Bogotá ethics committees.

Outcome variables

Predicted maximum oxygen uptake. VO_2max was calculated using the Leger 20m shuttle run test for girls and boys aged 7 to12 years based on the longest distance (m) run by each child, which had been previously validated for Bogotá (27). The test consisted of asking a child to run between 2 lines marked 20 meters apart according to an increasing pace audio record, and to stop because of fatigue. VO_2max was calculated from the Leger equation based on each child's age and the longest distance (m) they ran (28).

Independent variables

Sociodemographic factors. Individual variables included gender, age, maternal educational attainment, socioeconomic status, health insurance and maternal employment. The children had to have lived for at least one year in the particular area.

Health-related characteristics. The International Study on Asthma and Allergies in Childhood (ISAAC) questionnaire (previously adapted for children in Bogotá) was used to evaluate respiratory- and asthma-related symptoms (29).Health-related factors for each child included past respiratory diseases, wheezing during the last 12 months and during PA, a diagnosis of asthma, current smoking and passive exposure to smoking in their households.

PA was assessed by using an adapted version of the 3-day physical activity recall (3DPAR) questionnaire (30); the Bogotá version measured two days (a weekday and a Sunday). PA variables included meeting PA recommendations (PAR) (at least 1 hour of moderate to vigorous PA per day) for school-aged young people (31). Height and weight, measured by trained personnel using calibrated equipment, were used to calculate the body mass index (BMI) according to World Health Organization growth charts (32); children were classified accordingly.

Lung function testing. Lung function was tested on a subsample of 434 children by a certified respiratory therapist following American Thoracic Society recommendations. A portable Jaeger Spiro Pro was used for spirometry, based on the Knudson spirometric reference values for Hispanic children (33). The tests for forced expiratory volume (FEV1) and forced vital capacity (FVC) were performed at least three times during the trial and the results were reviewed by a paediatric pneumologist.

Air pollutant concentration. The schools PM_{10} was measured using gravimetric techniques, namely Air Diagnostics Inc.'s Harvard Impact or (HI) and MS&T area sampler (MS&T area sampler; Air Diagnostics Inc, Harrison, USA) located inside the schools at 3 locations: the Closest point to the nearby road, 2 to 5 meters from the edge of the main road and 1–5 meters from outdoor PA facilities. Samples were taken daily at each school between 7:00 am and 3:00 pm for four weeks (34).

School 1, located in a slightly-polluted area (SP), served as the control group (55.3$\mu g.m^{-3}PM_{10}$ mean value: SE 4.2); because it had a mean 50 $\mu g.m^{-3}PM_{10}$concentration it was considered a less-polluted area (34). Schools 2, 3 and 4 did not differ significantly regardingPM_{10} concentration (90.5$\mu g.m^{-3}$, 87.8 $\mu g.m^{-3}$ and 90.4 $\mu g.m^{-3}PM_{10}$, respectively) and were put into the highly-polluted category (HP).

Personal exposure to PM_{10} and traffic density were measured (such data was not included in the statistical analysis). PM_{10} concentration was not measured during the Leger 20-m shuttle run test.

Statistical analysis

The first step in multilevel analysis described differences between HP and SP schools regarding the students' socio-demographic and health characteristics as assessed by X2 or t-test (depending on whether they were percentages or means). A hierarchical linear regression analysis was used for estimating unadjusted and adjusted means for VO_2max. Additional analysis stratified the data by gender in the subpopulation of children suffering asthma and the subpopulation of children who had a spirometry reading. The models were fitted using the MIXED procedure in SAS 9.1 (SAS Institute, Cary, NC, USA) to adjust the clustering effect within schools; all models assumed only the random intercept form.

RESULTS

General characteristics

Mean PM_{10}concentration outside school during 2007 was 35.1$\mu g.m^{-3}$in the SP school and 70.1$\mu g.m^{-3}$, 72.3$\mu g.m^{-3}$and 70.1$\mu g.m^{-3}$in the HP schools; there was also higher traffic density outside HP schools than the SP school.

Study response rate was 95.4 % for children eligible for Leger test in HP locations and 64.3 % in the SP area. SP and HP school samples were not even because the SP school had few students and was the only school in Bogotá which met the stated criteria to be the control (Table 1). The children in the sample were evenly distributed by gender (48.8 % girls cf 51.2 % boys), average age being 9.8 years (SD=1.5). 79.6 % of the children's mothers had reached more than elementary education level, 30.9 % of the mothers/guardians were not currently working and 71.0 % of the population reported living in low- or middle-income neighborhoods. 92.1 % of the children were covered by health insurance. Regarding respiratory symptoms, 6.5 % reported wheezing during the last year, 2.3 % reported wheezing during exercise and 4.0 % had had asthma diagnosed by a doctor.

Less than 1.0 % of the parents reported smoking and 13.6 % reported their children being exposed to second-hand smoking. More than 70.5 % of the children met PA recommendations and 80.5% had normal BMI; however, 18.5 % of children were at risk of being overweight, were overweight or obese.

Severely wasted and wasted categories were collapsed into one due to a lack of data. No differences by type of school emerged for most sociodemographic and health characteristics (Table 1), except for age, SES and vigorous PA, i.e. students from HP schools were older, more likely to live in middle-income neighborhoods but less likely than students from SP locations to meet vigorous PAR.

VO_2max

Overall VO_2max mean was 46.5ml.kg-1.min-1 (SE=0.4). Significant differences between VO_2max were found in unadjusted analysis by age-group and BMI classification in girls and boys.

Significant differences in VO_2max were only found in the subsample of girls with spirometry regarding lung function (specifically, 45.9 ml.kg-1. min-1 for the girls with FEV1/FVC>80.0 % and 44.2 ml.kg-1.min-1 for girls with FEV1/FVC<80.0 %; p=0.03) (Table 2).

Table 1. Sociodemographic and health characteristics of students from schools in highly or slightly polluted schools

Variable	SP[1]	%	HP[2]	%	p-value
Sociodemographic characteristics[3]	N=166		N=879		
Gender					
Girl	73	44.0	437	49.7	0.18
Boy	93	56.0	442	50.3	
Age[4]	9	1.4	10	1.5	<0.001
Maternal education					
≤elementary school	42	74.7	171	19.5	0.09
>elementary school	124	25.3	708	80.6	
Socioeconomic status					
1-2	86	51.8	217	24.7	<0.001
>2	80	48.2	662	75.3	
Health insurance					
Yes	153	92.2	806	92.3	0.98
No	13	7.8	69	7.7	
Maternal employment					
Yes	113	68.1	609	69.3	0.75
No	53	31.9	270	30.7	
Child's health-related characteristics					
History of past respiratory disease					
Yes	13	7.8	86	9.8	0.42
No	153	92.2	792	90.2	
Wheezing during the last 12 months					
Yes	10	6.0	58	6.6	0.78
No	156	94.0	821	93.4	
Wheezing during physical activity					
Yes	4	2.4	20	2.3	0.91
No	162	97.6	859	97.7	
Asthma diagnosed by a doctor					
Yes	6	3.6	36	4.1	0.76
No	160	96.4	837	95.9	
Currently smoking					
Yes	1	0.6	9	1.0	0.60
No	165	99.4	867	99.0	
Exposure to second-hand smoke					
Yes	17	10.5	123	14.1	0.21
No	145	89.5	747	85.9	
Met physical activity recommendations[5]					
Yes	106	66.3	621	71.3	0.19
No	54	33.8	250	28.7	
Met vigorous physical activity recommendations[6]					
Yes	82	51.3	372	42.7	0.04
No	78	48.8	499	57.3	
Body mass index					
Normal	125	78.6	698	81.6	0.37
Overweigh to obese	34	21.4	157	18.4	

[1] SP: slightly polluted school; [2]HP: highly polluted schools; [3]The total does not add up to 1,045 because of missing data; 4 Mean and standard deviation; [5] At least 1 hour of physical activity having >3 mets intensity during the two days the questionnaire was applied; [6] At least 1 hour of physical activity with >8 mets intensity during the two days the questionnaire was applied

Table 2. VO_2max (ml.kg-1.min-1) mean estimates by sociodemographic and health characteristics

	Girls N	Girls M(SE)[1]	p-value	Boys N	Boys M(SE)[1]	p-value
Schools						
Overall[2]	510	44.6(0.8)		535	48.0(0.4)	
SP[3]	73	45.8(0.6)	0.11	93	47.2(1.0)	0.41
HP[4]	437	44.6(0.3)		442	48.2(0.5)	
Sociodemographic characteristics						
Age						
7–10 years	316	46.9(0.5)	<0.0001	308	49.3(0.6)	<0.0001
11–12 years	194	43.2(0.5)		227	46.9(0.5)	
Maternal education						
≤elementary school	108	44.9(0.9)	0.34	105	48.2(0.6)	0.36
>than elementary school	402	44.5(0.8)		430	47.8(0.4)	
Socioeconomic status						
1–2	160	44.7(0.9)	0.79	143	48.1(0.5)	0.53
>2	350	44.6(0.9)		392	47.8(0.4)	
Health insurance						
Yes	469	44.6(0.8)	0.82	490	48.0(0.4)	0.13
No	39	44.7(1.0)		43	46.9(0.7)	
Maternal employment						
Yes	352	44.7(0.9)	0.29	370	47.9(0.4)	0.75
No	158	44.4(0.9)		165	47.8(0.5)	
Child's health-related characteristics						
History of past respiratory diseases						
Yes	32	45.0(1.1)	0.54	67	47.1(0.6)	0.10
No	477	44.6(0.8)		468	48.0(0.4)	
Wheezing in the last 12 months						
Yes	28	44.6(0.8)	0.77	40	47.7(0.9)	0.73
No	482	44.9(1.1)		495	47.9(0.4)	
Wheezing during physical activity						
Yes	10	44.5(1.2)	0.71	14	46.5(1.2)	0.24
No	500	44.6(0.8)		521	47.9(0.4)	
Asthma diagnosed by a doctor						
Yes	17	44.0(1.3)	0.48	25	47.5(0.9)	0.62
No	490	44.7(0.8)		507	47.9(0.4)	
Currently smoking						
Yes	5	44.8(2.0)	0.95	5	44.9(1.9)	0.11
No	503	44.6(0.8)		529	47.9(0.4)	
Exposure to second-hand smoke						
Yes	69	44.5(0.9)	0.71	71	48.2(0.6)	0.52
No	435	44.7(0.8)		457	47.8(0.4)	
Met physical activity recommendations[5]						
Yes	346	45.2(0.7)	0.13	381	48.1(0.4)	0.18
No	159	44.7(0.8)		145	47.5(0.5)	
Met vigorous physical activity recommendations[6]						
Yes	110	45.0 (0.8)	0.40	344	48.1(0.4)	0.25
No	395	45.0(0.7)		182	47.6(0.5)	
Body mass index						
Normal	413	45.3(0.7)	<0.001	410	48.7(0.5)	<0.001
Over weight obese	85	43.6(0.8)		106	45.1(0.6)	
Lung function[7]						
FEV1/FVC >80%	155	45.9(3.8)	0.03	141	47.9(4.6)	0.64
FEV1/FVC <80 %	30	44.2(3.5)		46	47.5(3.9)	

[1] Mean and standard error; [2]The total does not add up to 1,045 because of missing data; [3]SP: slightly polluted school; [4]HP: highly polluted schools; [5]At least 1 hour of physical activity with >3 mets intensity during the two days the questionnaire was applied; [6] At least 1 hour of physical activity with >8 mets intensity during the two days the questionnaire was applied; [7]Adjusted by school, gender, age, maternal education, socioeconomic status, health insurance, maternal employment, history of past respiratory disease, wheezing in the last year, asthma diagnosis, exposure to second-hand smoke, vigorous physical activity recommendation and BMI

A significant difference in VO_2 max was found in adjusted analysis for BMI regarding gender (girls' BMI 45.2 ml.kg-1.min-1 for normal BMI and 43.1 ml.kg-1.min-1 for overweight or obese category; p=<0.001). Regarding PAR and VO_2max, children who met the PAR in the SP had slightly higher VO_2max values than those in the HP; however, the results were not statistically significant (Table 3).

Table 3. Adjusted mean VO_2max ($ml.kg^{-1}.min^{-1}$) estimates by gender*

	Girls n=485			Boys n=510		
	M[2]	SE[3]	p-value	M[2]	SE[3]	p-value
Adjusted mean VO_2 max by school[1]						
SP[4]	45.8	0.6	0.11	47.2	0.9	0.41
HP[5]	44.6	0.3		48.2	0.5	
Adjusted mean VO_2 max by meeting physical activity[6] recommendations						
Yes	44.8	0.3	0.48	48.2	0.5	0.82
No	44.6	0.4		47.5	0.6	
Adjusted mean VO_2 max by meeting vigorous physical[7] activity recommendations						
Yes	44.7	0.4	0.82	48.2	0.5	0.24
No	44.8	0.3		47.7	0.6	
Adjusted mean VO_2 max by BMI						
Normal	45.2	0.3	<0.0001	48.8	0.5	<0.0001
Overweight or obese	43.1	0.4		45.1	0.6	
Adjusted mean VO_2 max by asthma diagnosed by the doctor						
Yes	43.5	0.7	0.13	47.3	0.9	0.42
No	44.8	0.3		48.0	0.5	

[1] The total does not add up to 1,045 because of missing data; *All the categories were adjusted by school, gender, age, maternal education, socioeconomic status, maternal employment, history of past respiratory disease, wheezing in the last year, asthma diagnosis, exposure to second-hand smoke, physical activity recommendations and BMI; [2] Mean; [3] Standard error; [4] SP: school in less polluted area; [5] HP: schools in highly polluted areas; [6]at least 1 hour of physical activity with > 3 mets intensity during the two days the questionnaire was applied; [7] at least 1 hour of physical activity with >8 mets intensity during the two days the questionnaire was applied.

DISCUSSION

High air pollutant concentrations have been related to health problems in children living in urban areas (5-9,35). A low CF in children and adolescents is associated with an increased risk of NCD (36,37). Nonetheless, no significant difference was found in this study regarding the VO_2max of girls or boys attending the SP or HP schools, or for meeting the PA recommendation for children attending the SP or HP schools.

The harmful respiratory effect of PM air pollution on VO_2max has yet to be determined due to the limited information available concerning this topic. For example, a previous study in Hong Kong showed abnormal VO_2max values having 1 ml.kg-1.min-1difference between HP and SP areas (20); also, PA had no beneficial effect on VO_2max values for children living in HP areas.

Although the VO_2max values in our results were considered normal according to FITNESSGRAM cardio respiratory fitness standards for adolescents (a VO_2max value below 35 ml.kg-1.min-1 for girls and 42 ml.kg-1.min-1for boys) in recent studies with American and European populations (37), a longitudinal study should be undertaken to show how VO_2max in children is affected by longer exposure to air pollutants.

Recommended policy change in Bogotá (Law 15/2008) aimed to promote a healthy environment for the population by enhancing diesel quality by 2012 to comply with the 50 parts per million of sulphur international standard. By so reducing PM emission, urban air quality can be improved and air pollution's negative respiratory health impact reduced. Other examples of air pollution policy can be seen in Chile, Sao Paulo and Mexico where air quality management plans and surveillance systems have been created for controlling air pollution levels. Sustainable transport projects in Chile, Colombia, Mexico, Peru and Brazil have been aimed at decreasing PM concentrations to improve outdoor air quality (1).

This study's limitations included the uneven SP school sample compared to the HP schools and assessment of exposure to outdoor pollutants only took PM_{10}into account. The cross-sectional study design necessarily limited analysis of any cause and effect relationship between VO_2max and PM_{10} air pollution. Despite these limitations, this study has provided a baseline for longitudinal assessment of cardiorespiratory fitness in children and took most factors affecting VO_2maxinto account. Changes in Bogotá's transport system may facilitate a natural experimental study aimed at assessing the effects of PM on children's cardiorespiratory fitness.

It is thus recommended that physicians and parents who are currently uncertain about proper recommendations for PA in highly-polluted environments should encourage children to engage in PA when daytime concentrations of PM_{10} are at their lowest in open rural land or indoors if they are engaging in PA close to a road or during peak PM_{10} hours. Based on real-time PM_{10} and PM 2.5 measurements, the lowest concentrations outdoors and in PA facilities occur between 10:30 am and noon, which should therefore be the recommended time for physical education classes. Thermal inversion significantly increases PM concentration before 9:00 am, and thereby exposure; students should preferably not be engaging in PA (especially outside and near major highways) at that time (34) ♦

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