

PEDIATRICS

Asthma screening of inner city and urban elementary school-aged childrenPriyal Amin, DO¹, Linda Levin, PhD², Andrew Smith, MD, MS³, Benjamin Davis, MD³, Laura Nabors, PhD², and Jonathan A. Bernstein, MD³¹Division of Allergy and Immunology, Department of Internal Medicine and ²Department of Environmental Health, University of Cincinnati, Cincinnati, OH, USA, and ³Division of Allergy and Immunology, Department of Internal Medicine, University of Cincinnati College of Medicine, Cincinnati, OH, USA**Abstract**

Objective: Currently, in the United States there is a lack of a standardized method to effectively screen school children with undiagnosed or poorly controlled asthma. The purpose of this proof-of-concept study was to assess the use of the American College of Allergy, Asthma, and Immunology's (ACAAI) Asthma Screening Questionnaire to identify elementary school-age children at risk for asthma (undiagnosed) or poorly controlled asthma. **Methods:** Children in grades 3–5 from one urban and two suburban schools completed ACAAI's 14 question asthma screening questionnaire and had their peak expiratory flow (PEF) measured. Children were considered to have a positive asthma screen and be at risk for having undiagnosed or poorly controlled asthma if they answered 'yes' to more than three questions. Children were referred to a physician if they had a positive asthma screen, a previous history of asthma, or a low PEF. **Results:** Of the 86 participants, 52 were identified as being at risk for asthma. The number was higher among children attending an urban versus suburban school ($p = 0.04$). The sensitivity and specificity of the screening questionnaire for identifying asthma risk were 90% and 66%, respectively, when the number of 'yes' responses for a positive screen was increased from three to five of 14 questions. **Conclusions:** The ACAAI's Asthma Screening Questionnaire identified 52 children at risk for undiagnosed or poorly controlled asthma. Our findings support the need to validate this questionnaire to be used in conjunction with PEFR for identifying elementary school children at risk for asthma.

Keywords

Control/management, education, epidemiology, pediatrics

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Asthma is one of the most common chronic diseases of childhood. The prevalence of childhood asthma continues to rise in developed countries and is associated with significant morbidity [1–3]. Unfavorable outcomes including number of missed days from school, poor compliance with taking medications, restrictions in physical activity and increased medical and emergency room visits are common for children with asthma from low-income families and/or who reside in inner-city areas [4,5]. Many elementary schools have nurses or health centers that can address acute asthma problems, but lack the ability to identify children with undiagnosed or poorly controlled asthma. Nationwide there is a striking lack of standardized methods to effectively screen and diagnose asthma in a school setting.

Much of the morbidity associated with asthma is preventable with early diagnosis. Hence, asthma screening for

identifying children early in the course of their illness leading to initiation of appropriate treatment would help significantly reduce morbidity in this vulnerable population. Several methods have been used to increase the accuracy for diagnosing asthma, but many have proven difficult to implement and/or are very costly to apply on a large scale [6]. Among the approaches used, school-based parent and student screening questionnaires provide a non-invasive cost-effective means for identifying children with possible undiagnosed asthma [7].

There are several factors that affect proper asthma screening in the pediatric population. These include poor access to healthcare among certain ethnic groups and those with lower socio economic status in addition to agreement between parental and student reporting of asthma symptoms or control [8,9]. In addition, to be useful throughout the United States educational system, a screening tool must be validated across multiple ethnic groups, socio-economic classes and age groups [8]. Another important issue that impacts asthma screening is the availability of a screening questionnaire which has an acceptable sensitivity and specificity and correlates well with a physician diagnosis of asthma and objective spirometric measurements of lung function [9,10]. A limited number of health care personnel available to

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administer asthma screening in schools also plays a role as to why it has not been widely implemented in elementary schools nationwide.

To address these unmet needs, the objectives of this cross-sectional proof-of-concept study was to assess the outcome of performing asthma screening in urban and suburban elementary schools for identifying children at risk for developing asthma or those with uncontrolled asthma using the ACAAI's Asthma Screening Questionnaire, which is currently being used for asthma screening in many settings nationwide.

Methods

Study population

Three Cincinnati, Ohio elementary schools agreed to participate in the American College of Allergy, Asthma and Immunology's (ACAAI) Nationwide Asthma Screening program during 24–26 May 2011. One school was located in an urban setting and the others were located in a suburban setting (referred to as suburban A and suburban B). IRB approval for the study was obtained from the ACAAI and the University of Cincinnati's Institutional Review Board. Parental/guardian assent was obtained by completion of a parental questionnaire that was sent to 538 parent(s)/guardian(s) of children in grades 3–5. Signed informed consents of children whose parents/guardians assented were obtained prior to the administration of the screening questionnaire. Children were also given the opportunity to answer six questions if they had a history of physician diagnosed or were previously prescribed asthma medications (Appendix). All children spoke English as their native language.

Study design

The parental questionnaire collected information regarding the parent(s) history of asthma and/or allergic rhinitis, and the child's history of allergic rhinitis and/or exercise induced asthma. On the screening day, the ACAAI's 14 asthma screening questions designed for children ages 8–14 years was administered to all the participating children with the assistance of a physician, nurse or a research assistant. Question numbers 15–20 (Appendix) were administered only to those children who had a self-reported history of asthma or were on asthma medication(s) at the time of the screening. Screening questions were answered in a 'yes' or 'no' format and were focused on evaluating the presence of asthma-type symptoms, their severity and possible triggers. In addition, all children had their height, weight, and peak expiratory flow (PEF; L/min) measured on the day of screening. Children who responded 'yes' to more than 3 of the 14 screening questions, or answered 'yes' to at least one question from 15 to 20, or had a low PEF, were referred to their pediatrician or asthma specialist for further testing or to further assess asthma control and modify controller medications, if warranted.

Definitions

A positive screen for asthma or risk of having undiagnosed or uncontrolled asthma was defined as more than three 'yes' responses to the 14 ACAAI's asthma screening questions.

A self-reported history of asthma was defined as at least one 'yes' response to ACAAI's questions numbered 15–20, answered by those children who had a self-reported history of asthma or were taking asthma medication(s) at the time of the study as described above (Appendix).

Statistical analysis

The ability to predict asthma from responses to each of the 14 asthma screening questions was assessed using multiple logistic regression. The model was analyzed with child's history of self-reported asthma as the outcome and the 14 question responses as independent variables, coded as 1 or 0, indicating a positive (yes) or negative (no) response, respectively. A tri-level categorical school variable was included in the model to adjust for possible residual effects of race, age and gender on asthma status. Differences between demographic and other characteristics of the children were compared by school location (urban vs. suburban), a positive asthma screen (i.e. more than three 'yes' responses) and child's history of self-reported asthma. Demographic and other characteristics included age (8–9, 10–11, 12–13 years), gender, race (Caucasian vs. other including African American, Asian, American-Indian, Latino, Hispanic, Pacific Islander or mixed), PEF, self-reported history of allergic rhinitis, parental history of self-reported allergic rhinitis or asthma. Differences were evaluated by Pearson chi-square or Fisher's exact tests for count data and unpaired *t*-tests for continuous data. The 'optimum' number of positive responses to the screening questions, above which asthma risk could be predicted, was determined from a receiver–operating characteristic (ROC) analysis of the data. The optimum cutoff was determined by selecting sensitivity and specificity values, which were realistic with respect to the goals of future questionnaire surveys for predicting asthma in children ages of 8–14 years. This analysis was repeated for the five screening questions (1, 3, 4, 6 and 13) which most closely reflected the previously validated ISAAC questionnaire for 8–14 year olds, and areas under the curves (AUCs) were compared. Analyses were performed using SAS for Windows, version 9.3, SAS Institute, Cary, NC. Statistical significance was set at 5%, unless stated otherwise.

Results

A total of 86 children (16% of the 538 potential respondents) returned an informed consent/assent for participation in the ACAAI's Nationwide Asthma Screening program from all three schools; 39 were from the urban school and 47 were from the two suburban schools. Table 1 shows the percent of 'yes' responses to all 14 screening questions. *p* values test the association between each screening question and at least one positive response to question 15–20 by children who self-reported asthma or taking asthma medication(s) at the time of the study. Question 4 (Sometimes I wake up at night with coughing or trouble breathing) and question 6 (Sometimes I make wheezing sounds in my chest) were significantly associated with a self-reported history of asthma ($p < 0.05$ and < 0.001 , respectively). The significance level for question 1 ('When I walk or play hard with friends, I have trouble breathing or cough') was $p = 0.07$. Question 12 (Colds make

Table 1. Mean number of positive responses to each screening question and the *p* values testing significance for identifying risk of asthma by multiple logistic regression.

Screening question No.	ACAAI asthma screening questionnaire for children ages 8–14: specific questions (bolded questions reflect questions similar to the ISAAC questionnaire)	Number of positive responses <i>N</i> (% of 86)	<i>p</i> Value ^a
1	When I walk or play hard with friends, I have trouble breathing or cough.	42 (49)	0.07
2	When I walk up hills or stairs, I have trouble breathing or I cough.	20 (23)	0.56
3	I don't like to run or play sports because I have trouble breathing or I cough.	16 (19)	0.12
4	Sometimes I wake up at night with coughing or trouble breathing.	21 (24)	<0.05
5	Sometimes I have trouble taking a deep breath.	29 (34)	0.44
6	Sometimes I make wheezing sounds in my chest.	31 (36)	<0.001
7	Sometimes my chest feels tight or hurts.	37 (43)	0.33
8	Sometimes I cough a lot.	46 (53)	0.35
9	Being outdoors or around dust or pets makes my breathing worse.	14 (16)	0.70
10	It's hard to breathe in cold weather.	27 (31)	0.13
11	It's hard to breathe when people smoke or there are strong odors.	43 (50)	0.66
12	Colds make me cough or wheeze.	56 (65)	0.91
13	I went to the doctor's office or emergency room for asthma or trouble breathing this year.	7 (8)	0.35
14	I stayed in the hospital overnight for asthma or trouble breathing this year.	3 (3)	0.57

The regression model included 14 questions and a tri-level site variable (1 = urban school, 2 = suburban school A, 3 = suburban school B).

^aQuestions 4 and 6 were significantly associated with a self-reported history of asthma ($p < 0.05$, $p < 0.001$, respectively). In addition, the odds of self-reported asthma was 88% lower among students in suburban school B ($p < 0.05$), and 21% lower in suburban school A ($p = 0.84$), than students attending the urban school. Highlighted questions 1, 3, 4, 6 and 13 most closely mirror questions in the ISAAC asthma screening questionnaire for this age group.

Table 2. Student and parental characteristics by school location (*N* [% of column total]).

Student characteristic	Location (number of schools)		All (total = 86)	<i>p</i> Value
	Urban (1) Total = 39	Suburban (2) Total = 47		
Age groups (years): 8–9: 10–11: 12–13	<i>N</i> = 15/38: 18/38: 5/38 (39: 47: 13)%	<i>N</i> = 18: 29: 0 (38: 62: 0)%	<i>N</i> = 33: 47: 5 (38: 55: 6)%	0.06
Gender:				
Male	15 (38%)	33 (70%)	48 (56%)	<0.01
Race:				
Caucasian	20 (51%)	47 (100%)	67 (78%)	<0.001
>3/14 positive screening questions	29 (74%)	23 (49%)	52 (60%)	0.02
Number of positive screening questions/student Mean [Min, Max]	6 [0, 11]	4 [0, 9]	5 [0, 11]	<0.01
Physician referral	26 (67%)	29 (62%)	55 (64%)	0.63
PEF (L/min) Mean $\pm$ SD	256.6 $\pm$ 66.1	271.6 $\pm$ 48.8	264.8 $\pm$ 57.4	0.24
Self-reported Asthma	16 (41%)	5 (11%)	21 (24%)	0.01
Allergic rhinitis (yes) ^a	15 (38%)	14 (30%)	29 (34 %)	0.40
Parental characteristic				
Allergic rhinitis (yes) ^a	1 (3%)	6 (13%)	7 (8%)	0.12
Asthma (yes) ^a	11 (28%)	6 (13%)	17 (20%)	0.07

N = 38/39 urban school participants provided age information.

^aSelf-reported history.

me cough or wheeze) had the largest number of “yes” responses.

Table 2 summarizes the characteristics of the student and parental population by school location. Ages ranged from 8 to 13 years in all schools (mean age 9 years, 10 months result not shown). The age distributions of children attending urban and suburban schools differed; the maximum age was 13 years in the urban school, and 11 years in the suburban schools ($p = 0.06$). There was a significantly greater percent of females in the urban school compared to the suburban schools ($p < 0.01$), and greater racial diversity in the urban school compared to the two suburban schools, with 51% being Caucasian and 49% being a mix of African-American, Asian, American-Indian, Latino, Hispanic, Pacific Islander, or mixed in the urban school ($p < 0.001$). There was a significantly higher percentage of children with

a positive asthma screen (i.e. more than 3 ‘yes’ responses) attending an urban school (74% urban vs. 49% suburban schools; $p = 0.02$). In comparison to the two suburban schools, children in the urban school were significantly more likely to have a self-reported history of asthma (41% urban vs. 11% suburban schools; $p = 0.01$). On average, children in the urban school responded ‘yes’ to a greater number of questions compared to those in suburban schools (means are 6 and 4, respectively, $p < 0.01$). However, the number of children referred to physician (67% vs. 62%; $p = 0.63$) and the PEF (257 $\pm$ 66 vs. 265 $\pm$ 57; $p = 0.24$) did not differ significantly between the two school locations. There was no statistically significant difference between the urban and suburban populations with respect to self-reported history of allergic rhinitis, and parental history of self-reported allergic rhinitis or asthma.

Table 3. Student and parental characteristic stratified by a positive ACAAI asthma screen (*N* [% of column total]).

Student characteristic	>3/14 positive screening questions		<i>p</i> Value
	Yes Total = 52	No Total = 34	
Age group (years) 8–9: 10–11: 12–13	<i>N</i> = 23/51: 25/51: 3/51 (45: 49: 6)%	<i>N</i> = 10: 22: 2 (29: 65: 6)%	0.33
Gender:			
Male	23 (44%)	25 (74%)	<0.01
Race:			
Caucasian	38 (73%)	29 (85%)	0.18
School Location:			
Urban: Suburban A: Suburban B	<i>N</i> = 29: 10: 13 (56: 19: 25)%	<i>N</i> = 10: 8: 16 (29: 24: 47)%	0.04
Physician referral	43 (83%)	12 (29%)	<0.001
PEF (L/min) mean ± SD	254.6 ± 62.1	280.4 ± 46.1	<0.05
Self-reported asthma ^a	19 (37%)	2 (6%)	<0.01
Allergic rhinitis (yes) ^b	24 (46%)	5 (15%)	<0.01
Parental characteristic			
Allergic rhinitis (yes) ^b	5 (10%)	2 (6%)	0.54
Asthma ^b	15 (29%)	2 (6%)	<0.01

Age was reported for 51/52 students with a positive screening questionnaire.

^aStudents who had >1 “yes” response to ACAAI’s question number 15–20 because of a self-reported history of asthma or being on asthma medication(s) at the time of the study.

^bSelf-reported history.

Table 4. Student and parental characteristic stratified by self-reported history of asthma (*N*, % of column total)^a.

Student characteristic	Self-reported history of asthma ^a		<i>p</i> Value
	Yes Total = 21	No Total = 65	
Age group (years): 8–9: 10–11: 12–13	<i>N</i> = 10: 10: 1 (47: 47: 5)%	<i>N</i> = 23/64: 37/64: 4/64 (36: 58: 6)%	0.63
Gender:			
Male	11 (52%)	37 (57%)	0.72
Race:			
Caucasian	11 (52)%	56 (86)%	<0.01
School location:			
Urban: Suburban A: Suburban B	<i>N</i> = 16: 3: 2 (76: 14: 10)%	<i>N</i> = 23: 15: 27 (35: 23: 42) %	<0.01
>3/14 positive screening questions	19 (90%)	33 (51%)	<0.01
Number of positive screening questions/student Mean [Min, Max]	7 [0, 10]	4 [0, 11]	<0.001
Physician referral	20 (95%)	35 (54%)	<0.001
PEF (L/min) Mean ± SD	228.6 ± 56.7	276.5 ± 52.9	<0.001
Allergic rhinitis (yes) ^b	12 (57%)	17 (26%)	<0.01
Parental characteristic			
Allergic rhinitis (yes) ^b	2 (9.5%)	5 (7.7%)	0.79
Asthma ^b	16 (76%)	1 (1.5%)	<0.001

Age was reported for 64/65 students who did not report a history of asthma.

^aStudents who had >1 “yes” response to ACAAI’s question number 15–20 because of a self-reported history of asthma or being on asthma medication(s) at the time of the study.

^bSelf-reported history.

Table 3 summarizes the student and parental characteristics based on a positive asthma screen (i.e. more than three ‘yes’ responses out of 14 questions). A total of 52 children had a positive asthma screen. While there was no statistically significant difference in the age and race between those children with a positive versus negative asthma screen, a significantly higher number of females had a positive asthma screen ($p < 0.01$). In addition, children from the urban school were more likely to have a positive asthma screen, while the suburban school population was more likely to have a negative asthma screen ($p = 0.04$). Furthermore, children with a positive asthma screen were more likely to be subsequently referred to their pediatrician or an asthma specialist (83% vs. 29%; $p < 0.001$), have lower PEF (254.6 ± 62.1 vs. 280.4 ± 46.1 ; $p < 0.05$), have a history of self-reported asthma (37% vs. 6%; $p < 0.01$), and have a self-

reported history of allergic rhinitis (46% vs. 15%; $p < 0.01$) than those with a negative asthma screen. Interestingly, those children with a positive asthma screen were significantly more likely to have at least one parent with history of asthma (29% vs. 6%; $P < 0.01$), however they were not more likely to have a parent with self-reported history of allergic rhinitis.

Table 4 summarizes student characteristics based on the presence versus absence of a self-reported history of asthma (defined as students who had >1 “yes” response to ACAAI’s question number 15–20 answered by children who had a self-reported history of asthma or were on asthma medication(s) at the time of the study). There was no statistical difference in age or gender between the two groups. However, Caucasian children were less likely to report symptom presence than non-Caucasians (52% vs. 86%; $p < 0.01$). A greater percent of children attending the urban school had a self-reported history

of asthma compared to the suburban schools ($p < 0.01$). Children who reported having asthma were more likely to have a positive asthma screen (90% vs. 51%; $p < 0.01$), to be referred to a physician (95% vs. 54%; $p < 0.001$), to report a history of allergic rhinitis (57% vs. 26%; $p < 0.01$), and have a parental history of asthma (76% vs. 2%; $p < 0.001$) but not allergic rhinitis. They also had a lower mean PEF (228.6 ± 56.7 vs. 276.5 ± 52.9 ; $p < 0.001$).

The sensitivity and specificity for predicting the presence versus absence of a self-reported history of asthma (as defined above), from a positive asthma screen (more than three positive responses to the 14-item screening questionnaire) was 90% and 49%, respectively. An ROC analysis was performed to determine the “optimum number” of positive screening questions that would most likely identify children with asthma based on the square root of the sum of $(1 - \text{sensitivity})^2 + (1 - \text{specificity})^2$. More than five “yes” responses were determined to be the optimum cut point, corresponding to a sensitivity and specificity of 90% and 66%, respectively. We also performed an ROC analysis based on five of the 14 screening questions (highlighted in Appendix) which mirrored questions used in the validated ISAAC questionnaire [10] for this age group. Interestingly, more than three “yes” responses to these five questions had a lower sensitivity of 76% for asthma screening compared to five “yes” responses to the 14-item screening questionnaire of 90%, but had a similar specificity (66%).

Discussion

The majority of asthma cases begin in early childhood, with 80% of asthma cases being diagnosed by age 6 and 95% by age 9 [11]. Nevertheless, under-diagnosis is still a common problem in this population. Numerous studies have shown that under diagnosis leads to a delay in initiating therapy resulting in increased morbidity and mortality [12,13]. Hence, implementation of an effective asthma screening program in an elementary school setting offers the important advantage of identifying children at risk or with poorly controlled asthma early in the course of the illness [7,11,13].

Although only 16% (86 out of 538) of children participated in this cross-sectional study, the results of our proof-of-concept study demonstrate that the ACAAI's National Asthma Screening questionnaire is an easy to administer screening tool that can be used for screening children with undiagnosed or uncontrolled asthma in an elementary school setting. Using this questionnaire, we identified 52 children with possible undiagnosed or uncontrolled asthma. Of the 52 children 21 (40.4%) had a self-reported history of asthma (either physician diagnosed or were on asthma medication(s) at the time of this study), while the remaining 31 children were newly identified as being at risk for undiagnosed asthma. However, this needs to be interpreted with caution since there may be a participation bias due to the small sample size (i.e. children who experienced asthma-like symptoms were more likely to participate). Both subgroups of children were subsequently referred to their pediatrician or an asthma specialist for adjusting asthma medication(s) if needed, or confirmation of the diagnosis of asthma with objective testing, respectively.

Multiple studies have shown that children living in inner cities have a higher prevalence and mortality from asthma in the United States [14,15]. We therefore compared the outcomes of asthma screening between children from an inner city school with those attending suburban schools (Table 2). Findings from this study demonstrate that the number of children with a positive asthma screen and a self-reported history of asthma were significantly higher in the urban school population compared to the two suburban schools. This may be partially explained by gender differences or greater racial and ethnic diversity between the inner city and suburban populations. In addition, this study did not evaluate differences in exposure to traffic-related air pollution as a potential cause of asthma. Surprisingly, despite this finding, the rates of referral to an asthma specialist did not differ significantly between these groups. A lack of significant differences in the PEFs between the inner city and suburban populations may account for this discrepancy. For example, if the child self-reported a history of asthma but had a negative asthma screen and/or had normal PEFs he/she may not have been referred based on the study physician's discretion. In addition, there were no significant differences in the prevalence of student-reported allergic rhinitis or parental self-reported allergic diseases between the urban and suburban schools. The later may be due to the small number of parental reports of allergic rhinitis.

To evaluate the outcomes of asthma screening using the ACAAI's Asthma Screening Questionnaire in an elementary school setting we compared characteristics of those with a positive asthma screen to those without (Table 3). Those children with a positive asthma screen were more likely to be females, children who attended the inner city school, and have higher rates of physician referral. It is well recognized that PEF measurement is a useful adjunctive tool for asthma diagnosis and monitoring for deterioration or response to asthma treatment [16]. In our study, a positive asthma screen using the ACAAI's Asthma Screening questionnaire correlated well with lower PEF (254.6 ± 62.1 vs. 280.4 ± 46.1 ; $p < 0.05$). Such correlation between the responses to a subjective questionnaire with an objective test like PEF implies that the ACAAI asthma screening questionnaire is a reliable screening tool for identifying children at risk for asthma and/or those with uncontrolled asthma-type symptoms. In addition, children with a positive asthma screen were not only more likely to have a self-reported history of asthma but also of allergic rhinitis. This is consistent with previous findings that early and persistent allergic sensitization is a known risk factor for development of asthma later in life [17–19]. Furthermore, those children with a positive asthma screen had at least one parent who also had a self-reported history of asthma. This is consistent with the well-established importance of genetic determinants for the development of asthma. Our findings are concordant with the literature review by Burke et al. on the effect of family history as a risk factor for childhood asthma which concluded that having one parent with asthma increased the child's risk for having asthma by 2–4 times [20]. In a population-based cohort of 3430 school children between the ages of 7 and 8 years old, Bjerg et al. also found a higher prevalence of asthma in children of parents with atopy or at least one parent with asthma [21].

Studies have also demonstrated that parental history for allergic diseases increases the risk of asthma in their offspring [20,22]. In our study, we did not find a significant correlation between parental report of allergic rhinitis with a positive asthma screen, which may be due to the small number of parental reports for allergic rhinitis.

When comparing those children with a history of self-reported asthma to those without, the former group was more likely to have greater racial diversity. This is consistent with other studies that have demonstrated that the prevalence of self-reported and physician diagnosed asthma is twice as high in non-Caucasian compared to Caucasian populations [23,24]. In our study, those children with a self-reported history of asthma were more likely to attend the inner city school, have a positive ACAAI asthma screen, respond “yes” to a greater number of questions, have higher rates of physician referral with significantly lower PEFs, have concomitant self-reported allergic rhinitis, and at least one parent with a history of asthma (Table 4). These findings of self-reported disease correlate well with those children who were identified as having uncontrolled asthma with a positive ACAAI asthma screen (Table 3).

To date, no study has determined the optimal cut-point for predicting future asthma risk using the ACAAI's Asthma Screening Questionnaire. This is the first study to report that the sensitivity and specificity of the ACAAI Asthma Screening Questionnaire can be increased to 90% and 66%, respectively, if the cut-point for defining a positive asthma screen is raised to 5 out of 14 ‘yes’ responses instead of 3 responses. This may be of great value during future use of this questionnaire to avoid missing potential children at risk or with uncontrolled asthma type symptoms. Although our findings suggest that the ACAAI Asthma Screening Questionnaire may be a simple and useful tool for identifying children with undiagnosed asthma at school age, it is important to note that only two questions (numbers 4 and 6 – the two ISAAC-type questions, see Table 1) out of 14 were significantly associated with a history of self-reported asthma, while only one other question (question number 1) trended towards significance ($p=0.07$). Despite this, there was good correlation between a positive ACAAI's asthma screen and the objective finding of lower PEFs among these children.

The limitations of this study include a low participation rate, lack of a validated questionnaire, and the lack of follow-up evaluations for those children referred to an asthma specialist to confirm a diagnosis and/or uncontrolled asthma. Participation of children in this study would likely have been greater if multiple screening sessions were scheduled. However, this was not the intent of this proof-of-concept study. Furthermore, because results of survey studies and cross-sectional screening study designs such as ours have inherent population selection bias (i.e. children with asthma or suspected of having asthma by their caregivers would have been more likely to participate) these findings may not be generalizable to the entire elementary school population in the US and should be interpreted with caution. In addition, recall bias is also another potential intrinsic limitation to survey studies. Despite the aforementioned limitations, the findings of this study provide vital information that should help to advance national efforts examining the unmet need related to

asthma identification among elementary school-age children and demonstrates that efforts to validate the ACAAI's Asthma Screening Questionnaire are warranted. Future studies in this setting should be designed to evaluate the physician follow-up rate and the result of referrals made based on questionnaire responses to assess treatment outcomes.

Conclusions

In summary, our study indicates that the ACAAI's Asthma Screening Questionnaire is a useful tool for asthma screening in elementary school age children. Future studies should incorporate a PEFR as part of the asthma screening process, since low PEFR was a significant predictor of having a positive asthma screen and hence being at risk for undiagnosed or uncontrolled asthma. Our results support a state or federal initiative for implementing asthma screening in elementary schools similar to those currently implemented for scoliosis [25] and vision disturbances [26] given that asthma is one of the most prevalent and costly chronic diseases of childhood.

Declaration of interest

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Appendix

American College of Allergy, Asthma and Immunology's Questionnaire for kids 8–14 years

Please answer the following questions 'yes' or 'no':

- (1) When I walk or play hard with friends, I have trouble breathing or cough.
- (2) When I walk up hills or stairs, I have trouble breathing or I cough.
- (3) I don't like to run or play sports because I have trouble breathing or I cough.
- (4) Sometimes I wake up at night with coughing or trouble breathing.
- (5) Sometimes I have trouble taking a deep breath.
- (6) Sometimes I make wheezing sounds in my chest.
- (7) Sometimes my chest feels tight or hurts.
- (8) Sometimes I cough a lot.
- (9) Being outdoors or around dust or pets makes my breathing worse.
- (10) It's hard to breathe in cold weather.
- (11) It's hard to breathe when people smoke or there are strong odors.
- (12) Colds make me cough or wheeze.
- (13) I went to the doctor's office or emergency room for asthma or trouble breathing this year.
- (14) I stayed in the hospital overnight for asthma or trouble breathing this year.

Answer the following questions 'yes' or 'no' if appropriate, or were told by a physician that you have asthma, or are currently taking asthma medications':

- (15) I use my asthma inhaler two or more times a week.
- (16) Sometimes my asthma medicine(s) makes me feel bad.
- (17) I only take medicine when I don't feel well.
- (18) I can't do some things because of my asthma.
- (19) I get scared because of my asthma.
- (20) I worry that I may die from my asthma.

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Please answer the following questions 'yes' or 'no':

1. When I walk or play hard with friends, I have trouble breathing or cough.
2. When I walk up hills or stairs, I have trouble breathing or I cough.
3. I don't like to run or play sports because I have trouble breathing or I cough.
4. Sometimes I wake up at night with coughing or trouble breathing.
5. Sometimes I have trouble taking a deep breath.
6. Sometimes I make wheezing sounds in my chest.
7. Sometimes my chest feels tight or hurts.
8. Sometimes I cough a lot.
9. Being outdoors or around dust or pets makes my breathing worse.
10. It's hard to breathe in cold weather.
11. It's hard to breath when people smoke or there are strong odors.
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