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ORIGINAL RESEARCH

Analysis of the association between exercise induced bronchospasm, cardiorespiratory fitness, and physical activity levels of adolescents

Análise da relação entre broncoespasmo induzido por exercício, aptidão cardiorrespiratória e nível de atividade física de adolescentes

Análisis de la relación entre el broncoespasmo inducido por el ejercicio, la capacidad cardiorrespiratoria y el nivel de actividad física entre adolescentes

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ABSTRACT | This study aims to verify the association between exercise-induced bronchospasm (EIB), cardiorespiratory fitness, and physical activity levels in adolescents. To do so, we evaluated 202 healthy adolescents aged from 13 to 18 years, out of which 94 (46.5%) were females and 108 (53.5%) males. Participants performed a bronchial challenge test in a treadmill (Master Super ATL, Inbramed®) to evaluate bronchial hyper-responsiveness; a spirometric test (Microquark, Cosmed®) to evaluate lung function; answered the Baecke's Questionnaire of Habitual Physical Activity; and performed the progressive aerobic cardiovascular endurance run test. Data were analyzed using Spearman's correlation, chi-square test, and odds ratio. The significance level adopted was $p<0.05$. No statistically significant correlations were found between the decrease of the forced expiratory volume in the first second (FEV_1), cardiorespiratory fitness, and physical activity levels. Likewise, the chi-squared test revealed no significant differences between classifications of cardiorespiratory fitness (low or adequate) and EIB (presence or absence) ($\chi^2=0.155$; $p=0.694$). Finally, odds ratio showed no increased chances of the presence of EIB in participants who presented low cardiorespiratory fitness (OR=1.130; CI: 0.616-2.073). We concluded that cardiorespiratory fitness and physical activity levels are not associated with the decrease of FEV_1 and that there is no relation between the presence of EIB and the classification of cardiorespiratory fitness of adolescents.

Keywords | Spirometry; Physical Fitness; Exercise.

RESUMO | Este estudo teve como objetivo verificar a associação entre o broncoespasmo induzido pelo exercício (BIE), a aptidão cardiorrespiratória e o nível de atividade física de adolescentes. Para tanto, participaram do estudo 202 adolescentes saudáveis com idades entre 13 e 18 anos, sendo 94 (46,5%) do sexo feminino e 108 (53,5%) do sexo masculino. Os participantes realizaram um teste de broncoprovocação em esteira ergométrica e um teste espirométrico, além de responderem a um questionário de nível de atividade física (*Baecke's Questionnaire of Habitual Physical Activity*) e realizarem um teste de aptidão cardiorrespiratória (*progressive aerobic cardiovascular endurance run test*). Os dados foram analisados por meio da correlação de Spearman, teste qui-quadrado e cálculo de razão de chances (*odds ratio*). O nível de significância adotado foi $p<0,05$. Não foram encontradas correlações significativas entre a queda do volume expiratório forçado no primeiro segundo (VEF_1), a aptidão cardiorrespiratória

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e o nível de atividade física dos adolescentes. Da mesma maneira, o teste qui-quadrado não revelou diferenças significativas entre as classificações da aptidão cardiorrespiratória (baixa ou adequada) e o BIE (presença ou ausência) (χ^2=0,155; p=0,694). Por fim, a análise de razão de chance não demonstrou maiores chances de se verificar a presença de BIE nos participantes que apresentaram baixa aptidão cardiorrespiratória (OR=1,130; IC: 0,616-2,073). Conclui-se que a aptidão cardiorrespiratória e o nível de atividade física não estão associados com a queda do VEF_1, e que não há relação entre a presença de BIE com a classificação da aptidão cardiorrespiratória de adolescentes.
Descritores | Espirometria; Aptidão Física; Exercício.

RESUMEN | Este estudio tuvo como objetivo verificar la asociación entre el broncoespasmo inducido por el ejercicio (BIE), la capacidad cardiorrespiratoria y el nivel de actividad física entre adolescentes. Para ello, participaron en el estudio 202 adolescentes sanos de entre 13 y 18 años, de los cuales 94 (46,5%) son mujeres y 108 (53,5%) hombres. Los participantes realizaron una prueba de provocación bronquial en cinta rodante (Master Super ATL, Inbramed®) y una prueba espirométrica (Microquark, Cosmed®), respondieron un cuestionario de nivel de actividad física (*Baecke's Questionnaire of Habitual Physical Activity*) y realizaron una prueba de aptitud cardiorrespiratoria (*progressive aerobic cardiovascular endurance run test*). Los datos se analizaron mediante la correlación de Spearman, la prueba de chi-cuadrado y la razón de probabilidades (*odds ratio*). El nivel de significancia adoptado p<0,05. No se encontraron correlaciones significativas entre la caída del volumen espiratorio forzado en un segundo (VEF_1), la capacidad cardiorrespiratoria y el nivel de actividad física de los adolescentes. Asimismo, la prueba de Chi-Cuadrado no reveló diferencias significativas entre las clasificaciones de capacidad cardiorrespiratoria (baja o adecuada) y la BIE (presencia o ausencia) (χ2=0,155; p=0,694). Finalmente, el análisis de la razón de posibilidades no mostró mayores posibilidades de presencia de EIB en participantes que tenían baja capacidad cardiorrespiratoria (OR=1,130; IC: 0,616-2,073). Se concluye que la capacidad cardiorrespiratoria y el nivel de actividad física no se asocian con una caída del VEF_1 y que no existe relación entre la presencia de BIE y la clasificación de capacidad cardiorrespiratoria de los adolescentes.
Palabras clave | Espirometría; Aptitud Física; Ejercicio.

INTRODUCTION

Exercise induced bronchospasm (EIB) is characterized by the transitory thickening of the lower airways due to intense exercise[1,2]. The main symptoms of EIB are coughing, wheezing, chest tightness, and dyspnea. EIB usually occurs in people diagnosed with asthma but is also common in children and adolescents without other signs or clinical symptoms of asthma[3].

The diagnosis of EIB is performed through the evaluation of signs and symptoms reported by the patient and by the bronchial challenge test with exercise[4]. In this test, lung function is evaluated before and after exercise via spirometry; the presence of EIB is defined by the decrease equal to or above 10% of the pre-exercise forced expiratory volume in the first second (FEV_1)[5].

Even though exercise can function as a trigger for EIB[6], regular physical activity can improve quality of life, cardiorespiratory fitness, and lung function, reducing the inflammation of airways and bronchial responsiveness[7]. However, adolescents that present EIB often show lower cardiorespiratory fitness and physical activity levels when compared with their peers without EIB[8,9].

Physical activity is widely accepted as an important tool for children and adolescents when it comes to bone growth, motor skills, higher physical fitness, and self-esteem. The symptoms associated to EIB, however, can occur during or after physical education classes, leading children to avoid participating and avoid physical activity all together (sedentarism)[10]. In this scenario, our study aimed to verify the association between EIB, cardiorespiratory fitness, and physical activity levels in adolescents.

Studies regarding this topic are important to physical education teachers, as well as other health professionals, such as physical therapists, to better understand the associations between EIB and exercise-related variables. Moreover, with the increase of sedentary behavior among adolescents, studying associations of physiological responses to exercise can encourage more adolescents to engage in a healthier lifestyle.

METHODS

This study has a cross-sectional design and was performed with asymptomatic adolescents aged 13 to 18 years, male and female, students from a public school from the municipality of Petrolina, state of Pernambuco, Brazil. Adolescents who presented any respiratory infection in the four weeks before the study, were pregnant, had a history of muscular or cardiovascular disease, or referred any metabolic disorders were excluded from the study. Their participation was conditioned to presenting the informed consent form, signed by their parents or guardians, and signing the informed assent form (for participants under 18 years old).

When data was collected, between February and June 2018, 469 students were enrolled in the school. The sample size estimate for finite populations showed the need for 212 participants. However, only 206 students presented the consent forms signed and were included in the study. Additionally, four participants were excluded during data collection for not having completed all tests (three decided to leave the study and one did not perform the cardiorespiratory fitness test). Thus, 202 adolescents aged between 13 and 18 year old, 94 (46.5%) females and 108 (53.3%) males, completed all stages of data collection.

Data was collected in two stages: a) evaluation of EIB, spirometry test, answering a physical activity level questionnaire, and anthropometric evaluation (for characterization purposes); and b) cardiorespiratory fitness test (PACER test).

Bronchial hyper-responsiveness was evaluated through the bronchial provocation test on a treadmill (Master Super ATL, Inbramed®, Brazil) according to the protocol of the American Thoracic Society[11]. Before starting the test, all procedures regarding the use of the treadmill and safety procedures were explained to the participants.

Exercise was performed on the same treadmill, with an intensity equal or higher than 85% of maximum heart rate, which was measured using a heart rate monitor (Polar® Electro Oy, Finland). Maximum heart rate was estimates using the equation $HR_{max}=208 - (age \times 0.7)$, suggested by Tanaka, Monahan, and Seals[12], with results expressed in beats per minute (bpm). After pre-exercise spirometry, participants walked on the treadmill for 30 seconds for familiarization. Afterwards, speed was gradually incremented to reach 85% of HR_{max} in the first minute of the test[13], and then was maintained for at least six minutes. All participants underwent pulse oximetry measurements before and after exercise.

The parameter of lung function evaluated was the FEV_1 before and after exercise, using a spirometer (MicroQuark, Cosmed®). Participants were familiarized with the test and were oriented to remain seated using a nasal clip to perform three acceptable spirometric maneuvers. The base value of FEV_1 was 3.23±0.68L (2.83±0.43L for females and 3.56±0.68L for males). These values were considered normal according to Pereira[14]. The maneuver with higher FEV_1 value was used based on Polgar and Promodhat[15], according to age, gender, height, and body mass. Lung function after the test was evaluated through FEV_1, in liters, at the 5th, 10th, 15th, and 20th minute after exercise. In this procedure, three maneuvers were also performed. All values of maneuvers had proper quality; they were reproducible and acceptable according to the parameters set by Graham et al.[16]. The EIB was considered positive when a reduction equal to or higher than 10% was found in comparison to the pre-exercise values. After the exercise, a decrease of FEV_1 was considered mild if values were between 10% and 25%; moderate if between 25% and 50%; and severe if equal to or above 50%[1]. To estimate odds ratio, participants were divided as showing "presence" or "absence" of EIB.

To evaluate lung function, participants were advised not to drink coffee, tea, or sodas with caffeine 2 hours before the test; not to use short or long duration bronchial dilators 12 hours before the test; and to suspend anti-histaminic drugs of short and long duration for 48 hours and 5 days before the test, respectively. A trained physical therapist was responsible to conducting the tests in a closed environment with controlled temperature (between 20°C and 25°C) and air humidity (below 50%) (Perception II Digital Hygrometer, Davis®, São Paulo, Brazil).

Physical activity level was assessed using Baecke's Questionnaire of Habitual Physical Activity (BQHPA)[17], validated and translated to Portuguese by Guedes et al.[18]. This instrument is self-administered and uses the period of the last 12 months as reference. The questionnaire is divided in 16 questions distributed in three distinct sessions. The first group of questions refers to physical activity at school (PA_{school}); the second group, to sports activities (PA_{sports}); and the third, to leisure activities ($PA_{leisure}$). Each part of the questionnaire provides necessary data to estimate the three levels of physical activity, and the sum of these values determine total physical activity (PA_{total}).

The answers of the questionnaire are presented as a Likert type scale of 5 points. The classification of the activities was performed according to the codes provided in the instrument, considering weekly frequency, number of months in which the activity was performed, and intensity. The results of BQHPA are given in arbitrary values (scores).

Cardiorespiratory fitness was evaluated through the PACER test, which is a multistage test adapted from the 20-meter shuttle run test. This test consists of running back and forth a 20-meter distance accompanied by an audio recorded "beep". At each "beep" the participant must complete the 20-meter distance (lap). The test begins at a speed of 8km/h and the interval between "beeps" decreases every minute, making the participant increase speed in 1km/h. The test ends when the participant cannot keep up with the "beep" for two consecutive laps[19]. During the tests, verbal stimuli was given by the research team.

Cardiorespiratory fitness was calculated using the equation proposed by Boiarskaia et al.[20], as follows: $VO_2max=32.57+0.27\times(\text{number of laps})+3.25\times(\text{gender})+0.03\times(\text{age})$. For gender, "zero" was considered for females and "one" for males. After the test, participants were categorized as "low" and "adequate" according to the values of cardiorespiratory fitness postulated by the California Department of Education[21], according to age and gender.

After data collection, the information was inserted in Microsoft Excel for Windows®, version 2010, in which data was checked for typing errors. Afterwards, data were transferred to SPSS version 22.0 for Windows® to be analyzed. Data normality was assessed through Kolmogorov Smirnov's test, followed by a descriptive (mean, standard deviation, and relative (%) and absolute (n) frequency) and inferential analysis.

Considering that the data was not normally distributed, comparisons between female and male participants were performed through Mann-Whitney's U test. Additionally, the association between the variables (decrease in FEV_1, physical activity level, and cardiorespiratory fitness) was verified through Spearman's correlation. The chi-squared test was performed to verify differences in the frequency of EIB presence according to cardiorespiratory fitness (low or adequate). Finally, odds ratio was estimated using cross tabulation to see if participants with low cardiorespiratory fitness had higher chances of presenting EIB. The level of significance adopted was $p<0.05$ and the confidence interval used was 95%.

Since only 202 adolescents participated in the study, an *a posteriori* estimated of statistical power of analysis was performed with the aid of G*Power 3.0.10. For the Spearman's correlation, considering an effect size of 0.44 and a margin of error of 5%, the power found for the analysis was 0.99.

RESULTS

In total, 202 adolescents, 94 (46.5%) females and 108 (53.5%) males, participated in the study. The mean age of the participants was 14.97±1.31 years. The classification of the EIB test showed that 50 participants (24.8%) presented mild EIB (28 females and 22 males), 18 (8.9%) presented moderate EIB (13 females and 5 males), and 1 (0.5%) had severe EIB (one female). Regarding cardiorespiratory fitness, 128 students (63.4%) presented low results, while 74 (36.6%) were considered adequate according to the PACER test classification. Table 1 shows other main characteristics of the sample.

Table 2 shows the comparison of the main characteristics of the participants according to gender. In this scenario, the analysis performed by Mann-Whitney's U test showed that male adolescents presented significantly higher results in all variables (except body mass index) when compared with female participants.

No statistically significant correlations between the decrease in FEV_1, cardiorespiratory fitness, and physical activity levels were found (Table 3). On the other hand, positive significant correlations were observed between cardiorespiratory fitness and the domains of physical activity (school, sport, leisure, and total).

The analysis of frequency of EIB and classification of cardiorespiratory fitness also showed no statistically significant results (chi-squared test). Likewise, odds ratio analysis revealed that having low cardiorespiratory fitness did not significantly increase the risk of presenting EIB (Table 4).

Table 1. Main characteristics of the participants. Petrolina, Pernambuco, Brazil. 2018

Variable	Mean±SD	95%CI
Body mass (Kg)	56.94±11.20	55.39-58.50
Height (m)	1.67±0.09	1.65-1.68
Body mass index (kg/m²)	20.27±3.23	19.82-20.71
Pre-exercise FEV_1 (L)	3.23±0.68	3.13-3.32
Decrease in FEV_1 (%)	8.68±10.04	7.29-10.07
VO_2max (mL/kg/min)	43.69±6.63	42.77-44.61
Physical activity in school (AU)	2.59±0.50	2.52-2.66
Physical activity in sports (AU)	2.57±0.83	2.45-2.68
Physical activity in leisure (AU)	2.75±0.68	2.74-2.75
Total physical activity (AU)	7.91±1.52	7.70-8.12

AU: arbitrary unit (score); SD: standard deviation; CI: confidence interval.

Table 2. Comparison of main characteristics of the participants according to gender. Petrolina, Pernambuco, Brazil. 2018

Variable	Females (n=94) Median (Q1-Q3)	Males (n=108) Median (Q1-Q3)	p-value
Body mass (Kg)	53.00 (46.30-60.15)	58.20 (51.62-66.37)	**0.001**
Height (m)	1.63 (1.58-1.67)	1.72 (1.66-1.77)	**<0.001**
Body mass index (kg/m^2)	19.74 (18.17-22.75)	19.49 (17.63-21.38)	0.165
Pre-exercise FEV_1 (L)	2.83 (2.55-3.16)	3.62 (3.08-4.16)	**<0.001**
Decrease in FEV_1 (%)	9.15 (3.53-18.15)	4.13 (0.99-9.95)	**0.001**
VO_2max (mL/kg/min)	37.46 (36.43-39.47)	48.69 (44.59-51.96)	**<0.001**
Physical activity in school (AU)	2.50 (2.00-2.65)	2.68 (2.40-3.00)	**<0.001**
Physical activity in sports (AU)	2.00 (1.75-2.75)	3.00 (2.25-3.50)	**<0.001**
Physical activity in leisure (AU)	2.50 (2.00-2.81)	3.00 (2.50-3.50)	**<0.001**
Total physical activity (AU)	7.12 (6.25-8.00)	8.62 (7.75-9.72)	**<0.001**

AU: arbitrary unit (score); SD: standard deviation; CI: confidence interval.

Table 3. Spearman's correlation between the decrease of forced expiratory volume in the first second, cardiorespiratory fitness, and physical activity levels. Petrolina, Pernambuco, Brazil. 2018

	D FEV_1	VO_2max	PA_{School}	PA_{Sports}	$PA_{Leisure}$	PA_{Total}
D FEV_1	-	−0.113	0.024	−0.081	−0.030	−0.045
VO_2max		-	0.367*	0.516*	0.388*	0.577*
PA_{School}			-	0.396*	0.201*	0.600*
PA_{Sports}				-	0.430*	0.866*
$PA_{Leisure}$					-	0.729*
PA_{Total}						-

*p<0.05.
D FEV_1: decrease of forced expiratory volume in the first second; PA: physical activity.

Table 4. Frequency and odds ratio of classifications of cardiorespiratory fitness and presence or absence of exercise induced bronchospasm. Petrolina, Pernambuco, Brazil. 2018.

	Cardiorespiratory fitness			
	Low	Adequate	$\chi 2$	p-value
Presence of EIB	45 (65.2%)	24 (24.8%)	0.155	0.694
Absence of EIB	83 (62.4%)	50 (37.6%)		
	Presence of EIB			
	Odds Ratio		95% Confidence interval	
Adequate CRF	1		-	
Low CRF	1.130		0.616-2.073	

EIB: exercise induced bronchospasm; CRF: cardiorespiratory fitness.

DISCUSSION

The results of our study showed no association between the decrease of FEV_1, cardiorespiratory fitness, and physical activity levels of the participants. Moreover, the comparison of the frequency of EIB according to the classification of cardiorespiratory fitness, analyzed by the chi-squared test, showed no differences. Odds ratio show no increased chances of the presence of EIB in participants with low cardiorespiratory fitness. However, significant statistical differences were found when comparing participants according to gender.

The effect of gender on anthropometry, cardiorespiratory fitness, and physical activity levels in adolescents is well established in literature[20,21]. Several studies point to male adolescents being heavier, higher, and more physically active than females. This occurs due to several factors, including cultural (males are more encouraged to practice sports than females during childhood and adolescence) and biological factors (process of maturation and growth hormones during adolescence)[22,23].

Moreover, 128 students (63.4%) presented low physical fitness according to PACER test's cut-off points and the mean VO_2max was 43.69±6.63mL/Kg/min. Despite most of the participants being characterized with inadequate values, the results of our study are similar to others with Brazilian adolescents[24]. A similar scenario was found for physical activity levels[25]. This infers that our sample follows the trend of physical activity levels of Brazilian adolescents.

Sixty-nine (69) participants presented EIB, of which 50 were considered mild; 18, moderate; and 1, severe. Other studies have shown similar prevalence to the ones reported here[26]. According to Correia Junior et al.[27], cities with dry climate, high temperature, and scarce rain during winter, such as Petrolina (located in a Semiarid region of Brazil) can favor the presence of EIB. This could explain the occurrence of EIB in healthy adolescents, such those in this study.

Regarding the effects of exercise/sports on EIB of asthmatic youth, Lopes, Porto, and Leite[6] performed a systematic review and the results indicated insufficient evidence for the benefits of exercising on EIB in this population. According to the authors, of the eight papers included in the review, five present no statistically significant differences. Moreover, the authors pointed out that several factor could explain the lack of congruency between the data, such as: type, duration, frequency, and intensity of the exercise.

In a study with a design similar to ours, Correia Junior et al.[26] evaluated the effects of EIB on physical activity of 134 asthmatic students, aged between 10 and 19 years; they observed no associations between EIB and low physical activity levels. Likewise, Pazini, Pietta-Dias, and Roncada[28] aimed to establish an association between physical activity levels and lung function of 605 students aged 8 to 16 years and found no statistically significant results.

Johansson, Berglund, and Holmbäck[29], in an elegant study, found no differences in physical activity levels of participants with presence or absence of EIB. Thus, authors suggested that the presence of EIB cannot be a factor that predisposes low physical activity levels in individuals. In another study, Johansson et al.[30] also suggested that EIB does not seem to affect physical activity levels of adolescents, since they found no statistically significant differences in minutes of moderate to vigorous daily physical activity of participants with and without EIB.

Pike et al.[31] compared the levels of physical activity of children with and without asthma in a large representative prospective cohort of all United Kingdom using objectively measured data of 6,497 children aged 7 and 8 years. Approximately half of the children who presented a diagnosis of asthma did not reach the 60 minutes of daily moderate to vigorous physical activity, as recommended by the World Health Organization. Additionally, the authors found that physical activity levels were similar when comparing children with and without asthma.

On the other hand, Anthracopoulos et al.[32] found associations between EIB and low physical activity levels in children aged 10 to 12 years and reported that those were independent of body mass index and of symptoms associated to asthma. The authors suggested that the causality was due to the decrease of physical activity levels of this population, leading to a higher prevalence of EIB, and not the other way around.

Lochte et al.[33], in a systematic review with metanalysis, analyzed studies that examined the associations between physical activity and asthma in children and adolescents. The cohort studies included in the review showed that the risk of asthma or recent wheezing increased up to 35% in children with low physical activity levels, and three cross-sectional studies revealed significant positive correlations between asthma and low physical activity. Of the 11 studies included in the research, more than 50% suggested positive associations between childhood asthma and low physical activity. The metanalysis also reported higher risks of recent asthma in children with low physical activity.

The etiology of EIB is still controversial. However, two main theories can explain how EIB is triggered: the osmotic hypothesis[34] and the thermic hypothesis[35]. The osmotic hypothesis can be mostly explained by the dehydration of the airway mucosa that occurs during exercise induced hyperpnea. This dehydration can lead to a hyperosmolarity of the mucosa and subsequent release of inflammatory mediators, causing bronchoconstriction. The thermic hypothesis, on the other hand, affirms that exercise induced hyperpnea causes the cooling of the airways. After exercise, when hyperpnea ceases, the airways are rapidly reheated, leading to the engorgement of the vascular bed of the airways and subsequent bronchoconstriction[5].

Given the exposed, several gaps are still to be filled in literature when it comes to the associations of physical fitness and EIB. Lots of variables should be considered when approaching the topic, such as: (1) type, frequency, duration, and intensity of exercise; (2) methods to evaluate physical fitness and physical activity levels; and (3) influence of environment on respiratory behavior.

Despite our study bringing valuable information on the association between EIB, cardiorespiratory fitness, and physical activity levels in adolescents, it has some limitations. Initially, both cardiorespiratory fitness and physical activity levels were indirectly estimated. Even though the Questionnaire of Habitual Physical Activity and the PACER test are widely used tools in this populations, there is a possibility of overestimation or underestimation of the variables. Moreover, this study was conducted with a sample of adolescents from a public school of the Brazilian Semiarid Region. Thus, these findings should not be generalized for other regions of the country, especially those with humid climates.

CONCLUSION

We conclude that cardiorespiratory fitness and physical activity levels are not associated with the decrease of VEF_1 of adolescents. Additionally, no significant differences between the frequency of EIB in adolescents with low or adequate cardiorespiratory fitness were found. Finally, participants with low cardiorespiratory fitness did not show a tendency of presenting EIB.

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