Development and validation of school-based asthma and allergy screening questionnaires in a 4-city study

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Background: Asthma and allergies are commonly undiagnosed in children. Schools provide settings for potentially accessing almost all children for asthma and allergy screening.

Objective: To evaluate the feasibility and validity of using a questionnaire-based screening tool to identify undiagnosed asthma and respiratory allergies in children in kindergarten to grade 6.

Methods: A student questionnaire (SQ) and a parent questionnaire (PQ) were developed, administered in 4 diverse communities, and validated against standardized clinical assessments. Children without diagnosed asthma and representing a range of symptoms participated in a validation study that consisted of independent, standardized, clinical assessments. Sensitivity, specificity, and predictive values for questionnaire items were evaluated against expert consensus designations.

Results: A total of 190 children (age range, 7–13 years) completed the validation study. Affirmative responses to individual questions from either the SQ or PQ regarding asthma and allergy were modestly to moderately predictive of the clinical assessments (odds ratios, generally 2.5–5.0). When considering a positive asthma screen as affirmative responses to 3 of the best 7 SQ asthma questions, the odds ratio for asthma was 9.3 (95% confidence interval, 4.1–21.1), with 80% sensitivity and 70% specificity. Considering the allergy screen as positive based on affirmative response to either of the 2 SQ allergy questions yielded 81% sensitivity and 42% specificity.

Conclusions: Either a 9-item SQ or a 10-item PQ can be used in diverse settings to screen for asthma and respiratory allergies. The SQ, obtained by directly screening students, may provide a sensitive approach for detecting children with previously undiagnosed asthma and allergies.

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INTRODUCTION

Asthma is a common chronic condition that most often begins in childhood[1–3] and has been reported to affect between 7% and 20% of children by the age of 18 years.[4] Despite the high prevalence of recognized asthma in school-aged children, many additional schoolchildren may have unrecognized asthma.[5–7] These children may experience symptoms, lost school days, and lost activity days due to this unrecognized and thus untreated chronic health condition.[8]

Allergies are also common, affecting as many as 10 million to 20 million children in the United States, including approximately 80% of children with asthma.[9,10] Allergic rhinitis may trigger asthma exacerbations and contributes to reduced quality of life, lost activity days, and increased health care costs.[10,11] Like asthma, allergies are often unrecognized.

Recent attempts to improve the identification of children with unrecognized asthma and allergies, thereby improving their chances of access to appropriate symptom management, have been focused on schools.[12–17] Schools are one of the few sites in which almost all children gather and thus are available for screening or identification programs.[18] Schools offer the opportunity to evaluate a large number of children and to identify treatable diseases, such as asthma.[13]

School-based asthma and allergy case identification programs require a validated screening tool that provides sufficient sensitivity to identify most of the cases, while limiting the number of referrals of children who do not have asthma or allergy. To be useful throughout the United States, the tool needs to be valid in multiple socioeconomic, racial, and ethnic groups and easy and inexpensive to administer. This study aims to evaluate the feasibility and validity of using a questionnaire-based screening tool to identify undiagnosed asthma and respiratory allergies in children in kindergarten to grade 6.

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METHODS

Study Design

Using information from a series of preliminary studies on school-based asthma and allergy screening performed by our collaborative research group, we developed a short questionnaire-based screening tool and validated it against independent, standardized assessments that included physical examination, pulmonary function testing, and allergy skin testing (Fig 1). The validation sites consisted of 4 geographically diverse centers that participated in an initial, collaborative school-screening program funded by the American College of Asthma, Allergy and Immunology.[14–17] The combined study population consisted of racially and ethnically diverse children across socioeconomic strata. The study was approved by the local institutional review boards at each site. The final validated asthma and allergy screening tool that resulted from this study is designed to be useful in a variety of geographic locales as the foundation for school-based programs to improve asthma and allergy recognition and care.

Questionnaire Development and Distribution

An asthma and allergy screening questionnaire was developed based on preliminary, independent phase 1 work performed at each of the 4 validation sites (Chicago, IL, Cleveland, OH, Dallas, TX, and Rochester, MN).[14–17] In brief, during phase 1, each site independently tested distinct asthma and allergy screening questionnaires, assessing their predictive validity, community acceptance, response rates, and feasibility of use. Using the aggregate findings, individual questionnaire items that appeared to have had the best psychometric properties and/or highest levels of concordance with asthma and/or allergy were selected. Items were modified to improve their face validity across sites. The Rochester

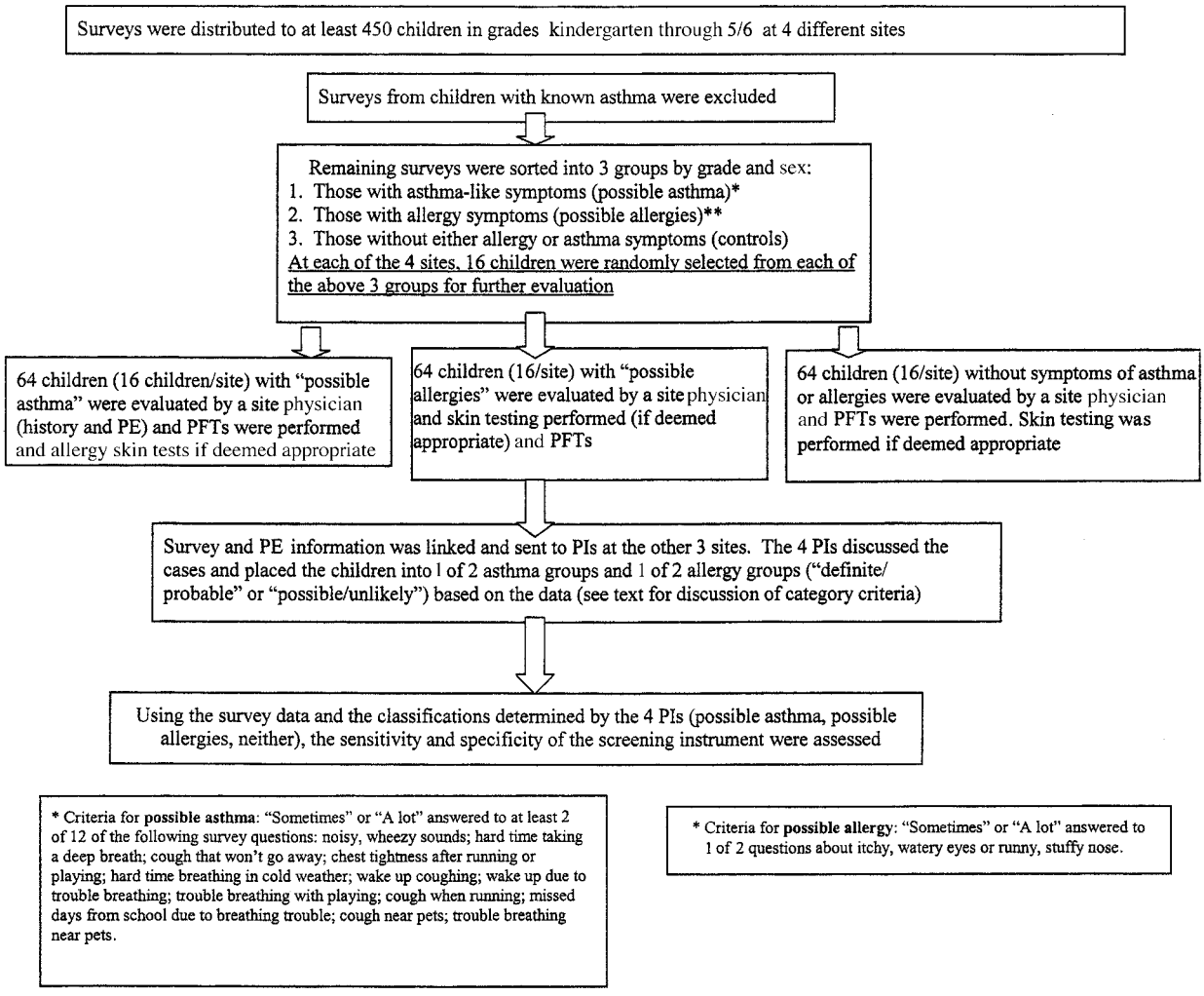

Figure 1. Schemata for study design. PE indicates physical examination; PFTs, pulmonary function tests; PIs, principal investigators.

Name: _____ Age: _____ Grade: _____ Teacher: _____

Race: African American ____ Asian American ____ Hispanic ____ White ____ Native American ____ Other ____

Please tell us how often you have any of the following:	Never	Sometimes	A lot
1. My breathing sounds noisy or wheezy.			
2. It is hard to take a deep breath.			
3. It is hard for me to stop coughing.			
4. My chest feels tight or hurts after I run, play hard, or do sports.			
5. It is hard to breathe in cold weather.			
6. I wake up at night coughing.			
7. I wake up at night because I have trouble breathing.			
8. I have trouble breathing when I run, climb stairs or play sports.			
9. I cough when I run, climb stairs or play sports.			
10. My eyes get itchy, puffy or burn.			
11. I have problems with a runny or stuffy nose.			
12. I am absent from school (miss school) because of breathing problems.			
13. When I am around pets I cough.			
14. When I am around pets I have trouble breathing.			

	YES	NO
15. A doctor or nurse told me that I have asthma		
16. I stayed in the hospital overnight for asthma or trouble breathing this past year.		
17. I take medicine or use an inhaler for asthma.		
18. I take medicine for allergies.		
19. I get very sick when a bee or other insect stings me.		
20. Some foods can make me break out, swell up or have trouble breathing.		

Figure 2. Student questionnaire used in the validation study.

site evaluated the test-retest validity of the selected questions in a sample of 25 fifth grade students. The concordance of students' answers was very high (94%) for the same survey administered twice in more than 48 hours. Two versions of the survey were developed: a student questionnaire (SQ) and a parent questionnaire (PQ; Figs 2 and 3).

The newly developed questionnaires were distributed to families of elementary-aged children at the 4 study sites.

Student's Name: _____ Age: _____ Grade: _____ Teacher: _____

Student's Race: African American ___ Asian American ___ Hispanic ___ White ___ Native American ___ Other ___

Please tell us how often your child has any of the following. (If your child has more problems in some seasons of the year, please tell us about problems during the *worst* season.) Does your child . . .

	Never	Sometimes	A lot	Don't Know
1. Make noisy or wheezy sounds when breathing?				
2. Have a hard time taking a deep breath?				
3. Develop coughs that won't go away?				
4. Complain about a chest that feels tight or hurts after running, playing hard, or doing sports?				
5. Have a hard time breathing in cold weather or when the temperature changes?				
6. Wake up at night coughing?				
7. Wake up at night because of trouble breathing?				
8. Have trouble breathing when running, climbing stairs or playing sports?				
9. Cough when running, climbing stairs or playing hard?				
10. Have eyes that itch, get puffy or burn?				
11. Have problems with a runny, stuff nose?				
12. Miss days of school (absent from school) because of breathing problems?				
13. Cough when around pets?				
14. Have trouble breathing when around pets?				

	YES	NO
15. Has a doctor or nurse told you that your child has asthma, reactive airway disease or wheezy bronchitis?		
16. Has your child stayed in the hospital overnight for asthma or for trouble breathing in the past year?		
17. Does your child take medicine (or use an inhaler) for asthma?		
18. Does your child take medicine for allergies?		
19. Does your child become very sick when stung by a bee or other insect?		
20. Do some foods make your child break out, swell up or have trouble breathing?		

Figure 3. Parent/guardian questionnaire used in the validation study.

Each site surveyed at least 400 children in kindergarten to grades 5 or 6, using distribution techniques specific for each site. Parents or guardians were asked to complete the PQ for each student in kindergarten through grade 6. Surveys were distributed by "backpack express" (ie, the child took it home for the parents to complete), by mail, and/or at school open house forums. All children in grades 2 to 6 also were asked to complete the SQ. According to the preferences of the local schools, these surveys were either distributed with the PQ and completed at home (Rochester) or distributed and completed in school (homeroom, health class, or special assemblies) (Cleveland, Chicago, and Dallas). If these surveys were distributed in schools, a standard preamble was read by a community volunteer or research staff member, and each question was read out loud, with no attempt to provide any asthma or allergy education that might influence answers.

Validation

Since the questionnaire was primarily developed to identify undiagnosed asthma and respiratory allergies, the validation study focused on students with a wide spectrum of asthma or allergy symptoms but without a diagnosis of asthma. In 3 sites, eligibility for the validation study was based on a completed PQ (ie, targeting children in kindergarten to grades 5 or 6). In one site, the local institutional review board restricted eligibility for the validation studies to children in grades 2 to 6. The PQs from these targeted students who also did not have a known diagnosis of asthma (reporting "no" to physician- or nurse-diagnosed asthma) were sorted by grade, sex, and categories of symptoms: possible asthma, possible allergies, and neither asthma nor allergies. Children with possible asthma were defined as those with responses of "sometimes" or "a lot" to questions regarding whether they had at least 2 of the following symptoms: noisy breathing; wheezy breathing sounds; hard time breathing; cough that won't go away; chest tightness; chest tightness with cold weather; waking up coughing; waking up with trouble breathing; trouble playing due to breathing problems; cough when running, etc; missing days from school due to breathing problems; coughing near pets; and/or trouble breathing near pets. From the remaining questionnaires, a group of students with possible allergies was identified based on a "sometimes" or "a lot" response to questions regarding whether they had "itchy eyes" or "runny, stuffy nose." All remaining questionnaires were categorized as "unlikely asthma/allergy." Each site randomly selected and invited students from each of the 3 categories to participate in the examination portion of the study until at least 16 from each category were enrolled.

Validation Protocol

The parents of all students who agreed to participate in the validation study were asked to bring their child to a convenient site for further evaluation. After informed consent from the parent or guardian and assent from the child were obtained, a physician with expertise in the treatment and diagnosis of asthma conducted a clinical evaluation of each student. The physician and/or a research nurse–physician team also obtained histories using standardized forms. Physicians and nurses were blinded to the results of the screening questionnaires. Baseline spirometry was performed using standardized approaches; spirometry was repeated 15 minutes following inhalation of 2 puffs of an albuterol bronchodilator for children with reduced or questionably reduced pulmonary function levels. Children with symptoms that the examining physician thought consistent with possible inhaled allergies underwent allergy skin prick testing. Allergens tested included *Dermatophagoides pteronyssinus*, *Dermatophagoides farinae*, cat, dog, rat, mouse, cockroach, *Alternaria*, *Cladosporium*, *Aspergillus*, *Penicillium*, ragweed mix, Timothy grass, Bermuda grass, histamine (positive control), and diluent alone (negative control). Testing, measurement, and interpretation were completed using standard procedures.[19]

Determination of Disease Status

De-identified copies of the validation data collection forms completed for each student were distributed to the principal investigators (R.S.G., S.R., R.L.W., B.P.Y.) at each of the 4 study sites. Each investigator reviewed the history and physical examination results and the spirometry and skin test results of the children of all 4 sites. Based on these data (and independent of data collected from the screening questionnaires), the 4 site principal investigators categorized the likelihood of asthma and allergic rhinoconjunctivitis for each student as definite, probable, possible, or unlikely. A *definite* designation of asthma required history-identified respiratory symptoms that were episodic and trigger related (by exercise, allergens, respiratory infections, or changes of weather conditions) with evidence of either reversible airflow limitation by spirometry or audible wheezing or prolongation of expiration by physician examination. The student was considered to have *probable asthma* when symptoms were consistent with asthma (as above) but supportive spirometry or physical findings were absent. *Possible asthma* identified students with some symptoms or other findings that could be consistent with asthma but were less typical than the ones above. *Unlikely* referred to absence of any symptoms or findings suggestive of asthma.

A definitive designation of inhalant allergies required symptoms such as sneezing, itching, and runny nose that either varied seasonally or were exacerbated in response to exposures to specific triggers, such as dust, animal dander, or pollens, in addition to demonstrating at least 1 positive skin prick test result.[19] Probable allergies were designated when these symptoms were recorded or there were physical findings consistent with the presence of inhalant allergies (eg, "allergic shiners"; transverse nasal crease; swollen, pale, bluish nasal mucosa; and clear nasal drainage) but when allergy skin test results were unavailable, either because the student refused to take the test or the test result was uninterpretable. Students were classified as having *possible allergy* when less typical symptoms and signs were noted and *unlikely allergy* when symptoms and findings were absent.

Each investigator's designation was further collapsed into *definite/probable* and *possible/unlikely* categories; the designations made by all 4 investigators for each student were summarized. Each student was assigned a final designation of *definite/probable* or *possible/unlikely* asthma and allergic rhinoconjunctivitis that reflected a consensus designation (ie, agreement by at least 3 of the investigators). When at least 3 investigators did not initially classify the student's disease status similarly, that case was discussed among investigators on one of several conference calls held to resolve differences in designations.

Statistical Analyses

Using the final clinical consensus designations as the gold standard, the sensitivity and specificity of data obtained from the PQ and SQ (ie, the screening instruments) were determined. Spearman correlation coefficient was used to describe the correlation among variables (SAS statistical software, version 8.2, SAS Institute Inc, Cary, NC). Both χ^2 and multiple logistic regression analyses were used to evaluate the relationships of each outcome (definite/probable asthma or allergy, each considered as distinct although not mutually exclusive outcomes) as determined by consensus designation to items from the questionnaires. Each symptom from the PQ or SQ was considered present if the symptom was reported as occurring "sometimes" or "a lot." Analyses evaluated the predictive ability of single questions, combinations of questions, and total scores. Initial models considered data from the PQ and SQ separately. Additional models were constructed that considered a "positive symptom complex" based on affirmative responses for a progressively increasing number of symptoms relevant to each outcome. For example, from a total of 12 asthma symptoms, the relative predictive values (sensitivity, specificity, and positive and negative predictive values) were computed for positive responses to 1 or more questions. Finally, alternative models, combining data from both the PQ and SQ, were constructed.

RESULTS

From all 4 sites, 1,673 PQs and 1,788 SQs were returned. The students screened in Chicago and Cleveland were predominantly African American (100% and 84%, respectively), whereas in Rochester they were mostly white (81%) and in Dallas they were of varied racial/ethnic backgrounds and included the largest proportion of Hispanic children (30%). The age of the students from each site ranged from 5 to 13 years; there was an approximately equal representation of boys and girls. The characteristics of the 190 students in the validation sample largely reflected the underlying ethnic composition of the targeted populations. Most students (63%) in the validation study were in grades 2 to 6, and the remaining were in kindergarten to grade 1.

Corresponding SQ and PQ forms were available for a total of 171 parent-student pairs in the validation sample. Although the responses to most of the individual questions were significantly associated, the magnitude of agreement was generally modest (Table 1). The strongest correlation between parent and child responses was to the question regarding use of medicines for allergies ($r = 0.53$, $P < .001$). There was little, if any agreement, for the item "it is hard to breathe in the cold" ($r = 0.10$, $P = .18$).

The sensitivity, specificity, and positive and negative predictive values for each of the 12 asthma questions and the 2 allergy symptom questions, using the parent or the student responses, are shown in Table 2. Overall, using data from either the SQ or PQ, most of the individual asthma symptoms were moderately predictive of the asthma clinical consensus designation, with odds ratios of approximately 3 (Table 2). However, the 2 questions regarding symptoms in association with exposure to pets had no significant association with asthma. Parent, but not student, responses to the question regarding missing school due to breathing problems was associated with asthma. Each of the allergy symptoms was modestly to moderately predictive of the allergic rhinoconjunctivitis designation, using either student- or parent-reported responses (Table 2).

A series of logistic regression models was then fit to identify the best combination of symptoms that predicted each of the clinical outcomes (asthma or allergic rhinoconjunctivitis). A number of alternative approaches were used, including modeling the most significant univariate predictors, using various combinations from the pool of 12 asthma symptoms, and combining parent and student responses. These analyses showed that for asthma little predictive ability

Table 1. Correlations of Parent and Child Responses for Asthma and Allergy Symptoms from the Validation Sample*

Symptom (question No.)	Child-parent Spearman *r*	*P* value
Noisy breathing (1)	0.15	.06
Hard to take deep breath (2)	0.26	.001
Hard to stop coughing (3)	0.32	<.001
Chest hurts after sports (4)	0.27	<.001
Hard to breathe in cold (5)	0.10	.18
Night coughing (6)	0.32	<.001
Trouble breathing at night (7)	0.15	.05
Trouble breathing during sports (8)	0.24	.001
Cough during sports (9)	0.12	.12
Eyes get itchy or burn (10)	0.29	<.001
Problems with runny nose (11)	0.20	.01
Miss school due to breathing problems (12)	0.31	<.001
Cough around pets (13)	0.19	.01
Trouble breathing around pets (14)	0.32	<.001
Doctor or nurse said child has asthma (15)†	. . .	. . .
Stayed in hospital overnight for asthma on breathing in last year (16)†	. . .	. . .
Take medicine for asthma (17)	0.25	.001
Take medicine for allergies (18)	0.53	<.001

* n = 171 for complete parent-child pairs.

† Parent questions 15 and 16 were entered as "no" for all subjects.

Table 2. Odds Ratios and Predictive Properties of Parent and Student Responses to Individual Questions Relative to Asthma and Allergic Rhinoconjunctivitis Clinical Consensus*

Symptoms (question No.)	Parent report					Student report				
	OR (95% CI)	Sensitivity, %	Specificity, %	PPV, %	NPV, %	OR (95% CI)	Sensitivity, %	Specificity, %	PPV, %	NPV, %
Asthma symptoms										
Noisy breathing (1)	1.7 (0.7–4.0)	19	88	38	73	**3.8 (1.9–7.8)**	56	75	45	83
Hard to take deep breath (2)	2.2 (0.8–5.6)	17	92	45	73	**3.4 (1.6–7.1)**	44	81	45	80
Hard to stop coughing (3)	**5.2 (2.6–10.6)**	51	83	55	81	**3.0 (1.5–6.0)**	60	66	39	82
Chest hurts after sports (4)	**3.1 (1.5–6.3)**	40	82	45	79	**3.4 (1.6–7.0)**	69	60	38	84
Hard to breathe in cold (5)	**3.0 (1.3–6.9)**	25	90	50	75	**3.5 (1.7–7.1)**	58	72	43	83
Night coughing (6)	**2.5 (1.3–4.9)**	51	71	41	78	**2.8 (1.4–5.7)**	51	73	40	81
Trouble breathing at night (7)	2.8 (0.9–8.3)	13	95	50	73	**2.9 (1.2–6.9)**	27	89	46	77
Trouble breathing during sports (8)	**3.7 (1.7–8.2)**	32	89	53	77	**2.5 (1.2–5.0)**	56	67	37	81
Cough during sports (9)	**4.1 (1.9–8.7)**	38	87	54	78	**3.3 (1.6–6.9)**	49	78	44	81
Miss school due to breathing problems (12)	3.3 (0.9–12.9)	9	97	56	73	1.5 (0.5–4.5)	11	92	33	74
Cough around pets (13)	0.6 (0.1–3.0)	96	6	29	80	1.3 (0.4–4.0)	11	91	31	74
Trouble breathing around pets (14)	1.3 (0.2–7.3)	4	97	33	72	2.1 (0.6–7.1)	11	94	42	75
Allergy symptoms										
Eyes get itchy or burn (10)	4.5 (2.3–8.7)	49	83	69	66	2.7 (1.4–5.2)	50	73	59	66
Problems with runny nose (11)	3.4 (1.8–6.3)	73	55	57	72	5.3 (2.6–10.6)	80	57	59	79

Abbreviations: CI, confidence interval; NPV, negative predictive value; OR, odds ratio; PPV, positive predictive value.
* Numbers in bold are statistically significant at $P < .05$.

was lost when restricting the pool of asthma-like questions from the student questionnaire to 7 and from the parentquestionnaire to 8 (eliminating questions with weak predictive ability, those that were redundant, and those thought to be poorly generalizable to diverse geographical areas). Also, no single question or specific combination of questions appeared to be clearly superior to others. Rather, optimal prediction appeared to relate to considering the number of positive questions from the best "pool" of questions.

Tables 3 and 4 show the tradeoff in sensitivity and specificity for predicting the clinical designation of asthma when considering a progressively increasing number of symptoms as constituting a positive screen. As expected, sensitivity declines and specificity improves when requiring increasing number of positive responses. Analyses of data from the SQ suggest that high levels of sensitivity (87%) and moderate specificity (59%) can be achieved by requiring at least 2 positive symptom responses, with slight decreased sensitivity (80%) and improved specificity (70%) when considering a positive screen based on 3 affirmative item responses. Similar patterns were seen for analyses using the PQ (Table 4). However, for any given combination of positive responses, the overall levels of sensitivity were lower (and specificity higher) using parent-reported compared with student-reported data. Analyses that combined data from the PQ and SQ (eg, 2 positive responses from the student and 1 from the parent) did not reveal any improvement in the overall ability to predict asthma (data not shown).

Table 5 shows the odds ratios and predictive values for various combinations of allergy symptoms. Requiring a positive response to either "itchy eyes" or "runny nose" appears to have relatively high levels of sensitivity using either the student (81%) or parent (78%) responses. Specificity is again modest (42% and 53%, respectively). Requiring affirmative

Table 3. Odds Ratios and Predictive Properties of Groupings of Asthma Symptoms for the Student Questionnaire*

No. of student-reported asthma symptoms	OR (95% CI)	Sensitivity, %	Specificity, %	PPV, %	NPV, %
At least 1	4.3 (1.6–11.8)	89	35	33	90
At least 2	9.3 (3.7–23.4)	87	59	43	93
At least 3	9.3 (4.1–21.1)	80	70	49	91
At least 4	4.0 (1.9–8.2)	53	78	46	82
At least 5	2.5 (1.1–5.8)	27	87	43	77
At least 6	3.1 (1.0–9.5)	16	94	50	76

Abbreviations: CI, confidence interval; NPV, negative predictive value; OR, odds ratio; PPV, positive predictive value.
* From a pool of 7 student-reported symptoms (ie, questions 1–4, 6, 7, and 9); all ORs significant at $P < .05$.

Table 4. Odds Ratios and Predictive Properties of Groupings of 8 Asthma Symptoms for the Parent Questionnaire*

No. of parent-reported asthma symptoms	OR (95% CI)	Sensitivity, %	Specificity, %	PPV, %	NPV, %
At least 1	3.5 (1.7–7.1)	75	54	39	85
At least 2	3.1 (1.6–6.0)	58	69	42	81
At least 3	4.7 (2.3–9.6)	47	84	54	80
At least 4	5.0 (2.0–12.4)	27	93	61	76
At least 5	4.2 (1.4–12.6)	17	95	60	74
At least 6	13.5 (1.5–118.2)	9	99	83	73
At least 7	5.2 (0.5–58.8)	4	99	67	72

Abbreviations: CI, confidence interval; NPV, negative predictive value; OR, odds ratio; PPV, positive predictive value.
* From a pool of 8 parent-reported questions (ie, 1–4, 6, 7, 9, and 12); all ORs significant at $P < .05$ other than "at least 7."

Table 5. Odds Ratios and Predictive Properties of Groupings of Allergy Symptoms Relative to the Allergic Rhinoconjunctivitis Clinical Consensus Using Student and Parent Responses*

Allergy symptoms	OR (95% CI)	Sensitivity, %	Specificity, %	PPV, %	NPV, %
S10 or S11	3.1 (1.5–6.4)	81	42	52	75
S10 and S11	7.3 (3.4–15.9)	49	89	77	69
P10 or P11	4.1 (2.1–7.8)	78	53	57	75
P10 and P11	4.3 (2.2–8.5)	44	84	70	65
S10 or S11 or P10 or P11	10.0 (2.9–34.3)	96	28	52	90
S10 or S11 and P10 or P11	3.4 (1.8–6.4)	62	68	59	70

Abbreviations: CI, confidence interval; NPV, negative predictive value; OR, odds ratio; PPV, positive predictive value.
* S10 and P10 refer to the "itchy eyes" question for student and parent, respectively. S11 and P11 refer to the "runny nose" question for student and parent, respectively. All ORs significant at $P < .05$.

responses to both symptoms lowers sensitivity to 49% and 44%, respectively, for student and parent questionnaires, with improved specificity (89% and 84%, respectively). Using various combinations of student- and parent-reported symptoms did not appear to improve overall prediction.

Using data from the entire screened sample provided site-specific estimates of the potential number of subjects who might screen positive for asthma and allergy. Of the 7 best asthma symptoms from the SQ, considering 3 or more positive responses as a positive screen would identify 42%, 49%, 39%, and 35% of students from Chicago, Cleveland, Dallas, and Rochester, respectively. Using a positive response to either of the allergy questions would have identified 70%, 69%, 61%, and 51% of students from each of these sites, respectively, as candidates for follow-up.

DISCUSSION

Several methods have been proposed for school-based asthma and allergy screening,[20–22] including questionnaire screening, pulmonary function testing, and exercise challenges. Of these, questionnaires are the least invasive and expensive and the easiest to implement in diverse settings. Before a widespread adoption of any screening instrument, its universal applicability across diverse communities must be demonstrated. Most of the screening questionnaires that have been validated to detect asthma among schoolchildren are specific for a particular population in which the validation was performed[21,23–25]; the generalizability of such findings to other populations is often uncertain. For example, the questionnaire developed from the International Study of Asthma and Allergies in Childhood (ISAAC), a widely used but population-specific tool, did not adapt well to an inner-city population of schoolchildren.[15] For the present study, we created a composite tool informed by the coordinated experiences of 4 sites that represented broad geographic, ethnic, and socioeconomic backgrounds with the goal of developing a screening instrument that would be broadly generalizable. The current work demonstrates the potential utility of a single questionnaire for screening asthma and allergy in school-aged children and further shows that most children in grades 2 to 6 can complete the questionnaire.

We evaluated 2 almost identical questionnaires, one for parents and one for students, both of which used similar Likert-type frequency response scales. The overall correlations between parent and child responses were generally small to modest and of similar or somewhat lower levels of magnitude than what had been observed in our individual site-specific pilot work.[14,17] The modest levels of agreement may reflect differences in the approaches and setting for completion of the PQ and SQ (which in 2 sites were based on in-school administration for the children and in-home for the parents), variable levels of literacy among the targeted adults and children, and real differences in how parents perceive their child's asthma or allergy symptoms compared with the child's self-perceptions and reports. Overall, compared with their parents, children tend to report more symptoms, a finding that has

also been observed by others.[26] Despite the rather low levels of agreement for responses to individual items from each questionnaire, we found that after considering the best grouping of responses from each questionnaire, the PQ and SQ provided fairly equivalent levels of prediction regarding each outcome, with generally better sensitivity for analyses using the SQ and better specificity for the PQ. Furthermore, an extensive series of analyses demonstrated that there was no gain in combining the parent and student responses. The high sensitivity for data obtained directly from the students is of particular importance given that a major obstacle for school-based screening is in eliciting participation of parents, especially in some low-income neighborhoods where there are challenges in getting forms back and forth between the school and home. Our data suggest that directing initial efforts at screening the students, who may be directly surveyed in classroom settings, may provide a relatively easy means for accessing nearly all school-aged children. Having both questionnaires available, however, may provide flexibility for screening under differing circumstances, especially in circumstances where higher specificity may be needed or in situations where students' reading levels are extremely low.

Using our validation data and modeling the responses from the PQ and SQ against the independently determined consensus clinical designation, we attempted to identify the combination of symptoms that provided an optimal balance between sensitivity and specificity. As expected, when a positive asthma screen was based on increasing the numbers of affirmative responses to the pool of asthma questions, specificity increased at the expense of sensitivity. Decisions regarding threshold values (ie, number of symptoms to consider as constituting a positive screen) relate to the inherent goals of the specific school-based screening program. For example, if resources permit and community-specific concerns are to minimize the burdens and costs related to reduced quality of life, missed school and work days, and morbidity associated with undiagnosed asthma or allergy cases, one would aim to optimize sensitivity. In this regard, requiring at least 3 asthma symptoms provides a sensitivity of 80% and a specificity of 70%, suggesting that asthma may be suspected and referral considered in students reporting this number of symptoms.

Both the SQ and PQ contained 18 items, 14 of which were related to asthma and allergy symptoms. Our analyses allowed us to reduce the number of asthma-related items on the questionnaires to 7 (SQ) or 8 (PQ) by eliminating items that were individually weakly predictive or did not generalize well to diverse social and geographic groups. However, since using the pool of 7 (or 8) questionnaire responses provided better asthma prediction than modeling specific items, we could not justify further abbreviating the questionnaire (Figs 4 and 5).

We included the detection of allergies in the screen for several reasons. Like asthma, inhalant allergies are both common and often unrecognized in children.[27,28] Furthermore, there is significant morbidity associated with allergies, including sleep loss and school absenteeism.[27–29] Common pathophysiological mechanisms also often underlie allergic rhinoconjunctivitis and asthma,[27–32] and information on symptoms of each condition may help improve the identification of the other condition. Additionally, since allergies are relevant in the development and aggravation of asthma,[33–36] information on allergic symptoms may help target children at increased risk for developing asthma.

Analysis of the allergy-specific questions provided a similar pattern to that of asthma. We used only 2 allergy-specific questions, but requiring either "itchy eyes" or "runny nose" as constituting a positive screen showed high sensitivity and modest specificity. Combining the 2 allergy questions produced a marked reduction in sensitivity but made the screen very specific. If the goal of allergy screening is to minimize false-negative results, then considering a positive response to either student allergy question would yield a sensitivity of 80%.

The ultimate cost of any asthma-allergy screening program will depend in part on the number of children identified who will require additional testing. With a goal of achieving moderate sensitivity (ie, considering positive responses to 3 of the best 7 asthma questions), more than 35% of children (and as many as 49% of children in high-risk areas) with no reported history of prior asthma diagnosis would require additional testing for asthma. Our data suggest that approximately 50% of these children are likely to meet clinical criteria for asthma. The overall societal costs for identifying and treating between 15% and 25% of targeted school populations who may have undiagnosed asthma, as well as the costs of evaluating children whose test results prove to be false positive, need to be weighed against potential gains in reduced morbidity and improved quality of life of detecting and treating children with asthma and respiratory allergies.

Although the goal of this study was not to estimate the prevalence of undiagnosed asthma, it is important to note the variability among sites in asthma and allergy symptoms. These differences are consistent with the observed 20- to 30-fold international differences in wheezing and asthma[37] found by ISAAC. Internationally, the highest prevalence rates for wheezing symptoms have been from Australia, New Zealand, and Canada, where as many as 30% of school-aged children are reported to wheeze.[37–39] In our study, asthma and allergy symptoms were highest in our 2 inner-city, African American sites, where approximately 50% to 60% of children were reported to have asthma symptoms, resulting in an estimate of undiagnosed asthma as high as 25% to 30%. Previous research from Chicago, New York, and Detroit also has suggested that the prevalence of wheezing symptoms and undiagnosed asthma is extremely high among disadvantaged minority children,[40–42] with symptoms such as nocturnal cough reported by 54% of inner-city, African American children.[40]

Among the challenges in developing a screening instrument that detects asthma and allergy among children is the need to identify the appropriate "gold standard" for validity

STUDENT QUESTIONNAIRE

Name _____ Age _____ Grade _____ Teacher _____

Race: ❒ African American ❒ Asian American ❒ Hispanic ❒ White ❒ Native American ❒ Other

Please tell us how often you have any of the following:

1. My breathing sounds noisy or wheezy.	o NEVER	o SOMETIMES	O A LOT
2. It is hard to take a deep breath.	o NEVER	o SOMETIMES	O A LOT
3. It is hard for me to stop coughing.	o NEVER	o SOMETIMES	O A LOT
4. My chest feels tight or hurts after I run, play hard, or do sports.	o NEVER	o SOMETIMES	O A LOT
5. I wake up at night coughing.	o NEVER	o SOMETIMES	O A LOT
6. I wake up at night because I have trouble breathing.	o NEVER	o SOMETIMES	O A LOT
7. I cough when I run, climb stairs or play sports.	o NEVER	o SOMETIMES	O A LOT
8. My eyes get itchy, puffy or burn.	o NEVER	o SOMETIMES	O A LOT
9. I have problems with a runny or stuffy nose.	o NEVER	o SOMETIMES	O A LOT

Please answer the following questions:

10. A doctor or nurse told me that I have asthma.	O YES	O NO
11. I stayed in the hospital overnight for asthma or trouble breathing this past year.	O YES	O NO
12. I take medicine or use an inhaler for asthma.	O YES	O NO
13. I take medicine for allergies.	O YES	O NO

SUGGESTED SCORING KEY

Asthma: For Questions 1 through 7, assign a "1" for each "sometimes" or "a lot" response. Add the scores. If the total is 3 or more, referral for asthma diagnosis may be indicated. A total score of 3 has an estimated sensitivity of 80% and specificity of 70%, according to the clinical predictability of the questionnaire in a validation study.*

Allergy: For Questions 8 and 9, assign a "1" for each "sometimes" or "a lot" response. Add the scores. If the total is 1 or more, referral for allergy diagnosis may be indicated. A score of 1 has an estimated sensitivity of 81% and specificity of 42%, according to the clinical predictability of the questionnaire in a validation study.*

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Figure 4. Final version of the student questionnaire.

PARENT OR GUARDIAN QUESTIONNAIRE

Student's Name _____ **Age** ____ **Grade** ____ **Teacher** _____

Student's Race: ❒ African American ❒ Asian American ❒ Hispanic ❒ White ❒ Native American ❒ Other

Please tell us how often your child has any of the following. (If your child has more problems in some seasons of the year, please tell us about problems during the *worst* season.) Does your child . . .

1.	Make noisy or wheezy sounds when breathing?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
2.	Have a hard time taking a deep breath?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
3.	Develop coughs that won't go away?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
4.	Complain about a chest that feels tight or hurts after running, playing hard, or doing sports?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
5.	Wake up at night coughing?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
6.	Wake up at night because of trouble breathing?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
7.	Cough when running, climbing stairs or playing sports?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
8.	Miss days of school (absent from school) because of breathing problems?	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
9.	Have eyes that itch, get puffy or burn.	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know
10.	Have problems with a runny, stuffy nose.	o NEVER	o SOMETIMES	O A LOT	❒ Don't Know

Please answer the following questions about your child:

11.	Has a doctor or nurse told you that your child has asthma, reactive airway disease or wheezy bronchitis?	O YES	O NO	❒ Don't Know
12.	Has your child stayed in the hospital overnight for asthma or for trouble breathing this past year?	O YES	O NO	❒ Don't Know
13.	Does your child take medicine (or use an inhaler) for asthma?	O YES	O NO	❒ Don't Know
14.	Does your child take medicine for allergies?	O YES	O NO	❒ Don't Know

SUGGESTED SCORING KEY

Asthma: For Questions 1 through 8, assign a "1" for each "sometimes" or "a lot" response. Add the scores. If the total is 2 or more, referral for asthma diagnosis may be indicated. A total score of 2 has an estimated sensitivity of 58% and specificity of 69%, according to the clinical predictability of the questionnaire in a validation study.*

Allergy: For Questions 9 and 10, assign a "1" for each "sometimes" or "a lot" response. Add the scores. If the total is 1 or more, referral for allergy diagnosis may be indicated. A score of 1 has an estimated sensitivity of 78% and specificity of 53%, according to the clinical predictability of the questionnaire in a validation study.*

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Figure 5. Final version of the parent/guardian questionnaire.

evaluation. Asthma is not clearly defined in young children, and there are no good objective tests available for a pediatric age group that are easily applied. Often the "gold standard" adopted is based on the opinion of an expert in the diagnosis and management of asthma.[43,44] As has been done previously, we adopted this approach to validate the respiratory screen in this study. In a similar manner, Hall et al[45] presented data on a screening tool based on the International Union Against Tuberculosis and Lung Disease interview. They validated a 25-question instrument against a "gold standard" defined by the results of an examination by a pulmonologist and pulmonary function studies. Their final 4-item questionnaire included wheezing or whistling in the chest, nocturnal coughing, exercise symptoms, and symptoms that interfered with activities. Using a similar approach to enhance primary care diagnosis of asthma, Glasgow et al[25] and Halfon and Newachek[46] tested a short survey in rural Australia that also was validated against a history and physical examination. Their ideal balance showed a positive predictive value similar to our findings (51%) and a negative predictive value of 98%. Others have used less rigorous validation methods. Frank et al[39] used a postal questionnaire survey that was validated against a retrospective analysis of patient diagnosis of asthma or of use of asthma medication. In that study, one third of children for whom asthma was suggested by the survey did not have corroborating support in the physician's record.

Previously, one of us[14] addressed the problem of developing a validated screening tool by using a blinded panel of experts to make an independent determination on the presence of asthma and allergy in children who had responded to an asthma questionnaire. We adopted this approach for this study, with the modification that the expert panel was composed of the 4 investigators, one from each of the different study sites. We believe that this approach minimizes between-rater variability in the determination of the asthma and allergy outcomes, strengthening the validity and generalizability of our findings.

We chose to use site-specific methods for distributing and collecting the questionnaires to optimize local acceptability and maximize response rates. Three sites used modest incentives to enhance participation (Cleveland and Dallas used gift certificates to educational stores for teachers and food or ice cream certificates for children, and Chicago provided a pizza party for students). Our experience, however, indicated that even when distribution methods were designed to accommodate site-specific needs, participation rates varied substantially, suggesting the influences of intrinsic community, school, and cultural differences among the sites. Two of the sites that administered the SQs directly to students in school achieved nearly 100% participation rates (Dallas and Cleveland). The Chicago site, which also administered the SQs in schools, however, obtained only a 56% participation rate. Although this appeared to be due to difficulties some Chicago students had understanding the written form, this was not the experience in the other inner-city, predominantly African American site (Cleveland), where virtually all children in grades 2 and higher completed the questionnaire. Both sites used volunteers and research staff to read each question aloud to groups of students. In Dallas and Chicago, 74% and 85%, respectively, of PQs delivered home via backpack were returned; this is in contrast to Cleveland, where even after 2 attempts to either send via backpack or mail home the PQ, as well as attempts to have questionnaires completed by parents attending school functions, the return rate was only 38%. The Rochester schools did not allow classroom time for questionnaire administration, and both the PQs and SQs were mailed to the parents' homes. The resulting response rate of completed pairs of parent and student surveys was 57% after 2 reminders. Based on these site-to-site differences, we recommend that the choice of using a student or parent screen or both and the distribution method should be tailored to the prevailing culture of the school and community.

This study has several limitations that are often associated with multicenter studies. As discussed herein, not all sites were able to implement the study using the same methods of survey dissemination and completion, and the proportion of students who completed questionnaires varied. It is possible that differences in the relationships between symptoms and clinical designations may have been observed if the sample included in the validation studies was more cooperative and better able to complete questionnaires than the sample not represented. Also, different physicians or nurses at each of the sites completed examinations. This might affect the reproducibility of the findings on the history or physical examination. However, the examination was not complex and included findings that may be considered somewhat subjective in most any physician's hands. Finally, allergy testing and spirometry were not completed on every eligible student, and the criteria for performing postbronchodilator spirometry varied across sites. However, lack of postbronchodilator spirometry and allergy skin test data would most likely alter the consensus designations from definite to probable, categories that were later collapsed for analytic purposes. The strength of the diverse sample and geographic distribution of sites participating may offset the limitations experienced.

In conclusion, we have developed and validated a screening tool for use in schools. The purpose of this screen is to detect students who have symptoms that indicate that they would benefit from a further evaluation for asthma and allergies and therapy as indicated. We identified a range of groupings of questions that provide a spectrum of sensitivity and specificity. We also evaluated both a parental and a child's form of the questionnaire. Our data indicate that these forms are comparable, although the SQ in general provided greater sensitivity and the PQ greater specificity. Finally, our data suggest that 7 to 8 asthma symptom questions and 2 allergy symptom questions may provide approximately as much prediction ability as a longer series of items.

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