Effect of Submaximal Warm-up Exercise on Exercise-induced Asthma in African School Children

BF Mtshali[1], K Mokwena[2], OO Oguntibeju[3]

ABSTRACT

Background: *Regular physical activity has long been regarded as an important component of a healthy lifestyle. Exercise-induced asthma (EIA) is one of the major problems interfering with the performance of exercise. A warm-up exercise programme has been cited as a non-pharmacologic means of reducing EIA, but its effect has not been fully elucidated.*

Objective: *The aims of this study were to determine the prevalence of unrecognized EIA in Pretoria primary school children, determine the effect of a warm-up exercise programme on EIA and to establish the relationship between history of allergy, family history of asthma and EIA.*

Methods: *A random sample of 640 school children was selected. The study was divided into three phases. In phase one, a descriptive cross-sectional study was done using the standardized European Community Respiratory Health Survey (ECRHS) questionnaire. In phase two, non-asthmatic participants that returned a completed questionnaire were included in the field study. Pre-test and post-test experimental designs were used, where peak expiratory flow rate (PEFR) was measured at baseline and within ten minutes after exercise. A total of 340 subjects completed the Free Running Asthma Screening Test (FRAST); EIA was defined as a decrease in baseline PEFR ≥ 10% after exercise and 75 children (22%) had EIA. In phase three, 29 of the 75 subjects participated in the warm-up programme which was performed in the laboratory and subjects acted as their own controls. Predefined protocols for the study were followed.*

Results: *Seventy-five (22%) of the 340 participants had EIA. The mean age, height and weight were 10.51 years, 139.26 cm and 33.45 kg, respectively. Exercise-induced asthma symptoms were cough (25%), chest pain (16%), wheeze (12%) and chest tightness (12%). The history of allergy was 75%, family history of allergy 40% and positive history of allergy when near animals, feathers or in dusty areas 38%. Wheezing during or after exercise, wheezing when near animals, feathers or in dusty areas and chest pain was significant (*$p < 0.05$*). The mean PEFR after exercise without warm-up was 4.43 L/min. The mean PEFR after exercise (warm-up) was 4.98. The mean percentage change in PEFR between exercise without warm-up and exercise with warm-up was 14.83%. The paired t-test showed a significant difference between PEFR with warm-up and PEFR without warm-up (*$p < 0.05$*).*

Conclusion: *There was a high prevalence of EIA among study participants. Exercise-induced asthma symptoms were significant for wheezing and chest pain. Exercise after warm-up was significant in reducing EIA. This study reports the effect of warm-up exercise on EIA and highlights the need to screen school children for EIA.*

Keywords: Exercise-induced asthma, prevalence, Pretoria, school children, warm-up exercise

Efecto del Ejercicio de Calentamiento Submáximo sobre el Asma Inducida por Ejercicios en Niños Africanos

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RESUMEN

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Antecedentes: *La actividad física regular durante mucho tiempo ha sido considerada como un componente importante de un estilo de vida saludable. El asma inducida por ejercicio (AIE) es uno de los principales problemas que interfieren con el rendimiento del ejercicio. Un programa de ejercicios de calentamiento ha sido señalado como un medio no farmacológico para reducir el AIE, pero su efecto no ha sido aclarado completamente.*

Objetivo: *Los objetivos de este estudio fueron determinar la prevalencia del AIE no reconocida en los niños de escuela primaria de Pretoria, determinar el efecto de un programa de ejercicios de calentamiento sobre el AIE, y establecer la relación entre la historia de las alergias, los antecedentes familiares de asma, y el AIE.*

Métodos: *Se seleccionó una muestra aleatoria de 640 niños en edad escolar. El estudio se dividió en tres fases. En la primera fase, se realizó un estudio descriptivo transversal utilizando la estandarizada Encuesta de Salud Respiratoria de la Comunidad Europea (ECRHS, por sus siglas en inglés). En la segunda fase, los participantes no asmáticos que respondieron completamente un cuestionario, fueron incluidos en el estudio de campo. Se usaron diseños experimentales pre-test y post-test, en los que se midió la tasa de flujo espiratorio máximo (TFEM) al inicio del estudio y en los diez minutos después del ejercicio. Un total de 340 sujetos completó la Prueba de Carrera Libre para el Tamizaje del Asma (PCLTA). El AIE se definió como una disminución en la TFEM ≥ 10% de base, después del ejercicio, y 75 niños (22%) tuvieron AIE. En la tercera fase, 29 de los 75 sujetos participaron en el programa de calentamiento que se realizó en el laboratorio, y los sujetos actuaron como sus propios controles. Se siguieron los protocolos predefinidos para el estudio.*

Resultados: *Setenta y cinco (22%) de los 340 participantes tenían AIE. Los promedios de edad, altura y peso fueron 10.51 años, 139.26 cm y 33.45 kg, respectivamente. Los síntomas del asma inducida por el ejercicio fueron tos (25%), dolor en el pecho (16%), respiración sibilante (12%), y opresión en el pecho (12%). Los antecedentes de alergia fueron un 75%, los antecedentes de alergia en la familia fueron un 40%, y los antecedentes positivos de alergia en la cercanía de animales, plumas o en áreas polvorientas fueron un 38%. La respiración sibilante durante o después del ejercicio, la respiración sibilante en la cercanía de animales, plumas o en áreas polvorientas, y el dolor de pecho dolor, fueron significativos (*$p < 0.05$*). La TFEM promedio después de hacer ejercicios sin calentamiento fue 4.43 L/min. La TFEM promedio después del ejercicio (calentamiento) fue de 4.98. El cambio de porcentaje promedio de TFEM entre ejercicios sin calentamiento y ejercicios de calentamiento fue 14.83%. La prueba de t pareada mostró una diferencia significativa entre TFEM con calentamiento y TFEM sin calentamiento (*$p < 0.05$*).*

Conclusión: *Hubo una alta prevalencia de AIE entre los participantes del estudio. Los síntomas del asma inducida por el ejercicio fueron significativos para el dolor de pecho y la respiración sibilante. El ejercicio después de calentamiento fue significativo en la reducción de AIE. Este estudio reporta el efecto del ejercicio de calentamiento sobre el AIE, y destaca la necesidad de realizar tamizajes entre los escolares para detectar AIE.*

Palabras claves: Asma inducida por ejercicio, prevalencia, Pretoria, niños en edad escolar, ejercicios de calentamiento

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INTRODUCTION

Regular physical activity has long been regarded as an important component of a healthy lifestyle. This impression is reinforced by scientific evidence linking regular physical activity to a wide array of physical and mental health benefits. Regular physical activity improves aerobic endurance and muscular strength. Among healthy young people, physical activity and physical fitness may favourably affect risk factors for cardiovascular disease (1−4).

Regular physical activity among children and adolescents with risk factors for developing chronic disease is important as it is known to decrease blood pressure in adolescents with borderline hypertension, increase physical fitness in obese children and decrease the degree of overweight among obese children. Physical activity among adolescents is consistently related to higher levels of self-esteem and lower levels of anxiety, stress and high-risk health behaviours (5, 6). It is believed that children interact with each other through play, and the ability to engage in games and sport with their peers reduces psychological isolation (7−11). The healthy active student or pupil is more likely to be academically motivated, alert and successful. In adolescents, physical activity may enhance the development of a positive self-concept as well as the ability to pursue intellectual, social and emotional challenges. Throughout the school years, physical activity can promote social, cooperative and problem solving competencies (12).

Exercise-induced asthma (EIA) has been found to be one of the major problems interfering with performance of exer-

cises in general and in particular with participation in sport. Exercise-induced asthma, exercise-induced broncho-constriction and exercise-induced bronchospasm are all terms used to describe the phenomenon of transient airflow obstruction associated with physical exertion. It is a prominent finding in children and young adults because of their greater participation in vigorous activities (3, 13).

The symptoms of EIA are shortness of breath, cough, chest tightness and wheezing that normally follow the brief period of bronchodilation present early in the course of exercise. Bronchospasm typically arises within 10 to 15 minutes after an exercise is concluded and resolves about 60 minutes later (14). Exercise-induced asthma may also appear during sustained exertion (12, 15). Exercise-induced asthma occurs in up to 90% of asthmatics and 40% of patients with allergic rhinitis; among athletes and in the general population, its prevalence is between 6% and 13% (16).

On the other hand, asthma is a chronic inflammatory disorder of the airways associated with widespread but variable airflow obstruction that is often reversible spontaneously or with treatment. Increased airway responsiveness and airway inflammation characterized by T-helper-2 lymphocyte infiltration with eosinophils and neutrophils are characteristic of the disorder and EIA may be a symptom of asthma or it may be independent of asthma (12, 17).

Current data overwhelmingly document the existence of a world-wide asthma epidemic, though asthma has been considered to be relatively rare among African children. It is only recently that studies are reporting an increase in the prevalence of asthma in both urban and rural areas. Of interest is the fact that there are now more population based studies of asthma and bronchial hyper-responsiveness (BHR) in children and adolescents in South Africa, but these studies are limited almost entirely to areas in the Western Cape (WC) and Eastern Cape (EC) in South Africa.

More studies using standard methods are needed in other parts of the country to extend these regional comparisons. There may be variations in other parts of the country considering factors like differences in altitude, environmental pollution, race and physical activity habits of the children. It was imperative for the investigators to first determine the prevalence of unrecognized EIA asthma in Pretoria black school children before determining whether a warm-up exercise programme would have any effect in reducing EIA. We hypothesized that the submaximal warm-up exercise reduces EIA by less than 10% or more (null hypothesis). The reason for using a 10% fall in peak expiratory flow rate (PEFR) is due to the fact that a 10% decrease in PEFR has been documented as probable EIA. The researchers believe that a minimal decrease in PEFR affects sports performance.

SUBJECTS AND METHOD

This study was conducted in black dominated townships (Mamelodi, Atteridgeville and Soshanguve) in Pretoria, which is situated in the northern part of Gauteng Province in South Africa and has a population of 1.76 million.

The study population was identified through statistical approach obtained from the Gauteng Department of Education. The primary schools have grade 0 to grade 7 and the ages of the pupils range from five to 12 years. For the purpose of this study, the population consisted of pupils from grades 3 to 7. This included most of the children in the eight to 12-year age group. The total number of black urban schools in Gauteng North is 99 (Mamelodi 39, Atteridgeville 19, Soshanguve 41). Twelve out of the 99 schools (12%) were randomly selected through computer generated numbers. According to Seaberg (18), a 10% sample should be sufficient for controlling for sample errors.

Study design

A descriptive cross-sectional study was performed using the standardized European Community Respiratory Health Survey (ECRHS) questionnaire to determine the symptoms of EIA and allergy of pupils.

Questionnaire: The ECRHS covered demographic data, diagnosis of asthma, EIA symptoms, allergic symptoms, family history of asthma and allergy, smoking, home environment, effect of animals, dust and feathers on allergy symptoms, effect of trees, grass, plants and pollen on allergy symptoms.

Validity and reliability of questionnaire: The translation process of the questionnaire followed the established forward-backward translation procedure with independent translations and counter translations. Professional Tswana translators who were equally fluent in English performed forward and backward translations. The back translations were compared with the original, after which alterations to certain words and phrases were made accordingly. Some English words were changed into phrases after translation, *eg* wheezing was changed into "hoarse vibrations in the chest" because there is no Tswana word for "wheezing".

Administration of questionnaire: The school principals were given sealed envelopes each containing questionnaires, consent forms and covering letters to parents in both English and Tswana. The literacy level of the parents/guardians was not determined because it was thought to be sufficient as the schools communicate with parents/guardians usually in English. The principals and teachers helped with the distribution of the questionnaires. Pupils were given a seven-day period to return the questionnaires and consent forms. The parents were requested to assist the pupils in filling in the questionnaires. The investigators collected the questionnaires from the principals and reconciled the returned questionnaires with the class lists. Information from the questionnaires was captured on the Excel computer software programme.

Field work

This was designed to identify pupils with unrecognized EIA. All pupils who returned a completed questionnaire with signed

consent forms and who met the inclusion criteria were eligible for the field study. The exclusion criteria were asthmatic pupils (pupils who were identified as asthmatics, pupils suffering from respiratory tract infection at the time of the field study), pupils having any recognized musculoskeletal problems and those having any other illnesses during the time of the study that could interfere with the results. Pupils who were absent on the day of the study were also excluded. This work was conducted using Free Running Asthma Screening Test (FRAST) over a three-month period and all testing was done between 9:00 am and 11:00 am. The average temperature and relative humidity of the school soccer field were recorded. Free running asthma screening test was conducted on each school soccer field. The investigators trained research assistants to take and record height, weight, heart rate and PEFR using standard procedures (19) and all findings were recorded on a data collection form.

Validity and reliability of instruments: The National Asthma Education and Prevention Programme (20), which sets guidelines for the diagnosis and management of asthma, states that FRAST and peak flow metres are valid measures of EIA. A study conducted by Haby *et al* (21) found FRAST to have good validity and reliability. There are other studies that have tested the sensitivity and specificity of FRAST. Jones and Bowens (22) found a sensitivity of 43% and a specificity of 93%, whereas Randolph (16) found a sensitivity of 64% and a specificity of 94%. For our study, the Tanita electronic scale has an auto-calibration device. It calibrates itself for each and every measurement taken. The standing height metre stick and the assess peak flow metre have calibration certificates. The Polar heart rate monitor calibrates itself but the investigators performed the validity and reliability of inter-observer reliability for PEFR in fifteen pupils independently. The percentage agreement between the observers was 83% and the intra-observer reliability for PEFR was done by one investigator at baseline and 30 minutes interval in five pupils and the percentage agreement within the observer was 98%.

Field testing and measurements

The investigators arranged suitable dates and times with school principals in order to conduct the field study. The participants were advised not to engage in physical activity two hours prior to field-testing. They were also advised to bring suitable clothing for exercise. The participants were organized by the school teachers in one classroom and baseline measurements were done in the classroom and standard procedures were followed in taking baseline measurements. The formula 220-age was used to calculate maximal heart rate (MHR). The range of the target heart rate was 70% to 80% of MHR and this was set on the heart rate monitor (23). A group of ten participants (at a time) went to the school field to perform the exercise challenge test. Each group was supervised by investigators along with the school teachers. The school teachers clapped hands and called the pupils by their names and dictated the pace of the run by slow clapping of hands for the first two minutes (warm-up) and fast clapping during the last four minutes (high intensity exercise). Heart rate during running was monitored in five (through random selection) of the ten pupils using the Polar target heart rate monitor. The research assistants recorded three PEFR efforts for each participant during the first ten minutes after the run (14). The highest of the three mea-surements was taken to indicate the participant's best performance and this was used in the analysis of data.

Data processing and analysis

The investigators designed data collection form for recording age, height, weight, heart rate and PEFR and all measurements were recorded appropriately: age in years, height in centimetres, weight in kilograms, heart rate in beats/minute and PEFR in L/minute. The information was captured using the Excel computer programme and was reconciled with data from the questionnaire. Frequency distribution tables and pie charts were used to represent data. Age, gender, weight, height, region of residence, EIA symptoms, allergy, family history and home environment were analysed using descriptive statistics. The baseline and exercise values of PEFR were used to calculate the percentage of PEFR reduction as a measure of unrecognized EIA. The percentage of EIA was determined using the formula as described by Van Niekerk *et al* (24):

$$EIA = \frac{(Highest\ Baseline\ PEFR) - (Highest\ Exc\ PEFR)}{(Highest\ Baseline\ PEFR)} \times \frac{100}{1}$$

Univariate tests of association were used to test if there was any statistically significant association between the following: number of EIA symptoms (cough, wheeze, chest pain and chest tightness during or after exercise) to the positive exercise challenge. The significance between the histories of allergy (allergy to dust/pollen/eggs, skin allergy, itchy red eyes, bouts of sneezing, coughing, runny nose, stuffiness in the nose) was tested to the positive exercise challenge. A positive family history of asthma was also tested to the positive exercise challenge. The groups were divided into two *ie* < 10% EIA and ≥ 10% EIA, respectively. Data analysis was performed for these two groups. The mean height, age and weight were compared for the two groups. The *p*-values for the Mann-Whitney test were used for comparison. Associations were determined between status (< 10% EIA and ≥ 10% EIA) and all categorical variables using X^2 and Fisher's exact test.

Ethical consideration

Permission to conduct the study was obtained from the Gauteng Department of Education as well as from school principals. Request for consent was sent to parents/guardians and approval obtained and the pupils assented to participate in the study. These parents were advised to consult with healthcare professionals at the nearest health centre for further advice and counselling. The study also received the approval of the Research, Ethics and Publication Committee of the University of Limpopo, South Africa.

RESULTS

Of the 12 schools selected, only eleven schools participated in the study, as the principal of one school declined to allow pupils to participate, and 594 questionnaires were distributed. All the questionnaires were returned within a seven-day period. Out of the 594 pupils, twelve had asthma and their questionnaires were excluded from further analysis. Fifty-four pupils did not have parental consent to participate even though they completed the questionnaires and were also excluded. Five parents declined their children's participation and four questionnaires had responses that did not make sense and were therefore excluded. Eighty-one per cent (n = 519) of the returned questionnaires were eligible for statistical analysis, however, only 340 participants took part in the exercise challenge.

Demographic characteristics of participants

A large percentage (58.82%) of the participants fell into the 10 to 12-year age group; 45.29% were males and 54.71% were females. Table 1 summarizes the demographic characteristics of the participants.

Table 1: Demographic characteristics of participants (n = 340)

Characteristic	No.	%
Age in years		
7–9	91	26.76
10–12	200	58.82
≥ 13	49	14.41
Gender		
Female	186	54.71
Male	154	45.29
Weight in kilograms		
17–27	78	22.94
28–38	160	47.06
39–48	71	20.88
≥ 49	31	9.12
Height in centimetres		
117–127	26	7.65
128–137	109	32.06
138–147	123	36.18
≥ 148	82	24.11

Exercise-induced asthma symptoms of participants

There were four questions that related to EIA symptoms. A total of 233 (68.73%) had a negative history of cough during or after exercise, whereas 106 (31.27%) of the respondents had a positive history of cough during or after exercise. The history of wheezing was positive in 56 (16.52%) respondents and chest tightness was positive in 48 (14.16%) participants. Chest pain was positive in 68 (20.06%) respondents. Figure 1 depicts exercise-induced asthma symptoms of the participants.

Family history of asthma and allergy of participants

There were questions relating to the family history of asthma and allergy. Seven respondents reported a positive family history of asthma from mothers (2.27%), from fathers (1.71%) and siblings (2.90%). The history of allergy was much higher and ranged from 7.37% in fathers to 15.20% in mothers. The history of allergy in siblings was 13.75% and most of the participants (n = 275; 81%) reported that they had a history of allergy. Figure 2 depicts family history of asthma and allergic symptoms of participants, while Table 2 lists asthma symptoms along with family history of asthma and allergy.

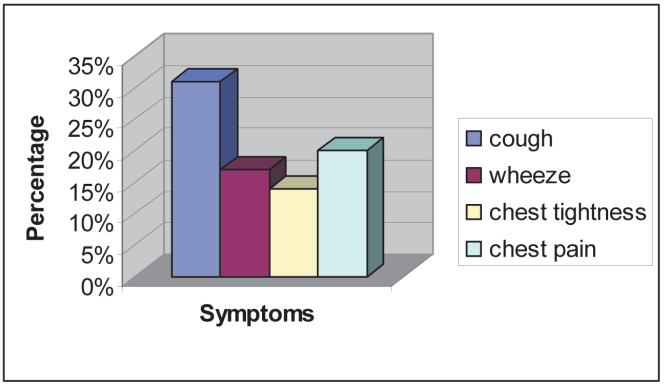

Fig. 1: Exercise-induced asthma symptoms of participants.

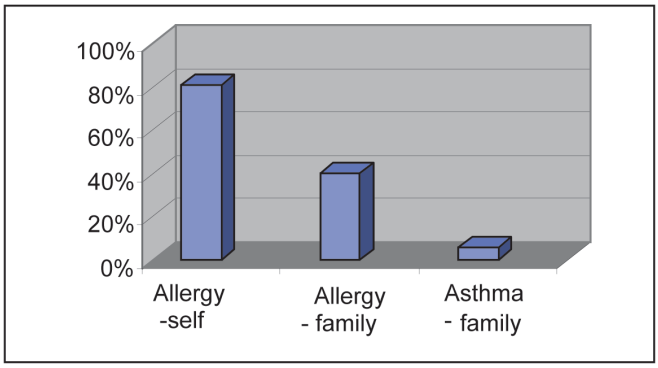

Fig. 2: Family history of asthma and allergy of participants.

Results of FRAST

Seventy-five (22%) pupils had a decreased FRAST that was equal to or more than 10%. The decrease was in relation to the individual's baseline/rest PEFR. By definition, the 22% are those participants that have a previously undetected EIA. Table 3 summarizes the results of FRAST.

Comparison of age, height and weight of EIA ≥ 10% *versus* EIA < 10%

Normality of the distribution of each variable was accessed by Shapiro-Francia criterion. Statistical analyses were performed using the *t*-test and the Mann-Whitney test. All *p*-values were two-sided. The mean age of participants with EIA ≥ 10 was 10.51 years compared to 10.75 years for participants with EIA < 10%. The participants that had EIA were younger, shorter and smaller as compared to the participants that did not have EIA. The *p*-value for age was not significant ($p > 0.05$). There

Table 2: Exercise-induced asthma symptoms, allergy and family history (n = 340)

Characteristic		No.	%
Exercise-induced asthma symptoms			
Cough	No	233	68.73
	Yes	106	31.27
Wheeze:	No	283	83.48
	Yes	56	16.52
Tightness:	No	291	85.84
	Yes	48	14.16
Pain:	No	271	79.94
	Yes	68	20.06
Family history of asthma and smoking			
Do your parents have?			
Asthma:			
Mother	No	302	97.73
	Yes	7	2.27
Father	No	287	98.29
	Yes	5	1.71
Siblings	No	301	97.10
	Yes	9	2.90
Allergy:			
Mother	No	251	84.80
	Yes	45	15.20
Father	No	264	92.63
	Yes	21	7.37
Siblings	No	251	86.25
	Yes	40	13.75
Self	No	65	19.11
	Yes	275	80.88

Table 3: Results of Free Running Asthma Screening Test (FRAST)

Exercise challenge	n	%
Positive	n = 75	22
Negative	n = 265	78
Total	**n = 340**	**100**

was no significant difference ($p > 0.05$) in mean height and weight of participants in terms of their EIA values.

EIA symptoms, allergy and family history for EIA participants

There were four questions that related to the presence of EIA symptoms. Exercise-induced asthma symptoms reported were cough (25%), wheeze (12%), chest tightness (12%) and chest pain (16%). There were six questions that related to the family history of allergy and asthma. A total of 30 (40%) respondents reported a positive family history of allergy. There were eight questions from the ECRH questionnaire that related to the presence of allergy/allergic reaction. A total of 54 (72%) of the respondents reported a positive history of allergy/allergic reactions. Only two EIA participants reported that their mothers and fathers had asthma. Eight EIA participants reported that their siblings had allergy symptoms. Figure 3 depicts EIA symptoms and allergy for EIA participants.

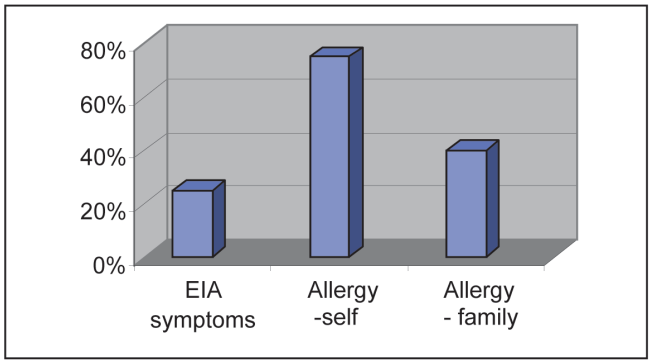

Fig. 3: Exercise-induced asthma (EIA) symptoms and allergy for EIA participants.

Air quality and home environment of EIA participants

A total of 21 (28%) EIA participants responded positively to the question that enquired whether there were members of their family who smoked regularly. Thirty-four (45%) EIA participants used coal, wood, paraffin and gas for cooking and for warming their homes. A total of 31 (41%) EIA participants have fitted carpets in their bedrooms. All their bedrooms had curtains and they slept on mattresses and pillows. There were questions that related to allergy symptoms when in close proximity/contact with animals, feathers, trees, flowers *etc*. A total of 11 (38%) EIA participants had a positive history of allergy when near animals such as cats, dogs, near feathers including pillows, or in dusty areas.

Classification on severity of EIA and percentage scores

Most of the participants were within mild and moderate classification. Only 5% fell in the severe classification (16). Children with EIA were more likely to report that they wheezed during or after exercise and the *p*-value was significant ($p < 0.05$). The presence of chest pain during or after exercise was significant ($p < 0.05$). Exercise-induced asthma pupils were also more likely to report that they wheezed when in contact or in close proximity with animals ($p < 0.05$).

Association of various independent variables with EIA

The odds of having EIA at 95% confidence interval for independent variables were as follows: Of the four EIA symptoms (cough, wheeze, chest tightness and chest pain), wheezing was significantly related to EIA (OR 0.33, CI 0.12, 0.90). Wheezing when near animals or dust was also related to EIA (OR 0.20, CI 0.04, 1.04). The odds of having EIA were significantly higher if participants' siblings had asthma (OR 4.84, CI 0.97, 24.21). The odds of having EIA were also significantly higher if the participants had a history of stuffiness in the nose (OR 2.23, CI 1.27, 3.93) [Table 4].

DISCUSSION

The primary aim of the study was to determine the prevalence of EIA in primary school children in Pretoria and the investi-

Table 4: Association of various independent variables with exercise-induced asthna

Independent variable	Odds ratio	95% CI
Exercise-induced asthma wheezing	0.33	0.12, 0.90
Stuffiness in nose	2.23	1.27, 3.93
Sibling with asthma	4.84	0.97, 24.21
Wheezing when near animals/dusty areas	0.20	0.04, 1.04

gators used the modified ECHR questionnaire and the field study to determine unrecognized EIA.

A total of 75/340 (22%) participants who were subjected to an exercise challenge had EIA. This means that seventy-five participants had a decrease in PEFR greater or equal to 10% after exercise compared to pre-exercise PEFR. A 10% decrease in PEFR was chosen because some authors had suggested using a 10% decrease in PEFR as an outcome measure of EIA, as any appreciable airway obstruction could be detrimental to exercise performance (18, 25−27). Peak flow metres (instruments for measuring PEFR) are practical and economical to use in a large group of school pupils in their field of play. Most of the pupils play and do sporting activities outdoors where they are exposed to environmental factors such as changing weather conditions, air pollution, dust and aeroallergens.

Although spirometers are more accurate, they are not cost-effective, especially when used in a large population. The investigators acknowledged that the forced expiratory volume in one second (FEV_1) is one of the most reliable values for assessing lung function; however, a full spirometry evaluation was not practical in the field study. A PEFR value was used because it can give a reasonable indicator of broncho-constriction as suggested in other studies (26, 28).

Although EIA showed higher values in younger, shorter and light-skin participants, these values were not significantly different from others. In contrast, Terblanche and Stewart (29) in a study in the northern suburbs of Cape Town found that EIA was prevalent in coloured children and higher in the age group of six to nine years. Yobo *et al* (28) found a prevalence of EIA in Ghanaian school children to be higher in the younger age group as well. The probable reason would be the high level of physical activity in the younger age group. Exercise-induced asthma was equally distributed in both males and females. This finding is similar to the findings of Kyle *et al* (30). Exercise-induced asthma ratio in developed countries shows a male preponderance.

Only nineteen (25%) of the participants of the seventy-five reported a positive history of coughing, wheezing, chest tightness or chest pain during or after exercise. This means that 56 (75%) would have not been tested if the exercise challenge was done on only those participants who responded that they had EIA symptoms in the questionnaire. This finding is in line with other studies that have found that negative EIA symptoms do not necessarily exclude EIA (10, 28, 31).

Hallstrand (32) conducted a study on the effectiveness of screening examination to detect unrecognized EIA and found that 11 (45.8%) out of 24 participants did not report symptoms in the screening questionnaire but tested positive after an exercise challenge test. This demonstrates that EIA is common and often unrecognized in school children. Most authors reported that exercise challenge testing or metacholine challenge testing provides more useful and reliable information than symptoms or surveys in assessing EIA. The reason is because there is a lack of correlation between subjective symptomatic parametres and testing positive for EIA (25, 33−35).

In the present study, cough during or after exercise was the most commonly observed symptom, although not significant ($p > 0.05$). Other studies have also noted that cough during or after exercise is a common EIA symptom. For instance, Luyt *et al* (36) found that 93.3% of black school children in Soweto, Johannesburg, reported coughing during or after exercise. In the present study, wheezing and chest pain were significant. Steinman *et al* (37), in a study conducted on bronchial hyper-responsiveness and atopy in Cape Town children, found that there was no significant association between positive bronchial hyper-responsiveness and chest pain as well as wheezing during or after exercise in black rural children but that a significant correlation between bronchial hyper-responsiveness and wheezing during or after exercise was found in white children.

Fifty-four (72%) of the participants with EIA reported a positive history of allergy/allergic reaction. Allergy in black South African children is believed to be rare and less common in children living in inland areas. However, Luyt *et al* (36) found that 75% of black children living in Johannesburg suffered from allergy. Most allergic symptoms were due to hay fever. Our current study and the study by Luyt *et al* (36) were conducted in areas that have similar climatic conditions. The study population had similar characteristics in that all the three studies were conducted in historically disadvantaged urban areas for blacks. Nichols and Longsworth (23) conducted a similar study in Jamaica (warm, humid climate) and found that 24 (55.8%) subjects who had a positive history of allergy tested positive on exercise challenge. We report that the history of stuffiness in the nose was significantly related to EIA. Steinmann *et al* (37) found a significant correlation between positive bronchial hyper-responsiveness and sneezing spells as well as a stuffy or blocked nose.

Steinman *et al* (37) also found the prevalence of bronchial responsiveness of 34.4% in urbanized black children compared to 3.17% in the study by Van Niekerk *et al* (24). The authors attributed the increase in atopic sensitization to a shift from traditional to a more westernized lifestyle of Xhosas in rural communities. In our opinion, the increase in bronchial hyper-responsiveness could be associated with environmental factors such as air pollution and aeroallergens. The environmental factors could be the probable reason for the increase in allergy and bronchial hyper-responsiveness. Further studies to investigate the causes of the increase in allergy are required (6).

Only two EIA participants reported that their mothers and fathers had asthma. Eight EIA participants reported that their siblings had a history of allergic symptoms. The participants that reported that their siblings had asthma were more likely to test positive on exercise challenge. In other words, they were more likely to have EIA. The current study did not find a strong relationship between family history of asthma, allergy (in mothers and fathers) and EIA. However, there was a strong relationship between asthma in siblings and EIA. In atopic subjects, exposure to air pollution increases airway responsiveness to aeroallergens. The airway mucosal damage and impaired mucocilliary clearance induced by air pollution may facilitate the penetration and the access of inhaled aeroallergens to the cells of the immune system, and so promote airway sensitization (38). Children spend more time outdoors while playing when compared to adults and playing involves activities that increase ventilation rates which can increase the exposure to air pollutants compared with adults (39). This implies that air pollution and outdoor playing could contribute to the development of EIA in children.

The other factor that might explain a greater exposure of children to air pollution compared to adults is that the lung develops rapidly in the young. During this time, the lung epithelium has a greater permeability and children have a larger lung surface area per kilogram of body weight than adults. Children normally breathe 50% more air per kilogram weight than adults. This suggests that there is a critical exposure time when air pollution may have lasting effects on respiratory health (39, 40). The increase in allergy and bronchial responsiveness in school children could be explained by factors such as modern houses that have fitted carpets, curtains, pillows and mattresses. This is an environment that promotes house dust and air pollution. The increase in air pollution, cold weather and dusty conditions that the school children are exposed to may have compounded the problem.

In the current study, a total of 21 (28%) EIA participants lived with heavy smokers and 45% of EIA participants used coal, wood and paraffin for cooking and warming their homes. There was no significant difference between passive smoking and EIA, however, Steinman *et al* (37) found a significant association between smoking fathers and bronchial hyper-responsiveness. Jordaan *et al* (41), in a study on environmental tobacco smoke exposure in children in South Africa, reported that 80% of children were exposed to environmental tobacco smoke and that maternal smoking accounted for the most (22%) variation in urinary nicotine as compared to all other sources.

A low percentage of participants had pets in their homes. In the present study, the history of wheezing when near animals such as cats and dogs, near feathers including pillows, quilts or duvets or in a dusty part of the house was significantly related to EIA. The odds ratio was 0.20 at 95% CI (0.04, 1.04).

The general impression is that allergy and bronchial hyper-responsiveness is on the increase in South Africa. This is in keeping with the rest of the world where research provides documentation of higher prevalence of allergy and bronchial hyper-responsiveness. The EIA symptoms that were significant were wheezing and chest pain. Wheezing when near animals, feathers and dusty areas was significant. The odds of having EIA were significantly higher if the subject reported that he/she had a history of stuffiness in the nose and that his/her siblings had asthma.

RECOMMENDATIONS

Based on the findings of this study, it is recommended that further studies regarding the prevalence of EIA in South Africa be conducted on broader communities in order that the prevalence of EIA in South Africa can be determined. It is also recommended that further studies on the effect of warm-up exercise be conducted in order to be able to have a better perspective on this subject.

AUTHORS' CONTRIBUTION

K Mokwena designed and supervised the work. B Mtshali performed all the experiments and did all analyses while OO Oguntibeju wrote, edited, revised the manuscript and acted as the corresponding author.

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