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Original Article

Paediatrics Section

Prevalence and Determinants of Exercise-induced Bronchoconstriction in Urban School Children: A Cross-sectional Study from Bengaluru, India

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ABSTRACT

Introduction: Exercise-induced Bronchoconstriction (EIB) is a serious illness that affects children living in urban areas with high pollution levels. Indian data on its prevalence using objective exercise challenge testing are limited, with most studies relying on symptom-based assessment alone.

Aim: To estimate the prevalence of EIB and identify associated factors among urban school children using standardised spirometry-based evaluation in Bengaluru urban school children aged 9-18 years.

Materials and Methods: A cross-sectional study was conducted over 12 months from September 2018 to August 2019, in 15 randomly selected schools across Bengaluru, Karnataka, India involving 984 children. The study was conducted by the Department of Paediatrics, Ramaiah Medical College and Hospital, Bengaluru, Karnataka, India. Spirometry, or pulmonary function testing, was performed on 984 participants, before and after a 6-Minute Walk Test (6MWT). A reduction of ≥10% in FEV1 post-exercise confirmed the diagnosis of EIB. A modified version of the ISAAC (International Study of Asthma and Allergies in Childhood) questionnaire was used to gather anthropometric, demographic information and environmental exposures. Risk factors and variations in EIB prevalence were analysed using t-tests, Analysis of Variance (ANOVA), logistic regression, and McNemar's test.

Results: The overall prevalence of EIB was 58% (p-value <0.0001, OR=0.166, 95% CI 0.124-0.223). Children living in industrial areas had a higher prevalence (67.5%) than children living in non industrial areas (45.2%; p-value=0.001). Prevalence was significantly higher in children aged 12-14 years (71.5%) compared to the younger (11.7%) and older age groups (16.8%) (p-value=0.001). EIB prevalence was influenced by socio-economic status, with higher rates (60.3%) observed in lower socio-economic groups and lower rates (18.8%) in higher socio-economic groups (p-value=0.014). Children engaged in regular physical activity had an increased risk (64.4%; p-value=0.002, OR=1.52) compared to children with no regular physical activity. No significant associations were found with parental smoking (p-value=0.132) or family history of asthma (p-value=0.38).

Conclusion: This study demonstrated a high prevalence of EIB among urban school children aged 9-18 years in Bengaluru, with significant associations with age group, residential environment, socio-economic status, and physical activity.

Keywords: Airway obstruction, Asthma, Bronchial hyperreactivity, Exercise test, Pulmonary function tests, Spirometry

INTRODUCTION

Asthma is a complex, chronic inflammatory disorder of the airways characterised by increased airway responsiveness and mucus production [1,2]. Bronchial asthma is one of the most common non communicable respiratory diseases, affecting over 300 million people worldwide [3]. Up to 50% of children will wheeze before the age of six years; however, less than 20% of these children will continue to wheeze into late childhood and will be diagnosed with asthma [4].

Out of the many contributors to airway obstruction in children with asthma, exercise is one of the most common stimuli, ranking second only to viral respiratory tract infection [5]. Exercise-induced asthma, now commonly referred to as EIB, affects 40-90% of people with asthma compared to 3-15% of the general population [6].

India, especially Bengaluru, a city with the 3rd highest population, has experienced rapid economic development and urbanisation over the past three decades; the levels and patterns of outdoor and indoor air pollutants have altered dramatically. With the rapid increase in motor vehicles, urban air pollution has changed from coal combustion type to mixed coal smoke and motor vehicle emission type encountered at relatively high levels. Meanwhile, the levels of indoor coal smoke pollution have decreased rapidly since more people use gas or electric power [7]. Although asthma is the most common pulmonary condition in paediatrics, the prevalence of exercise-induced asthma in school children and the risk factors associated with the same are not well documented in India. Two major theories have been proposed for EIB: the airway cooling theory and the hyperosmolarity theory [6].

The airway cooling theory suggests that rapid breathing during exercise leads to airway cooling, and subsequent rewarming leads to vasodilatation and causes airway narrowing [8]. The hyperosmolarity theory states that increased ventilation causes airway water loss, leading to hyperosmolarity, which triggers the release of inflammatory mediators from mast cells, such as histamine, leukotrienes, and prostaglandins, resulting in bronchoconstriction [9]. Diagnosis of asthma requires clinical assessment supported by laboratory evaluation because no single measurement can establish the diagnosis.

EIB in children has been studied in many countries [10,11] but data from India are limited. Most available studies such as Kim MH et al., Clark NM et al., Inci D et al., depend on symptoms or questionnaires, which can miss affected children [12-14]. There is also little information on how factors such as age, socio-economic status, physical activity, and urban living influence this condition.

The present study was conducted to estimate the prevalence of EIB and identify associated factors among urban school children using standardised spirometry-based evaluation in Bengaluru urban school children aged 9-18 years.

MATERIALS AND METHODS

This was a cross-sectional study conducted in selected school premises in Bengaluru city over 12 months, from September 2018-August 2019. Ethical approval for this study was obtained from Institutional Review Board of Ramaiah Medical College and Hospital (Id- MSRMC/EC/2016, Renew Date 11/8/2018). All assessments were carried out at the respective schools by the research team.

Inclusion criteria: All children aged 9-18 years who were present at the time of the survey during the school visit were included in the study.

Exclusion criteria:

1. Children with structural deformities of the thoracic cage;
2. Children suffering from any chronic respiratory or cardiac disease;
3. Children absent on the day of the visit.

Sample size: The sample size was calculated using the formula for estimating a single population proportion:

$$n=Z^2pq/d^2,$$

where, n is the required sample size, Z is the standard normal deviate at 95% confidence level (1.96), p is the expected prevalence, q=1-p, and d is the absolute precision. Assuming a prevalence of exercise-induced asthma of 40%, relative precision of 8% (absolute precision=3.2%), and 95% confidence level, the minimum required sample size was calculated to be 900 [8].

To obtain a representative population from elementary schools in each residential area, of the total 2200 schools in Bengaluru, 908 schools from Bengaluru North were included, and using a clustered random sampling method, 15 schools were included in the study. Residential areas were divided into industrialised and non industrial areas (medium traffic density). Before the conduct of the study, permission was obtained from the Deputy Director of Physical Instruction (DDPI), principals, and teachers of the respective schools. Letters of invitation, the questionnaire, and informed consent form were distributed by the research team and sent to parents through schoolteachers before enrolment of the students.

Data collection: A modified version of the ISAAC questionnaire is a widely used tool for assessing the prevalence and severity of asthma and allergic diseases in children [15]. Each symptom and exposure variable was recorded as a categorical variable (Yes/No) or as predefined categories (e.g., socio-economic status, duration of activity) which included the age at the time of enrolment, the socio-demographic and family characteristics, diet history, type and duration of physical activity, symptoms and other risk factors for exercise induced bronchoconstriction as given. Parents or caregivers of the children were asked to complete the questionnaire and sign the consent form.

After the students fulfilled the inclusion and exclusion criteria, 984 students were enrolled. Following this, anthropometry was measured, which included standing height to the nearest centimeter without footwear, weight in kilograms with light clothes, and the Body Mass Index (BMI) was calculated using the formula weight in kilograms by height in meters square and was divided into four groups (underweight, normal, overweight, and obese). Physical activity refers to regular participation in outdoor play or sports for at least 60 minutes per day, while media exposure refers to screen time exceeding two hours per day, including television and mobile device usage [16]. A baseline heart rate, respiratory rate, oxygen saturation, and systemic examination were recorded in each child before the pulmonary function test. Paediatric pulmonologist (SAR) was responsible for the development of standardised questionnaires, operating and training procedures, and a computerised program to identify screening errors. ARS The tests were carried out in the sitting position, and a nose clip was applied. Children were instructed to take a full breath in and then close their lips around the mouthpiece and blow as hard and fast as possible. Inspiration should be full and unhurried, and expiration, once it begins, should be continuous without a pause. A minimum exhalation time of six seconds was applied to obtain maximal Forced Vital Capacity (FVC) results. A minimum of three acceptable FVC and FEV1 maneuvers were obtained. At least two consistent readings were obtained from each child, and the highest value in litres was used for analysis. Percent predicted PFTs were computed for each individual, adjusted for age, gender, and height. Following this, the student underwent a stress test, which included outdoor walking on a flat surface for six minutes. At the same time, an odometer was used to determine the calories burnt during the 6-minute stress test. A post-stress test, vitals, systemic examination, and pulmonary function were recorded. EIB was defined as the reduction of FEV1 by > or equal to 10%, and classified as mild (70-79% of predicted), moderate (60-69% of predicted), and severe (50-59% of predicted) [4].

STATISTICAL ANALYSIS

All the quantitative parameters, such as age, heart rate, FEV1, etc., were expressed as mean and Standard Deviation (SD) or median and interquartile range. The t-test was used to know the differences in the means and SD of two independent variables, such as age, heart rate, respiratory rate, etc., and assess the statistical significance. ANOVA was employed to assess the statistical significance of the mean (±SD) of three or more groups for a particular independent variable (Ex, BMI, SES, etc.,). The post-hoc test was done to understand the statistical significance of the difference between the groups. Logistic regression analysis was employed to identify the risk factors associated with the development of EIB. The association between pre- and post-EIB was tested by McNemar for test of significance for the various categories.

RESULTS

A total of 984 children were included in the study (54.4% boys, 45.6% girls) with a mean age of 13.5±1.68 years. The mean heart rate before the stress test was 91.4/min with mean respiratory rate and oxygen saturation of 18.8/min and 98.5%, respectively. The mean heart rate increased significantly after the stress test (118.3/min). The mean distance covered by the children during the 6MWT was 2588.9 steps, and the mean calorie burnt was 158.5 kcal [Table/Fig-1].

The mean pre-exercise FVC values were within normal limits (92-95% of predicted) and did not show significant change following exercise, indicating preserved lung volumes.

Before exercise, 553 (56.2%) children had abnormal baseline pulmonary function tests (PFTs). Following the exercise challenge,

Parameter	Range	Mean±SD	Median	IQR
Age (years)	9-18	13.5±1.68	13.6	2.3
Weight (kg)	15-74	38.3±10.16	38	15
Height (cm)	110-181	148.0±12.01	149	16
BMI (kg/m^2)	10-31	17.2±3.07	16.65	4
Pre HR (per min)	60-160	91.4±16.58	92	22
Pre RR (per min)	12-32	18.8±6.98	18	4
Pre SpO_2 (%)	90-100	98.5±1.11	99	1
Post HR (per min)	68-198	118.3±27.70	118	38
Post RR (per min)	16-28	25.7±6.62	24	10
Post SpO_2 (%)	92-100	97.7±9.45	99	1
Distance steps	1120-36409	2588.9±1371.05	2417.5	1078.75
Calorie burnt (kcal)	50-410	158.5±84.79	130	90

[Table/Fig-1]: Baseline demographic characteristics, anthropometric measurements, and pre- and post-exercise physiological parameters of the study population.

571 (58.0%) children demonstrated exercise-associated abnormal PFTs suggestive of exercise-induced bronchoconstriction. Among children with abnormal baseline PFTs (n=553), 535 (96.7%) continued to have abnormal PFTs post-exercise, while 36 (8.4%) of children with normal baseline PFTs (n=431) developed abnormal PFTs after exercise. The distribution of severity categories showed a significant shift toward higher severity post-exercise (Bowker's test of symmetry: p-value <0.001) [Table/Fig-2].

Pre-exercise PFT category	Post-exercise normal	Post-exercise mild	Post-exercise moderate	Post-exercise severe	Total	p-value#
Normal	395 (91.6%)	15 (3.5%)	11 (2.6%)	10 (2.3%)	431 (100)	<0.001*
Mild	16 (6.6%)	163 (67.4%)	43 (17.8%)	20 (8.3%)	242 (100)	
Moderate	2 (1.0%)	27 (13.9%)	128 (66.0%)	37 (19.1%)	194 (100)	
Severe	0 (0.0%)	0 (0.0%)	29 (24.8%)	88 (75.2%)	117 (100)	
Total	413 (42.0%)	205 (20.8%)	211 (21.4%)	155 (15.8%)	984 (100)	

[Table/Fig-2]: Pre- and post-exercise pulmonary function severity distribution (Bowker's Test of Symmetry).
#Bowker's test of symmetry showed a significant shift in severity following exercise (χ^2=40.89, df=6, p<0.001)

The EIB prevalence was significantly higher among children aged 12-14 years, those from lower socio-economic strata, children residing in urban and industrial areas, those using gas as cooking fuel, and children who were physically active. There was no significant association with gender, media exposure, mode of transport, academic performance, family type, BMI category, anaemia, or parental smoking [Table/Fig-3]. Dietary history was collected as part of the questionnaire; however, it was not included in the final analysis as it did not show a significant association with EIB and had incomplete responses.

Variables	n=984	Prevalence n (%)	p-value	OR (Odds Ratio)	95% CI (Confidence interval)
Gender					
Boys	535	300 (56.1)	0.175	1.19	0.92-1.54
Girls	449	271 (60.4)			
Age					
9 y-11 y 11 m	170	67 (39.4)	0.001	3.08	2.17-4.37
12 y-14 y 11 m	612	408 (66.7)			
15 y-18 y	202	96 (47.5)			
SES					
Upper middle	63	38 (60.3)	0.014	4.2	1.21-6.59
Lower middle	192	110 (57.3)			
Upper lower	713	420 (58.9)			
Lower lower	16	3 (18.8)			
Family H/o asthma	50	32 (64)	0.38	1.3	0.72-2.35
Physical activity	362	233 (64.4)	0.002	1.52	1.16-1.98
Media exposure	628	374 (59.5)	0.395	0.723	0.47-1.09
Cooking mode					
Gas	593	381 (64.2)	0.0001	0.526	0.406-0.682
Others	391	190 (48.6)			
Residing in industrial area	566	382 (67.5)	0.001	2.52	1.94-3.27
Residence					
Urban	835	524 (62.8)	0.001	3.66	2.52-5.31
Rural	149	47 (31.5)			

[Table/Fig-3]: Prevalence of exercise induced bronchoconstriction by various factors, OR and 95% CI.

The strength of association between self-reported symptoms and spirometry-confirmed EIB was negligible to weak. Upper respiratory symptoms (φ=0.017), chest pain (φ=0.040), and throat signs (φ=0.062) demonstrated minimal correlation with objective bronchoconstriction. Only exercise-related symptoms showed a statistically significant but weak association (p-value=0.005, φ≈0.10) [Table/Fig-4].

Symptom	Total (n)	EIB Present n (%)	EIB Absent n (%)	χ^2	p-value	Phi (φ)
Upper respiratory symptoms	21	11 (52.4%)	10 (47.6%)	0.28	0.596	0.017
Chest pain	9	3 (33.3%)	6 (66.7%)	1.58	0.132	0.040
Throat signs	101	49 (48.5%)	52 (51.5%)	3.84	0.050	0.062

[Table/Fig-4]: Association between Self-Reported Symptoms and Spirometry-Confirmed Exercise-Induced Bronchoconstriction (EIB).
*Chi-square test was used to assess association
**Phi (φ) coefficient was calculated as a measure of effect size for 2×2 tables
Estimated φ value for exercise-related symptoms based on reported p-value and sample size

DISCUSSION

Evaluation of the EIB must consider the duration of exercise, the type of activity utilised, and standards for diagnosing it. The present study employed a 6MWT to assess EIB among schoolchildren. This approach was chosen, especially given resource constraints, for safety plus practicality within a school setting, similar to a study from Kuti BP et al., among rural school children in Ilesa, Nigeria [17].

EIB was defined as a ≥10% decline in FEV1 from the individual's baseline pre-exercise value. This relative change criterion was applied irrespective of baseline spirometry status. Children with abnormal baseline PFTs were not excluded; however, only those demonstrating a further significant post-exercise decline in FEV1 were classified as having EIB.

The estimated prevalence of EIB in the present study was 58%, which was higher compared to the studies done in Algeria [10] and Sweden [11], which reported a prevalence of 19.2% and 16.1%, respectively. Using the same exercise protocol for investigating 13-14-year-old adolescents, Johansson H et al., found a prevalence of 11% [10], while De Baets F et al., found a prevalence of 7.4% among primary school children in Algeria [11]. Lin LL et al., found a prevalence of 52.5%, which was similar to our study, and studies done by Weiler JM et al., and Hallstrand TS et al., found a prevalence of 9.4% when studying 256 adolescents; they used the six minutes free-running test but defined EIB as a decrease in FEV1 of ≥10% [18-20].

The prevalence of EIB can be influenced by age, sex, ethnicity/race, and environmental conditions (e.g., air temperature, humidity, allergen content, and pollution) in which exercise is performed [19,21,22].

The risk factors evaluated in the present study were selected based on previously published epidemiological literature and the framework of the International Study of Asthma and Allergies in Childhood (ISAAC), which emphasises demographic, environmental, and lifestyle-related determinants of asthma and allergic disorders in children [5,23-25]. Accordingly, variables such as age, gender, socio-economic status, family history of asthma, physical activity, media exposure, type of cooking fuel, and residential environment were included, as these factors have been consistently associated with respiratory morbidity.

There were no gender differences in the estimated prevalence of EIB, similar to other studies [26,27]. However, data from previous studies are inconsistent. De Baets F et al., found a prevalence of 8.5% in girls and 6.4% in boys [11], while Johansson H et al., also reported a higher prevalence of EIB among girls (13%) than boys (9%) [10]. In the present study, several boys were still prepubertal and had the narrow larynx of a child, which explains the lack of difference between genders.

Many studies report EIB to be more prevalent among those of low socio-economic status, which was observed even in the present study, with a prevalence of EIB of 60.3% in the lower socio-economic status [23]. In contrast to the study by Hancox RJ et al., which showed no association of the prevalence rates with the socio-economic status [24].

The results of the present study showed that parental smoking had no association with the prevalence of EIB, similar to studies by Vlaski E et al., Htakka K et al., and Akçakaya N et al., [28-30]. In contrast, the studies by Gonzalez-Barcala FJ et al., Oberg M et al., Pietinalho A et al., and Pirastu R et al., showed that EIB increases with the exposure to parental smoking, particularly in adolescents [25,31-33].

Studies have shown that an abnormal exercise induced bronchial response can be found in a high proportion of first-degree relatives of asthmatic children in association between family history of asthma and exercise induced bronchoconstriction [34], similar to studies done by Pascoe CD et al., [35]. There was no association of the school performance and the type of family with the prevalence rates.

The probable reason for observing a higher prevalence of EIB in children where gas was used for cooking could be that most of the houses used gas as the major mode for cooking, as compared to others like wood, kerosene, etc.

The prevalence of EIB was found to be higher amongst children with high BMI >25 (63.6%) as compared to children with low and normal BMI, which was consistent with previous studies [36,37] conducted in western countries. Many studies have proposed the potential underlying mechanisms for the relationship between obesity and asthma symptoms; systemic inflammation, airway hyper-responsiveness, common genetic pathways, changes in diet and physical activity, and mechanical factors: gastroesophageal reflux, obstructive sleep apnea, and reduced lung volumes [38,39], while asthma is more common in obese than non obese people, respiratory symptoms associated with obesity can mimic asthma. In obese patients with dyspnea on exertion, it is important to confirm the diagnosis of asthma with objective measurement of variable airflow limitation.

Limitation(s)

The cross-sectional design limits causal inference. The urban, school-based setting may restrict generalisability. Reliance on questionnaire-based data may introduce recall bias, and the use of a field-based exercise challenge instead of laboratory testing may affect precision.

Future research should focus on longitudinal designs and multi-center studies to improve generalisability and assess long-term respiratory outcomes.

CONCLUSION(S)

This study estimated the prevalence of EIB among urban school children aged 9-18 years in Bengaluru using a standardised exercise challenge test. A substantial proportion of children were identified with EIB, many of whom did not report prior respiratory symptoms or medication use. Significant associations were observed with age group (12-14 years), socio-economic status, regular physical activity, type of cooking fuel, and residential environment, including urban and industrial area residence, while no significant association was found with gender, parental smoking, or family history of asthma. These findings suggest the importance of objective testing into school-based screening programs rather than symptom-based assessment for identifying EIB in school-aged children.

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