Predictive Value of a Cross-Cultural Asthma Case-Detection Tool in an Elementary School Population

Stanley P. Galant, MD*; Linda J.R. Crawford, RN, PNP‡; Tricia Morphew, MS§; Craig A. Jones, MD∥; and Stanley Bassin, PhD¶

ABSTRACT. Objective. Bronchial asthma, which affects ~5 million US children, is vastly underdiagnosed and treated, particularly among minorities and those of low socioeconomic status. Because current methods of detecting those at greatest risk of asthma in a multicultural setting appear inadequate, we assessed the validity and reliability of a new asthma questionnaire across 3 dominant cultures in Orange County, California (white, Hispanic, and Vietnamese).

Methods. Children in grades 1, 3, and 5 and their families, in 3 different schools representative of these major ethnic groups, were randomly selected to participate in the validation process. Two schools with low socioeconomic status and dominant Hispanic or Vietnamese minorities were designated inner-city schools, whereas the third school was a suburban school with predominately white students. Participants completed a 7-question, 11-element questionnaire in their primary language, followed by an asthma evaluation (history, physical examination, and spirometry) by an asthma specialist (who was blinded with respect to the results of the questionnaire), at their respective schools. The physician then made a determination regarding the presence and severity (according to National Institutes of Health guidelines) of asthma. Several weeks later, the entire student body was asked to complete the questionnaire at home and return it to school for analysis. Validation of each item was evaluated for sensitivity, specificity, and positive and negative predictive values, and application of univariate analyses provided an estimated probability of an asthma diagnosis by the asthma specialist. A “best-fit” algorithm was determined with all 11 elements, if possible, and an abbreviated algorithm that selected the fewest-question combination that yielded the best asthma predictability was established. Reliability was established with the percent agreement between the 2 questionnaires and the κ statistic.

Results. Of the 401 children/families who participated in the validation analysis, 45% were Hispanic, 22% white, 19% Vietnamese, and 15% other. The overall prevalence of asthma specialist-diagnosed asthma was 28%, with 65% of cases being graded as intermittent and 35% as persistent. Sixty-two percent of the children had not been previously diagnosed with asthma. There were no significant differences among cultures in sensitivity or specificity for any of the individual questions or the complete or abbreviated algorithms. The abbreviated algorithm with 3 questions, ie, question 1 (asthma in the past 2 years), question 4 (cough, chest tightness, trouble breathing, or wheezing with exercise), and question 6 (same symptoms in the morning or day in the past 4 weeks) yielded comparable sensitivity and specificity for the complete algorithm in all groups. The abbreviated algorithm had >86% predictability in detecting children with persistent asthma and 56% predictability in detecting children with intermittent asthma. Reliability was also excellent, with percent agreement usually >80% and κ values of >.70.

Conclusions. This asthma detection tool has been shown to be suitable for detecting persistent asthma in a multicultural inner-city population, as well as in a suburban setting. An abbreviated algorithm with 3 questions and >80% predictability in detecting persistent asthma seems ideal for evaluating large numbers of school-aged children. The school setting is an excellent site for identifying children with asthma. Although there is concern that subjects detected in the school setting might not have access to ongoing medical care, case detection is an important first step that could lead to earlier diagnosis and treatment. Reducing the barriers to good care in inner-city environments is the next step.

ABBREVIATIONS. NIH, National Institutes of Health; SES, socioeconomic status; ED, emergency department; NPV, negative predictive value; PPV, positive predictive value.

Bronchial asthma, the most common chronic disease in childhood, has a reported prevalence of 4.3% to 6.7%. However, recent studies indicate a much higher prevalence, reaching 30% in inner-city populations, with a large percentage of cases not having been previously diagnosed. Furthermore, bronchial asthma is the most frequent cause of hospitalization and school absenteeism. To the extent that asthma morbidity, which is so prevalent today, is attributable to underdiagnosis and lack of appropriate treatment, schools and the medical community are faced with the issue of defining their roles in the care of children with asthma. This problem is particularly relevant for schools serving low-income and minority populations,
which have been shown to have disproportionately large asthma burdens, with increased hospitalization and mortality rates. Even in a population with a reported 27.1% prevalence of "self-reported asthma" in the past 12 months among children 6 to 7 years of age, the school health program does not routinely screen children for asthma. There are now adequate data suggesting that delays in diagnosis may influence asthma outcomes. For these reasons, it is imperative that there be a simple, standardized, screening tool that can identify children at high risk for asthma in the school setting.

Two basic methods have been used historically to assess the prevalence of asthma. Most commonly, a written or videotaped questionnaire has been used; less frequently, physiologic measurements of bronchial lability have been performed. Although the latter method may be more objective, it is more invasive and is difficult to administer to children in large epidemiologic settings. In addition, it exhibits less sensitivity and in some cases less specificity than the questionnaire. Since the 1950s, written questionnaires have been used to assess the prevalence of asthma. Although surveys have improved during the years, problems related to the lack of a universal definition of asthma remain, resulting in previously established physician diagnoses of asthma often underestimating true asthma prevalence. In addition, specific questions, particularly related to wheezing, may be poorly understood by the parent and may be difficult to translate into different languages and may address a symptom not present among all children with asthma (ie, cough-variant asthma). The ideal detection tool should be noninvasive, simple, easily understood even by less-educated populations, and consistent across cultures. To have good predictive values, it must have good repeatability, sensitivity, and specificity. Validation must be established with an accepted standard method, which is thought to be the approach involving history, physical examination, and spirometry used by asthma specialists.

The International Study of Asthma and Allergy in Childhood questionnaire (Appendix A) (which is primarily a survey tool, rather than a case-detection tool), with both written and videotaped questionnaire formats, has been the most frequently used model using self-reported techniques to determine the prevalence of asthma and allergic disease worldwide and is currently being used in 56 countries. Derived from the International Union against Lung and Tuberculosis Disease, it relies heavily on the symptoms of wheezing for the diagnosis of asthma under a variety of conditions. Furthermore, although several studies of the International Study of Asthma and Allergy in Childhood questionnaire showed adequate sensitivity and specificity, the questionnaire has been evaluated only among children 6 to 7 years and 13 to 14 years of age. Validation methods using physician evaluations, bronchial hyperreactivity assessments, and comparisons with established questionnaires have been variable and less than robust.

A growing number of studies with different validation methods have been performed with pediatric populations. Although potentially useful, several have methodologic problems (Table 1). Few randomly selected subjects from the community for validation and only some used validation by an asthma specialist. Although several were school-based, few questionnaires examined inner-city populations. Only 2 studies were cross-cultural (ie, simultaneous validation in >1 language) and none, to our knowledge, was validated in the Vietnamese asthma population in the United States. In addition, sensitivities (range: 61-100%) and specificities (range: 55-100%) were variable (Table 2). Only 2 questionnaires identified those at highest risk according to asthma severity (intermittent or persistent), as established by the new National Institutes of Health guidelines. These factors limit the applicability of these observations for the general multiracial populations of children in many communities in the United States. Because of these potential limitations, we evaluated the predictive value of a novel asthma questionnaire, developed by Jones et al, at school sites for 3 diverse ethnic groups in Orange County.
city, with low socioeconomic status (SES) (Hispanic and Vietnamese), and 1 in a suburban (predominantly white) setting, for comparison. This questionnaire also attempts to identify children at highest risk for asthma, ie, those with persistent asthma, who have the greatest need for additional evaluation and treatment, as established by the new NIH guidelines.32

METHODS

Study Population

Three elementary schools reflecting a dominant ethnic population, ie, white (Oak Grove School, 64%), Vietnamese (Morningside School, 54%), and Hispanic (Pio Pico, 100%), were asked to participate after permission was obtained from the school district. Inner-city schools (Morningside and Pio Pico) were so designated on the basis of low SES, as evidenced by reduced-price or free lunches for ≥85% of the children and the presence of a large minority population. At each school, classrooms from grades 1, 3, and 5 were selected with random numbers, without previous knowledge of asthma history. An attempt was made to enroll ~15% of the student body for the validation studies.

Asthma Detection Survey

The asthma detection survey includes 7 questions that address 11 elements of a child’s respiratory health. Each 1-page survey form is printed in English on 1 side and Spanish or Vietnamese on the other (Appendix B). Selected demographic information is requested, and each survey has an individual preprinted identifier number. The first question, which contains 5 elements with yes/no answer options, inquires whether the child has experienced repeated episodes of asthma, cough, chest tightness, trouble breathing, or bronchitis in the past 2 years. This is the only place in the survey that the word asthma is used. Questions 2 through 7 use graded answer options. Wheeze is not used as an isolated symptom, being combined with cough, chest tightness, and trouble breathing under a variety of conditions in questions 2 to 7, for reasons noted above. In questions 2 to 4, information about the frequency of emergency department (ED) visits, school absences, and exercise-related difficulties is requested. The focus of questions 5 through 7 shifts to medication use and symptom (cough, chest tightness, trouble breathing, or wheezing) frequency during the most recent 4-week recall period; the graded answer options correspond to the severity criteria described in the 1997 NIH Guidelines for the Evaluation and Treatment of Asthma.32 The protocol presented was approved by the institutional review board of Children’s Hospital of Orange County.

Study Design

Parents of children in the randomly selected classrooms received an introductory letter stating that they would be invited to participate in a study at a mobile clinic at their school. If they consented, then they would complete a respiratory-asthma questionnaire and their child would be evaluated by an asthma specialist at the school site. To reduce selection bias, no promise of health care was indicated, although there would be an opportunity to enroll in a low-cost health plan, if so desired. For their time and effort, the families were offered a $50 gift certificate for groceries if they participated. Additional, randomly selected classrooms were invited until an optimal number of children at each school were found to participate. Upon arrival at the school, parents were greeted by school personnel and then given the questionnaire in their primary language, with minimal prompting by bilingual speakers (to simulate the home or “real-world” situation). After completing the questionnaire, the family proceeded to a series of stations where vital signs were recorded, spirometry was performed by trained pediatric respiratory therapists, and an asthma-related history was recorded by bilingual nurses. Procedures at the last station for the asthma evaluation, ie, the history recording and physical examination, were performed by a board-certified allergist with the help of bilingual nurses. The final diagnosis regarding the presence and severity of asthma (either intermittent or persistent asthma) was made by using the NIH guidelines.32 Participating physicians were unaware of the responses to the asthma screening questionnaire, which had been completed previously. The study was conducted between August 2002 and March 2003. All evaluation forms were identified with preprinted numerical indicators, to ensure confidentiality. These numerical indicators were later correlated with the subjects’ names by school personnel, to provide the parents with the conclusions of the survey. To evaluate the reliability of the questionnaire, the survey tool was distributed to the entire student body several weeks later, taken home, and returned for comparison with the initial survey responses determined at the school site.

Statistical Analyses

The validity of each survey item as a case-detection tool for asthma was evaluated through calculation of standard parameters (ie, sensitivity, specificity, positive predictive value [PPV], and negative predictive value [NPV]) and application of univariate discriminant analysis procedures. The latter provided the estimated probability of an asthma diagnosis by an allergy specialist on the basis of parent responses to each survey item (negative or positive).

A large-scale school screening effort underway in Orange County uses scanning software and case-detection criteria developed and validated in Los Angeles County by Jones et al.28 Validation of this comprehensive (complete) algorithm, which considers previously diagnosed cases and potential undiagnosed cases with symptom experience indicative of asthma, was examined in our study population. Briefly, the scanning software generates 1 of 3 letters for each child, on the basis of prior diagnosis and probability of asthma. Letters reflect predicted asthma status, ie, not likely, possible, or probable asthma. Because children who have 50% to 79% probability receive a “possible” letter, we included this group in our positive category for calculation of validation statistics (negative screen: <50% probability and no prior diagno-

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### TABLE 2. Pediatric Asthma Validation Statistics Across Studies

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
<th>Age Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hall et al29</td>
<td>197</td>
<td>100</td>
<td>55</td>
<td>48</td>
<td>97</td>
<td>6 mo to 18 y</td>
</tr>
<tr>
<td>Bauer et al27</td>
<td>1103, year 1</td>
<td>94</td>
<td>87</td>
<td>55</td>
<td>99</td>
<td>5-12 y</td>
</tr>
<tr>
<td>1179, year 2</td>
<td>96</td>
<td>96</td>
<td>82</td>
<td>100</td>
<td>NR</td>
<td>5-12 y</td>
</tr>
<tr>
<td>Wolf et al20</td>
<td>129</td>
<td>74</td>
<td>73</td>
<td>NR</td>
<td>NR</td>
<td>6-12 y</td>
</tr>
<tr>
<td>Jenkins and Clarke24</td>
<td>168</td>
<td>85</td>
<td>81</td>
<td>61</td>
<td>94</td>
<td>13-14 y</td>
</tr>
<tr>
<td>Glasgow et al27</td>
<td>179</td>
<td>98</td>
<td>69</td>
<td>74</td>
<td>97</td>
<td>5-6 y</td>
</tr>
<tr>
<td>Frank et al31</td>
<td>157</td>
<td>61</td>
<td>95</td>
<td>75</td>
<td>NR</td>
<td>5-15 y</td>
</tr>
<tr>
<td>Solé et al28</td>
<td>52</td>
<td>92</td>
<td>100</td>
<td>NR</td>
<td>NR</td>
<td>6-7 y</td>
</tr>
<tr>
<td>Joseph et al30</td>
<td>262</td>
<td>77</td>
<td>93</td>
<td>63</td>
<td>96</td>
<td>7-11 y</td>
</tr>
<tr>
<td>Redline et al3173</td>
<td>109</td>
<td>80</td>
<td>75</td>
<td>50</td>
<td>92</td>
<td>4-13 y</td>
</tr>
<tr>
<td>Jones et al28</td>
<td>636</td>
<td>91/77/87*</td>
<td>88</td>
<td>84</td>
<td>94</td>
<td>3-18 y</td>
</tr>
<tr>
<td>Current study</td>
<td>401</td>
<td>83/56/66*</td>
<td>88</td>
<td>68</td>
<td>87</td>
<td>5-11 y</td>
</tr>
</tbody>
</table>

NR indicates not reported.
* Persistent asthma/intermittent asthma/overall, with the abbreviated algorithm (yes to question 1 asthma or positive responses to both question 4 and question 6).
CROSS-CULTURAL ASTHMA CASE-DETECTION TOOL

RESULTS

Demographic Features

Demographic data that describe children included in the reliability and validity analyses are shown in Table 3. Reliability, which was determined by analyzing the survey questionnaire responses obtained several weeks apart, was assessed for 193 children, including 57% Hispanic, 25% Vietnamese, 9% white, and 9% other children. The average age was 7.8 years (range: 5–11 years), and 57% of the children were female. Eighty-one percent of the Hispanic families responded in Spanish, whereas 19% of the Hispanic families responded in English. Children represented in the reliability sample were not excluded from participation in the validity study. The demographic composition of the group of 401 validity study participants was similar to that of the reliability sample (Table 3). A slightly smaller percentage of participants were female and Hispanic, compared with the reliability sample, with greater representation of Vietnamese and white children. Approximately 23% of Hispanic participants responded to the English version of the survey. A similar language determination for the reliability and validity analyses was not possible for the Vietnamese population. The prevalence of asthma in the validation sample of 401 children was 28% (stratified according to ethnicity: Vietnamese: 22.7%; Hispanic: 24.0%; white: 33.0%; other: 40.7%; P < .05). Among the 113 children with asthma, 65% were classified as having intermittent asthma and 35% as having persistent asthma; 62% were newly diagnosed and 38% were previously diagnosed. Persistent asthma was found in 21% of newly diagnosed cases and 58% of previously diagnosed cases.

Abbreviated Algorithm

Univariate discriminant analysis procedures revealed the following 5 items to be the most unique predictive classifiers for asthma status (from most to least predicative): question 1 asthma, question 4, question 6, question 1 trouble breathing, and question 1 chest tightness. These results contributed to development of the abbreviated scoring algorithm. Other considerations included the percentage of responders for each item, the balance of sensitivity and false-positive findings, and the ease of application in a school or pediatric care setting. The abbreviated version classifies a child as a potential asthmatic (requiring additional evaluation for diagnosis of asthma) when responses are positive to question 1 asthma and/or both question 4 and question 6, question 1 trouble breathing, and question 1 chest tightness. These results contributed to development of the abbreviated scoring algorithm. Other considerations included the percentage of responders for each item, the balance of sensitivity and false-positive findings, and the ease of application in a school or pediatric care setting.

Reliability

The reliability of each survey item scaled according to application as a case-detection tool and the complete and abbreviated scoring algorithms was

### TABLE 3. Distribution of Demographic Characteristics for Each Study Population (Reliability, Validity, and Survey)

<table>
<thead>
<tr>
<th>No. of Patients</th>
<th>Reliability Sample</th>
<th>Validity Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall</td>
<td>193</td>
<td>401</td>
</tr>
<tr>
<td>Age, y (mean ± SD) (range)</td>
<td>7.8 ± 1.5 (5–11)</td>
<td>7.8 ± 1.5 (5–11)</td>
</tr>
<tr>
<td>Female</td>
<td>108 (57.1%)</td>
<td>162 (51.7%)</td>
</tr>
<tr>
<td>Male</td>
<td>81 (42.9%)</td>
<td>151 (48.2%)</td>
</tr>
<tr>
<td>Vietnamese</td>
<td>48 (24.9%)</td>
<td>75 (18.7%)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>110 (57.0%)</td>
<td>179 (44.6%)</td>
</tr>
<tr>
<td>Caucasian</td>
<td>17 (8.8%)</td>
<td>88 (21.9%)</td>
</tr>
<tr>
<td>Other/unknown*</td>
<td>18 (9.3%)</td>
<td>59 (14.7%)</td>
</tr>
</tbody>
</table>

Language survey completed among Hispanic participants

- Spanish: 89 (80.9%) 137 (76.5%)
- English: 21 (19.1%) 42 (23.4%)

Asthma prevalence

| Total prevalence | 113/401 (28.2%) |
| Prior diagnosis  | 43 (38%)/25 (58%)* |
| New diagnosis    | 70 (62%)/15 (21%)* |

* Number for which ethnicity is unknown within each sample: reliability: N = 2; validity: N = 14;
† Persistent asthma.
assessed (Table 4). $\kappa$ values indicated acceptable reliability for the majority of items, with substantial agreement being observed for question 1 asthma, question 1 chest tightness, question 3 (missed school), and the complete algorithm ($\kappa > .70$). Although total percent agreement was slightly lower for question 4 (exercise-induced symptoms) (74.8%), this reliability indicator was $>80\%$ for all other items. Reliability findings were consistent across ethnic groups, with the exception of question 1 trouble breathing and question 5 (medicine use). Stability in reporting experience of trouble breathing was slightly lower among Vietnamese participants; however, $80\%$ answered in accordance with their earlier responses. Reported medicine use in the past 4 weeks (question 5) was less reliable among children in the other/unknown category ($61.2\%$), compared with Hispanic ($83.1\%$), Vietnamese ($87.5\%$), and white ($94.1\%$) participants.

**Validation of Individual Questions**

Response rates for particular questions did not show ethnic variation (Table 5). More than $97\%$ of all participants answered questions 2 to 7. Response rates for the health condition items represented in question 1 ranged from $80\%$ to $90\%$, with a higher rate being observed for question 1 cough ($95\%$). It was interesting to note that, among Hispanic participants, the percentage of nonresponders for specific items was higher among the Spanish-speaking Hispanic subjects than among the English-speaking participants; $21.2\%$ of Spanish-speaking subjects did not respond to question 1 asthma, compared with $4.8\%$ ($P < .05$), and $20.4\%$ did not respond to question 1 chest tightness, compared with $7.1\%$ ($P < .05$).

Item analysis showed consistent patterns of sensitivity and specificity across cultures, although repeated episodes of cough were significantly less specific for Vietnamese and Hispanic participants ($45.6\%$ and $39.5\%$, respectively, compared with white, $69.5\%$, and other, $67.7\%; P < .001$). Predictive values are directly influenced by prevalence. Lower prevalence for repeated episodes of cough and lower prevalence of asthma among Vietnamese and Hispanic participants likely contributed to the decreased positive predictive ability of this item for these participants. For all other items, significant differences in PPVs and NPVs were not detected at the Bonferroni adjusted level of $.001$.

**Algorithm Validity**

The validity of the complete and abbreviated algorithms with all ethnic groups is shown in Table 5. Overall, sensitivity was $63\%$ for the complete algorithm and $66\%$ for the abbreviated algorithm. The overall specificity was $87\%$ for the complete algorithm and $88\%$ for the abbreviated version.

**Algorithm Validity Across Cultures**

Two important comparisons are shown in Table 6. There were no statistically significant differences in validity (sensitivity, specificity, PPV, and NPV) among the ethnic groups with either the complete or abbreviated algorithm. In addition, the abbreviated questionnaire compared well with the complete algorithm for all groups.

**Validity Stratified According to Asthma Severity**

In Table 7, it can be seen that asthma severity greatly affected the sensitivity of each survey item and both algorithm scoring methods to detect asthma. Case identification of persistent asthma was consistently greater than that of intermittent asthma. This observed increased sensitivity of detection for persistent asthma was statistically significant with either the complete ($P = .02$) or abbreviated ($P = .008$) algorithm. Item analysis revealed similar trends, but differences in validity estimates according to severity were less pronounced for the following items: question 1 cough, question 1 bronchitis, question 2 (ED visits), question 3 (missed school), and question 4 (exercise-induced symptom experience).

<table>
<thead>
<tr>
<th>TABLE 4.</th>
<th>Reliability of Survey Items and the Complete and Abbreviated Scoring Algorithms Overall and According to Ethnicity</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Survey Items</strong></td>
<td><strong>Overall (N = 193)</strong></td>
</tr>
<tr>
<td><strong>k (95% CI)</strong></td>
<td>Agreement, %</td>
</tr>
<tr>
<td><strong>Q1: asthma</strong></td>
<td>0.86 (.73-.98)</td>
</tr>
<tr>
<td><strong>Q1: cough</strong></td>
<td>0.64 (.52-.76)</td>
</tr>
<tr>
<td><strong>Q1: trouble breathing</strong></td>
<td>0.69 (.53-.85)</td>
</tr>
<tr>
<td><strong>Q1: chest tightness</strong></td>
<td>0.71 (.51-.92)</td>
</tr>
<tr>
<td><strong>Q1: bronchitis</strong></td>
<td>0.60 (.29-.91)</td>
</tr>
<tr>
<td><strong>Q2: ED visits</strong></td>
<td>0.44 (.22-.66)</td>
</tr>
<tr>
<td><strong>Q3: missed school</strong></td>
<td>0.73 (.63-.83)</td>
</tr>
<tr>
<td><strong>Q4: exercise-induced</strong></td>
<td>0.47 (.34-.60)</td>
</tr>
<tr>
<td><strong>Q5: medicine use</strong></td>
<td>0.60 (.47-.72)</td>
</tr>
<tr>
<td><strong>Q6: day symptoms</strong></td>
<td>0.57 (.44-.70)</td>
</tr>
<tr>
<td><strong>Q7: night symptoms</strong></td>
<td>0.57 (.44-.69)</td>
</tr>
<tr>
<td><strong>Complete algorithm†</strong></td>
<td>0.63 (.50-.76)</td>
</tr>
</tbody>
</table>

Cl indicates confidence interval; NC; not calculated because of limited variation.

* Questions 2 to 7 were coded as ever versus never (relevant to specified time).

† Yes to question 1 asthma or symptom experience indicative of asthma (probability of asthma: $\geq 50\%$ or $\geq 80\%$ with more stringent criteria).

‡ Specifically, yes to question 1 asthma or positive responses to both question 4 and question 6.
Specifically, yes to question 1 asthma or positive responses to both question 4 and question 6.

Cross-cultural comparison indicates significant difference with respect to validity parameter (\(P < .01\)).

\(\chi^2\) test, Bonferroni adjusted level), \(P \leq .001\).

Overall, \(N = 401\); prevalence: 28.2%.

Questions 2 to 7 were coded as ever versus never (relevant to specified time).

Percentage based on those who responded to each question, reflecting a positive answer/classification.

Yes to question 1 asthma or symptom experience indicative of asthma (probability of asthma: \(\geq 50\%\) or \(\geq 80\%\) with more stringent criteria).

Specifically, yes to question 1 asthma or positive responses to both question 4 and question 6.

### TABLE 6. Validity of Algorithm Across Ethnic Groups

<table>
<thead>
<tr>
<th>Ethnic Group</th>
<th>No. (Asthma Prevalence)</th>
<th>Algorithm*</th>
<th>Sensitivity, %</th>
<th>Specificity, %</th>
<th>PPV, %</th>
<th>NPV, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vietnamese</td>
<td>75 (23%)</td>
<td>C</td>
<td>77</td>
<td>88</td>
<td>65</td>
<td>93</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>71</td>
<td>91</td>
<td>71</td>
<td>91</td>
</tr>
<tr>
<td>Hispanic</td>
<td>179 (24%)</td>
<td>C</td>
<td>54</td>
<td>82</td>
<td>49</td>
<td>85</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>63</td>
<td>84</td>
<td>55</td>
<td>88</td>
</tr>
<tr>
<td>Caucasian</td>
<td>88 (33%)</td>
<td>C</td>
<td>66</td>
<td>92</td>
<td>79</td>
<td>84</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>71</td>
<td>87</td>
<td>77</td>
<td>87</td>
</tr>
<tr>
<td>Other</td>
<td>59 (41%)</td>
<td>C</td>
<td>67</td>
<td>97</td>
<td>94</td>
<td>88</td>
</tr>
<tr>
<td></td>
<td></td>
<td>A</td>
<td>58</td>
<td>94</td>
<td>88</td>
<td>77</td>
</tr>
</tbody>
</table>

* C indicates complete algorithm; A, abbreviated algorithm.

### TABLE 7. Sensitivity According to Asthma Severity Classification

<table>
<thead>
<tr>
<th>Survey Items*</th>
<th>Intermittent ((N = 73))</th>
<th>Persistent ((N = 40))</th>
<th>(\chi^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q1: asthma</td>
<td>36.0% (18/50)</td>
<td>69.4% (25/36)</td>
<td>9.4 ((P = .002))</td>
</tr>
<tr>
<td>Q1: cough</td>
<td>82.9% (58/70)</td>
<td>91.4% (32/35)</td>
<td>1.4 ((P = .237))</td>
</tr>
<tr>
<td>Q1: trouble breathing</td>
<td>36.8% (21/57)</td>
<td>74.3% (26/35)</td>
<td>12.1 ((P &lt; .001))</td>
</tr>
<tr>
<td>Q1: chest tightness</td>
<td>27.3% (15/55)</td>
<td>53.6% (15/28)</td>
<td>5.6 ((P = .016))</td>
</tr>
<tr>
<td>Q1: bronchitis</td>
<td>22.6% (12/53)</td>
<td>36.7% (11/30)</td>
<td>1.9 ((P = .170))</td>
</tr>
<tr>
<td>Q2: ED visits</td>
<td>23.6% (17/72)</td>
<td>32.5% (13/40)</td>
<td>1.0 ((P = .309))</td>
</tr>
<tr>
<td>Q3: missed school</td>
<td>63.9% (46/72)</td>
<td>78.9% (30/38)</td>
<td>2.6 ((P = .104))</td>
</tr>
<tr>
<td>Q4: exercise-induced</td>
<td>77.5% (55/71)</td>
<td>90.0% (36/40)</td>
<td>2.7 ((P = .099))</td>
</tr>
<tr>
<td>Q5: medicine use</td>
<td>32.9% (24/73)</td>
<td>75.0% (30/40)</td>
<td>18.4 ((P &lt; .001))</td>
</tr>
<tr>
<td>Q6: day symptoms</td>
<td>50.0% (36/72)</td>
<td>85.0% (34/40)</td>
<td>13.4 ((P &lt; .001))</td>
</tr>
<tr>
<td>Q7: night symptoms</td>
<td>42.5% (31/73)</td>
<td>82.5% (33/40)</td>
<td>16.9 ((P &lt; .001))</td>
</tr>
<tr>
<td>Complete algorithm†</td>
<td>52.1% (38/73)</td>
<td>82.5% (33/40)</td>
<td>9.0 ((P = .003))</td>
</tr>
<tr>
<td>Abbreviated version‡</td>
<td>55.7% (39/70)</td>
<td>82.5% (33/40)</td>
<td>6.9 ((P = .008))</td>
</tr>
</tbody>
</table>

Overall, \(N = 401\); prevalence: 28.2%.

* Questions 2 to 7 were coded as ever versus never (relevant to specified time).

† Yes to question 1 asthma or symptom experience indicative of asthma (probability of asthma: \(\geq 50\%\) or \(\geq 80\%\) with more stringent criteria).

‡ Specifically, yes to question 1 asthma or positive responses to both question 4 and question 6.

### DISCUSSION

This study carefully evaluated the question of whether a novel asthma case-detection tool could detect children at high risk for asthma in several cultures. Our data suggest that this is the case. The tool, which was described recently by Jones et al., has worked well in identifying at-risk children 5 to 11 years of age (mean: 7.8 years) in both inner-city...
and suburban school sites, regardless of Hispanic, white, or Vietnamese ethnicity. This survey tool had an overall sensitivity of 83% and specificity of 88% (with the abbreviated algorithm) for children at greatest risk, with persistent asthma diagnosed by the asthma specialist during the validation procedure. Sensitivity was lower (56%) for those with less risk, with intermittent asthma. In terms of ethnicity, the prevalence across cultures of physician-diagnosed persistent asthma was similar for the Hispanic group (9%) and the white group (10%) and was slightly higher (12%) for the Vietnamese and other groups (data not shown). Validation fared well in all groups, in terms of sensitivity, specificity, PPV, and NPV. Although only trends could be analyzed, because the number in each group was small, there did not appear to be large differences, although the sensitivity of the algorithm was somewhat lower for the Hispanic group (Table 6). The patterns of response rates for question 1 through question 7, as well as the repeatability of each question, were not significantly different among the 3 ethnic groups. However, in the Hispanic population, nonresponses to certain questions, such as question 1 asthma and question 1 chest tightness, were fewer among subjects who answered in English (Table 3). This could reflect better SES and educational background for the English-speaking Hispanic families.

Because physician diagnosis of asthma is known to vastly underestimate its presence, particularly among minorities in inner-city environments, it was of great interest to evaluate the usefulness of an abbreviated algorithm, particularly for those with negative responses to question 1 asthma (because they stated no or did not answer the question). In comparison with question 1 asthma alone, we found that using a combination of questions in the algorithm analysis, particularly combinations of question 1 asthma and question 4 (exercise-induced asthma) and question 6 (daytime asthmatic symptoms), resulted in excellent sensitivity of 83% and specificity of 88% for those with the highest risk, with persistent asthma (Table 7). This abbreviated algorithm usually yielded results as good as or better than those of the complete 7-element algorithm (Table 6). Unique to this questionnaire was the incorporation of wheezing with other symptoms, including cough, trouble breathing, and chest tightness, instead of using wheezing as a “stand-alone” diagnostic tool, for reasons given earlier. In addition, this approach is consistent with the observation that the most frequent presenting symptoms of asthma among children are cough (92%), wheeze (90%), and shortness of breath (83%). Redline et al recently reported that cough and breathing problems were more useful criteria than was wheezing. However, because wheeze is such a common stand-alone criterion in many surveys, we analyzed the value of wheeze as a stand-alone criterion and evaluated its effect in adding it to the abbreviated algorithm. Because the question was used only by the physician evaluator and could include prompting, the result is only an estimate of its value. For wheeze as a stand-alone criterion, the overall sensitivity was only 53% (63% among persistently asthmatics), whereas the specificity was high (88%). This is very similar to the results for question 1 asthma as a stand-alone criterion, with a sensitivity of 50% and a specificity of 98%. Addition of wheezing to the abbreviated algorithm resulted in better overall sensitivity of 74%, compared with 66%, and specificity of 67%, compared with 56%, for the intermittent asthma group. Addition had very little effect on the sensitivity or specificity for the persistent group. We plan to examine the value of wheezing as a stand-alone criterion more directly in future studies.

Validation of the asthma detection tool has been a major problem in previously reported asthma studies (Tables 1 and 2). For adequate validation, the population should be sampled in the environment in which the tool will be used, with random selection from the community and not sampling in a clinic or hospital, where patient bias might be introduced. The questions selected for validation should not be judged (a priori) to indicate a positive or negative responder and should not be used as selection criteria for the validation process, and the questionnaire should be compared with the best standard available. The standard method has varied considerably in different studies and has included previously validated questionnaires, bronchial lability testing including exercise and bronchial constriction challenge, and evaluation by nonphysicians and by a panel of experts who did not directly examine the subjects. Assessment of bronchial lability for diagnosing clinical asthma has not been found to be a predictable tool and is therefore inadequate for validating an asthma detection tool, such as the questionnaire. The consensus is that the best standard is the asthma specialist who, in a blinded manner, examines the study population.

Our study model did attempt to address these critical issues. We validated an asthma detection tool in 3 different ethnic cultures, in both inner-city and suburban settings, and made an effort to select patients randomly from the community, using schools as our major sites. There was no a priori assumption of a positive questionnaire, and we used an asthma specialist to establish a diagnosis for all children at the time of the study.

Selection bias could not be totally avoided, because 41% of all invited patients participated. The small financial incentive could have resulted in recruitment of more financially needy patients, among whom asthma is thought to be more severe. Another potential limitation of this study was the assignment of severity to each case by the asthma specialist. This difficulty was illustrated by our finding that the asthma severity did not directly affect the sensitivity of detection based on ED visits, school absenteeism, and exercise-induced symptoms, although severity did correlate with most of the other parameters (Table 7). This calls into question what should be the standard method. Braganza et al found that pediatricians often underdiagnose the severity of asthma, according to NIH guidelines. Furthermore, Baker et
al\textsuperscript{35} reported major discrepancies regarding asthma severity even among asthma specialists. Some variability among the 9 asthma specialists participating in our study was thus expected. Nevertheless, asthma specialists have been found to be more likely to follow NIH guidelines than generalists and to be more effective in the validation process.\textsuperscript{36} Even with these limitations, there does not appear to be any substantial difference in this prediction model, in terms of sensitivity or specificity, among the ethnic groups, suggesting that our detection tool could be used universally for the cultures evaluated. Although our inner-city population may differ from the typical urban inner-city population, Jones et al\textsuperscript{28} found similar results for African American and Hispanic children evaluated in Los Angeles.

Although we have validated a survey tool that detects children at high risk for persistent asthma, there is concern that this may not be beneficial without adequate medical follow-up services.\textsuperscript{14} A recent publication by the Department of Health and Human Services suggested identifying only children with a previous diagnosis of asthma and avoiding mass screening or case detection, “since these methods have not been shown to meet the World Health Organization or the American Academy of Pediatrics’ criteria for population or school screening programs.”\textsuperscript{57}(p2) This conclusion was based mainly on several recent reports. Gerald et al,\textsuperscript{38} using a multistep approach (questionnaire, spirometry, and exercise provocation) among children with a previous diagnosis of asthma or suspected asthma, concluded that additional physiologic tests are necessary to reduce the overdiagnosis made with the questionnaire. However, spirometry and provocation testing are not practical or safe in the school setting, and neither is very specific or sensitive.\textsuperscript{14,24,26} Boss et al,\textsuperscript{39} using 9 World Health Organization criteria for determining the appropriateness of community-based screening programs, concluded that a number of criteria are not met for asthma detection in this setting. However, several key assumptions require clarification. Those authors suggested that children diagnosed with mild asthma uniformly have good prognoses. They asserted that treatment does not modify the underlying disease process, even among those with moderate disease, and thus early detection in the school setting has little impact on prevention among children \geq 5 years of age. However, it has been reported that as many children with clinical manifestations of mild disease die as those who have more serious disease.\textsuperscript{40} As shown in our data (Table 7) and reported by others, 41 children with mild disease experienced ED visits and hospitalizations. Even among asthma specialists, there is disagreement regarding the classification of asthma severity,\textsuperscript{35} which suggests that current methods of assessing disease severity might be inadequate. Furthermore, those with moderate asthma disease do experience profound changes in ED visits and hospitalizations when appropriately treated.\textsuperscript{41} Although there is no conclusive evidence that the natural history of the disease is changed, there is evidence suggesting that pulmonary function might be permanently lost if antiinflammatory treatment is not initiated within 2 years after diagnosis.\textsuperscript{8} Boss et al\textsuperscript{39} also suggested that previously undiagnosed asthma is usually mild. However, Clark et al\textsuperscript{14} reported similar asthma severity for previously undiagnosed (39\%) and previously diagnosed (55\%) cases, whereas we found that 21\% of previously undiagnosed cases involved persistent asthma. Although the cost/benefit ratio is always a concern for subjects identified at school, costs for inner-city children with asthma might actually be less, rather than more, if patients were given education and appropriately treated, because of fewer ED visits and hospitalizations.\textsuperscript{42} Yawn et al\textsuperscript{43,44} suggested that children who are previously undiagnosed and those with the diagnosis of asthma in the school setting infrequently seek medical care recommended by the school, to confirm the diagnosis and receive appropriate therapy. Those authors concluded that a school detection tool might be worthwhile for those previously diagnosed with asthma but not for those previously undiagnosed, in terms of accessing physician care. However, it could also be concluded that, if education and accessibility to better care were available for both suspected and previously diagnosed children, then better physician-based diagnosis and treatment would have been found.

Although we agree in principal with the assertion of Clark et al\textsuperscript{14} that school-based detection of children with asthma would be useful only if effective, affordable, and accessible medical services were available, we think that school-based detection is the first step. The challenge is to provide good ongoing medical care, particularly in inner-city settings, where it is needed most. Several programs, in fact, have begun to reduce the barriers to good care in inner-city environments, with promising results.\textsuperscript{45–48}

CONCLUSION

We found this asthma detection tool to be suitable for detecting children at high risk for persistent asthma across the dominant cultures in Orange County. The school setting seems to be well suited for detecting these children, with the enthusiastic support of school personnel, particularly for the inner-city minority population. An abbreviated modification of the complete 11-element questionnaire with only 3 questions, ie, question 1 asthma, question 4 (exercise-induced asthma symptoms), and question 6 (asthma symptoms during the day in the past 4 weeks), which yielded excellent prediction of persistent asthma, might be more suitable for inclusion in the health survey that all children are required to submit for school. Although there is concern that subjects detected in the school setting might not have adequate access to appropriate care, case detection is an important first step that could lead to earlier diagnosis and treatment of asthmatic children who are most in need. Reducing the barriers to good ongoing medical care in inner-city environments is the next step.
APPENDIX A: INTERNATIONAL STUDY OF ASTHMA AND ALLERGY IN CHILDHOOD QUESTIONNAIRE

Core questionnaire wheezing module for 6 to 7-year-olds and 13 to 14 year olds

1. Has your child ever had wheezing or whistling in the chest at any time in the past?
   Yes [ ] No [ ]

2. Has your child had wheezing or whistling in the chest in the last 12 months?
   Yes [ ] No [ ]
   If you answered “no,” please skip to question 6

3. How many attacks of wheezing has your child in the last 12 months?
   None [ ] 1 to 3 [ ] 4 to 12 [ ] More than 12 [ ]

4. In the last 12 months, how often, on an average, has your child’s sleep been disturbed due to wheezing?
   Never woken with wheezing [ ]
   Less than one night per week [ ]
   One or more nights per week [ ]

5. In the last 12 months, has wheezing ever been severe enough to limit your child’s speech to only one or two words at a time between breaths?
   Yes [ ] No [ ]

6. Has your child ever had asthma?
   Yes [ ] No [ ]

7. In the last 12 months, has your child’s chest sounded wheezy during or after exercise? Yes [ ] No [ ]

8. In the last 12 months, has your child had a dry cough at night, apart from a cough associated with a cold or a chest infection? Yes [ ] No [ ]

Los Angeles Asthma Health Screening Survey

Name of school: ____________________________  Class room number: ____________________________  Date: ____________  Child’s Gender: ○ Male  ○ Female

Identifier Number: 042290

Zip Code: [ ] [ ] [ ] [ ]

Child’s Age: [ ] 10

Parent’s ancestry (select all that apply):
- ○ African American
- ○ Arubian/Arab American
- ○ Asian/Asian American
- ○ Central American
- ○ Mexican/Mexican American
- ○ Other Hispanic
- ○ Pacific Islander
- ○ White/Caucasian
- ○ Other

Type of health care coverage or insurance (select all that apply):
- ○ Medi-Cal
- ○ Medi-Cal health plan
- ○ Health plan from work
- ○ Private health plan
- ○ Pay money each time we receive healthcare
- ○ No insurance or healthcare coverage

1. During the last 2 years, has your child had repeated episodes of any of the following health conditions? (Select all answers that apply)

   Asthma  ○ No
   Cough  ○ No
   Trouble Breathing  ○ No
   Chest Tightness  ○ No
   Bronchitis  ○ No

2. During the last 2 years, has your child been treated in an emergency room or hospital for episodes of cough, chest tightness, trouble breathing, or wheezing? (Select the one best answer)

   Never  ○
   One time  ○
   Two times  ○
   Three times  ○
   Four or more times  ○

3. How often does your child miss school because of cough, chest tightness, trouble breathing, or wheezing? (Select the one best answer)

   Never  ○
   Less than 5 days per year  ○
   5 to 10 days per year  ○
   More than 10 days per year  ○

4. Does your child have episodes of cough, chest tightness, trouble breathing, or wheezing when they play or exercise? (Select the one best answer)

   Never  ○
   Rarely  ○
   Sometimes  ○
   Often  ○
   Most of the time  ○

5. In the past 4 weeks, how often has your child used a medicine (a syrup, an inhaler, or a breathing machine) to treat episode of cough, chest tightness, trouble breathing, or wheezing? (Select the one best answer)

   Never  ○
   Less than two days a week  ○
   Two or more days a week but not every day  ○
   Every day  ○
   More than once a day on most days  ○

6. In the past 4 weeks, how often has your child had episodes of cough, chest tightness, trouble breathing, or wheezing in the morning or during the daytime? (Select the one best answer)

   Never  ○
   Less than two days a week  ○
   Two or more days a week but not every day  ○
   Every day  ○
   More than once a day on most days  ○

7. During the past 4 weeks, how often has your child had cough, chest tightness, trouble breathing, or wheezing at night or while sleeping? (Select the one best answer)

   Never  ○
   Less than one night a week  ○
   One to three a week or more but not every night  ○
   Every night  ○

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Predictive Value of a Cross-Cultural Asthma Case-Detection Tool in an Elementary School Population

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