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Validation of the Hospital Asthma Severity Score (HASS) in children ages 2–18 years old

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ABSTRACT

Introduction: The Hospital Asthma Severity Score (HASS) was developed to communicate inpatient asthma severity between providers. The purpose of this prospective study was to validate the HASS against the Pediatric Respiratory Assessment Measure (PRAM) and spirometry for assessment of inpatient asthma exacerbation severity in patients 2–18 years old, at a single point-in-time.

Methods: This study was registered with clinicaltrials.gov (NCT02782065). Children admitted to a tertiary care, free-standing children's hospital were assessed for asthma severity using the HASS, PRAM, and pulmonary function by spirometry. Inter-rater agreement of HASS and PRAM scores was assessed between two blinded clinician raters. Spirometry results were obtained by a certified pulmonary laboratory technician and correlated with HASS and PRAM scores.

Results: The sample included 58 subjects. Allowing for a one-point difference in continuous HASS and PRAM scores, inter-rater agreement was 79% for the HASS and 60% for the PRAM. When the scores were categorized as mild, moderate, and severe, inter-rater agreement was 62% for the HASS and 93% for the PRAM ($p < .0001$). Additionally, intra-rater agreement between HASS and PRAM severity categories was 71% for Rater 1 and 64% for Rater 2. A weak correlation was noted between both the HASS and FEV₁ ($r = -0.31$; $p = 0.11$), and PRAM and FEV₁ ($r = -0.30$; $p = 0.11$) for the 29 subjects with acceptable spirometry results.

Conclusions: The HASS and PRAM have acceptable inter-rater and intra-rater agreement. These results support validation of the HASS for managing hospitalized patients during asthma exacerbations.

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Introduction

Asthma is the leading chronic lung disease of children (1). According to the 2018 Centers for Disease Control report, 7.5% or approximately 5.5 million children under the age of 18 in the United States were diagnosed with asthma. Of those 5.5 million children, half (50%) had at least one acute asthma exacerbation. In 2017, there were over 500 000 emergency room visits by children under age 18, and of those children, 185 died from their asthma (1). Boston Children's Hospital cares for more than 3500 children with a primary diagnosis of asthma annually. In total, these patients account for over 7500 visits and admissions to the hospital per year.

The Hospital Asthma Severity Score (HASS) (Figure 1) was developed at Boston Children's Hospital in 2010 for use in inpatient management of asthma (2). It was created to fill the void of a practical tool that used reliable clinical guides regardless of age or body habitus to accurately determine inpatient asthma management through escalation or de-escalation of therapies (3,4). Each individual component in the HASS is rated from 1 to 3, resulting in an overall score ranging from 5 to 15. Face validity of the HASS consisted of consensus by a panel of over 20 providers from intensive care units, the emergency department, and acute inpatient floors. The first pilot study of the HASS was completed with 140 patients and showed

HASS Score

SpO₂ (%) Score 1 > 94% room air Score 2 90-94% room air Score 3 < 90% on room air or requiring O ₂ to maintain saturation >94%	
Auscultation Score 1 Clear or end expiratory wheeze Score 2 Expiratory wheeze Score 3 Inspiratory + expiratory wheezing, diminished breath sounds or both	
Retractions Score 1 One muscle group involved or none Score 2 Two muscle groups Score 3 Three muscle groups <i>Muscle groups include: Intercostal, substernal, supraclavicular</i>	
Dyspnea (respiratory effort) Score 1 Speaks in full sentences, normal vocalization Score 2 Speaks in partial sentences or utters short cries Score 3 Speaks in single words or short phrases or grunts <i>For sleeping patients: Score of 8 and above without this section necessitates the patient being woken to complete assessment</i>	
Respiratory Rate Score 1 2-5 years <30 per min 6-12 years <25 >12 years <20 Score 2 2-5 years 30- 40 per min 6-12 years 25- 30 >12 years 20- 25 Score 3 2-5 years >40 per min 6-12 years >30 >12 years >25	
HASS TOTAL SCORE:	

HASS SEVERITY CATEGORY: Mild (<7), Moderate (7-9), Severe (10-15)

PRAM Score (*Most severe side is used for rating if asymmetry is noted between right and left lungs)

O₂ saturation Score 0 ≥ 95% Score 1 92-94% Score 2 < 92%	
Air Entry* Score 0 Normal Score 1 Decreased at bases Score 2 Widespread decrease Score 3 Absent/minimal	
Wheezing* Score 0 Absent Score 1 Expiratory only Score 2 Inspiratory and Expiratory Score 3 Audible without a stethoscope/silent chest with minimal air entry	
Suprasternal retractions Score 0 Absent Score 2 Present	
Scalene Muscle retractions Score 0 Absent Score 2 Present	
PRAM TOTAL SCORE:	

PRAM SEVERITY CATEGORY: Mild (<5), Moderate (5-9), Severe (10-12)

Figure 1. HASS and PRAM scoring tools.

inter-rater agreement ($\kappa_{\text{pooled}} = 0.6\text{--}0.89$) when allowing for one-point difference between raters (2). Since that time, the HASS has been used consistently throughout the institution to communicate asthma severity of pediatric patients between providers and guide clinical care.

While there are many asthma severity tools found in the literature, few have been formally validated (5–8). Chacko et al. (5) identified the Pediatric Respiratory Assessment Measure (PRAM) as a well validated asthma severity tool through a systematic review. Also Eggink et al. (7), when comparing five asthma severity tools found the PRAM to be one of the most valid. The PRAM was originally created to address the void of a validated tool that could determine asthma severity in the 2 to 6 year old population (9). It was then re-validated to incorporate a wider pediatric age range from 2 to 17 years (10). The PRAM individual components are rated on a scale of 0 to 2 or 3, with an overall score ranging from 0 to 12. In the original research by Chalut, a significant correlation was found between the PRAM and a change from baseline respiratory resistance measurements at 8 Hz by forced oscillation (Rf_{08}) ($r = 0.58$) in a sample of children 3 to 6 years old (9). Ducharme studied the predictive validity of the PRAM and results demonstrated a statistically significant moderate association between the PRAM and asthma hospital admission rates ($r = 0.4$, $p < 0.0001$) (10).

Given the PRAM had similar components and was validated using comparable processes, it was considered the ideal tool for HASS validation. This is the first study to validate the HASS against another validated asthma severity tool, the PRAM, and against an objective measure of asthma severity, spirometry, for patients 2–18 years old.

Methods

Design and setting

This prospective cohort study was conducted in a 404 bed urban, tertiary care, free-standing children's hospital on inpatient, intermediate and critical care units. The hospital cares for local, regional, and international patients.

Pre-enrollment procedures

The study was approved by the hospital's Institutional Review Board and registered with clinicaltrials.gov (NCT02782065). Study staff was educated about the study procedures including the HASS and PRAM. In

addition, agreement between a primary rater (Rater 1: nurse) and five secondary raters (Rater 2: 2 nurses, 2 nurse practitioners, and 1 respiratory therapist) was established for the HASS and PRAM with patients who were not included in the study sample; data was collected until 90% agreement was achieved.

Study procedures

Eligible subjects aged 2 to 18 years old were identified by their primary diagnosis of asthma using the inpatient electronic medical record system. Patients were excluded from study participation if they were on continuous albuterol, required advanced airway protective therapies (i.e. noninvasive ventilation, intubation), and/or if they had a diagnosis of bacterial or viral lung infection, chronic lung disease, cardiac or kidney disease. Written informed consent was obtained by a parent/legal guardian and assent was obtained from the child, when they were able to sign their name.

Rater 1 and Rater 2 scored each subject with both the HASS and PRAM tools at a single point in time during the child's hospitalization (Figure 2). These single point assessments were completed at varying times during the child's hospitalization and after all subjects had received some form of medical treatment for asthma. When utilizing the HASS, the two raters obtained oxygen saturation, retraction, and dyspnea scores simultaneously. Auscultation and respiratory rate scores were obtained independently. When utilizing the PRAM, the two raters obtained oxygen saturation and retractions simultaneously, followed by independent assessments of air entry for wheezing. Blinding of the scores between the two raters was achieved by completion of the HASS and PRAM tools in a private area after leaving the patient's room.

For each subject encounter, each rater received their own envelope in which to place their scored HASS and PRAM tools. The envelopes were labeled with the subject's unique study ID. After sealing their envelopes, the raters signed their names over the envelope seals to ensure integrity of data.

Immediately following completion of the HASS and PRAM and before any additional medical interventions (i.e. albuterol or use of peak flow meter) were administered, the pulmonary laboratory technician entered the patient's room and prepared the child for spirometry using ComPAS software on a Morgan Scientific Inc. portable pneumotach spirometer (Haverhill, MA). Spirometry was conducted per American Thoracic Society (ATS) standards (11).

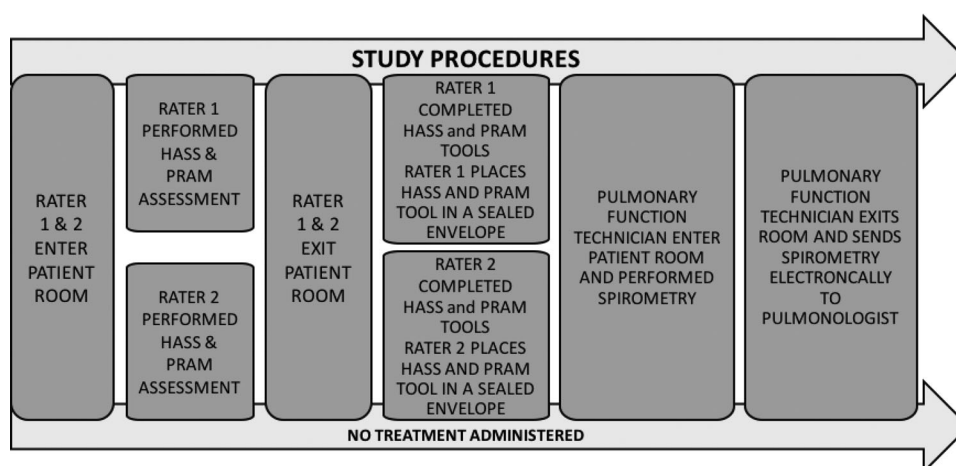


Figure 2. Study procedures at a single point in time.

Global lung function initiative predicted equations served as the spirometry reference values (12). To complete spirometry, the child was seated with a soft clip placed on their nose. The child was given the opportunity to perform the spirometry test a maximum of eight times to achieve acceptable and repeatable results. If the child could not perform spirometry based on cooperativeness or inability to follow instructions, the test was stopped. A member of the research team (research coordinator or manager) not involved in data collection conducted audits for every 20 subjects to ensure study procedure fidelity.

To facilitate blinding, spirometry results were electronically processed and transmitted for evaluation by a board-certified pediatric pulmonologist with expertise interpreting spirometry. The pulmonologist rated the quality of the test for inclusion based on ATS guidelines (13).

Data management

Data were managed by aligning subjects with a unique study ID, and this information was maintained in an electronic logbook. Using the study IDs, subjects' demographics, HASS and PRAM scores, and spirometry data were entered into the Research Electronic Data Capture (REDCap) database. All data was double checked for accuracy following transfer into REDCap.

Data analysis

Data entered into REDCap were exported to SAS 9.4 (SAS Institute, Cary, NC) for analysis. Descriptive statistics were used to describe the sample demographic and clinical characteristics. For the HASS and PRAM total summary scores, the percent agreement between raters and the intraclass correlation coefficients were

computed. Percent of rater agreement was calculated for the individual components of HASS and PRAM. HASS and PRAM total scores were also collapsed into three severity categories (mild, moderate, severe) and the percent agreement between raters was calculated.

In this study, intra-rater agreement refers to the with-in rater agreement between the PRAM and HASS categorical ratings. This was calculated separately for Rater 1 and Rater 2. The intra-rater agreement for Rater 2 was calculated by pooling the data from the Rater 2 clinicians. Inter-rater agreement refers to the agreement between the single clinician who was Rater 1 and the second clinician rating the patient (Rater 2), regardless of which clinician served as Rater 2. Agreement percents are presented rather than kappa because, when adjusting for chance agreement in cases where agreement is high and samples are small, as is the case with these data, kappa can be difficult to interpret and paradoxical (e.g. high agreement and negative kappa) (14,15). Fisher's exact test was used to compare rater agreement between the HASS and the PRAM. Pearson's correlation coefficient was used to describe the association between the percent predicted forced expiratory volume in 1s (%FEV₁) by spirometry and the HASS total score. The *p* values of less than 0.05 were considered statistically significant.

Results

For the 58 subjects, there were 116 total observations of HASS (Rater 1 and 2) and 116 observations of PRAM (Rater 1 and 2). Length of stay for subjects ranged between 0 and 6 days (mean = 1.69) and study assessments were completed on days 0 through 6 of hospitalization (mean = 1.03). There were nearly equal numbers of males and females (Table 1).

Twenty-four (41%) subjects were under seven years of age. The majority of subjects were either Black/African American (40%) or Caucasian (30%). Subjects were recruited from critical care (12.1%), intermediate care (12.1%), and inpatient floors (75.8%). All subjects were receiving nebulizer treatments for the management of asthma: 1.7% every hour, 20.7% every two hours, 32.8% every three hours, and 44.8% every four hours. Two subjects (3%) were receiving nasal cannula oxygen.

When using continuous total scores to examine agreement between the two raters, HASS had 29%

Table 1. Patient characteristics.

Patient characteristics of subjects (N = 58)	n (%)
Sex	
Male	28 (48.3)
Female	30 (51.7)
Age	
Under 7	24 (41.4)
7–18	34 (58.6)
Race	
Caucasian	17 (29.3)
Black/African American	24 (41.4)
Asian	2 (3.4)
Dominican	3 (5.2)
Other	4 (6.9)
Unknown	9 (15.5)
Ethnicity	
Not Hispanic or Latino	36 (62.1)
Hispanic or Latino	13 (22.4)
Unknown	9 (15.5)

exact agreement compared to PRAM which had 28% exact agreement. Allowing a one-point difference between raters, there was 79% rater agreement for the HASS and 60% rater agreement for the PRAM (Figures 3 and 4). The mean total scores for the HASS was 6.26 (SD: 1.36), and for the PRAM was 1.38 (SD: 1.62). Using Koo and Li (16) classifications for intraclass correlation coefficients, moderate reliability for the HASS (0.68; 95% CI 0.47, 0.82) and PRAM (0.51; 95% CI 0.17, 0.71) total scores was observed.

HASS and PRAM total scores were collapsed into three severity categories: mild, moderate, and severe. Using the HASS, Rater 1 scored 64% of the patients as mild, 34% moderate and 2% severe. Using the PRAM, Rater 1 scored 91% of the patients as mild, 9% moderate and none of the patients were categorized as severe. The HASS severity categories had 62% (36/58) agreement between Rater 1 and Rater 2, while the PRAM had 93% (54/58) inter-rater agreement ($p < .0001$). Upon examination of the individual components of the HASS, there was minimal variation in rater agreement for dyspnea, retractions and oxygen saturation scores, but there was greater variation in rater agreement for respiratory rate and auscultation. For the PRAM scores there was minimal variation for oxygen saturation and scalene muscle retraction, moderate variation for suprasternal retractions, and greater

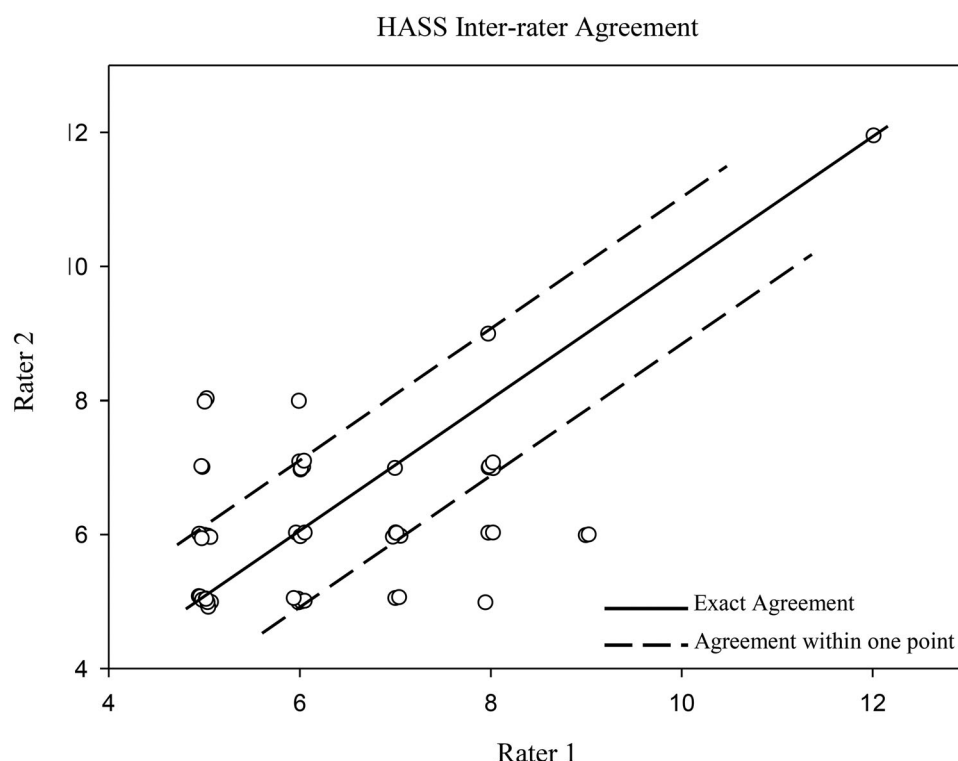


Figure 3. Continuous HASS inter-rater agreement.

PRAM Inter-rater Agreement

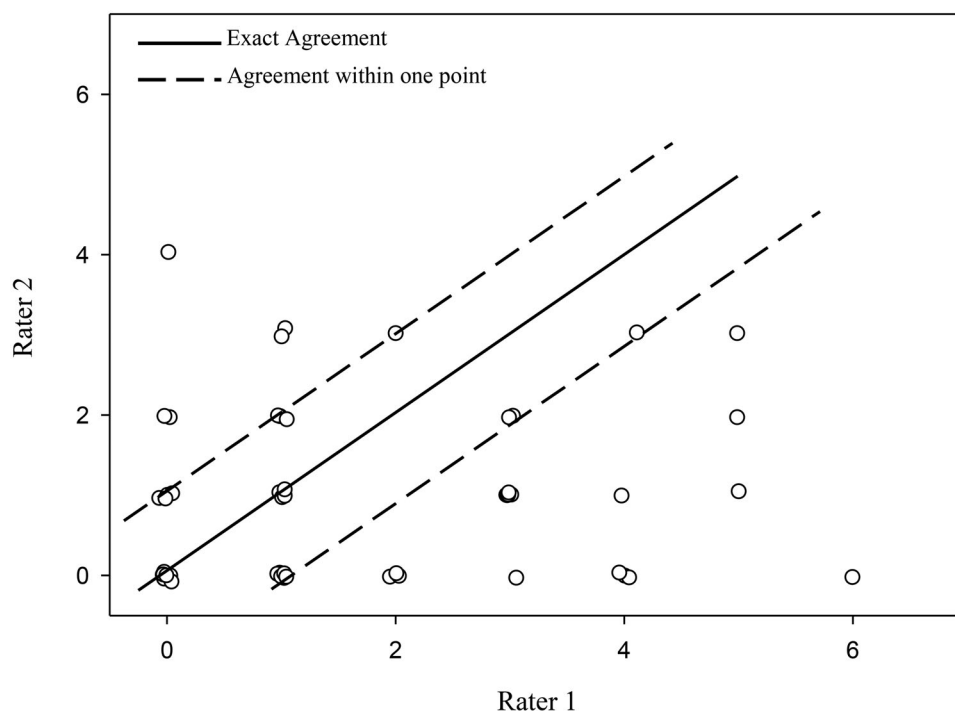


Figure 4. Continuous PRAM inter-rater agreement.

Table 2. Percent inter-rater agreement for HASS and PRAM components by severity category.^a

Individual components	All ages (N = 58) % agree	2–6 years (n = 24) % agree	7–18 years (n = 34) % agree
HASS: Percent inter-rater agreement of HASS by its individual components, overall and for each age group ^b			
Oxygen saturation	95%	96%	94%
Auscultation	55%	50%	59%
Retraction	84%	83%	85%
Dyspnea	88%	91%	85%
Respiratory rate	59%	63%	56%
HASS total score ^a	62%	46%	74%
PRAM: Percent inter-rater agreement of PRAM by its individual components, overall and for each age group ^c			
Oxygen saturation	86%	88%	85%
Air Entry	64%	75%	56%
Wheezing	48%	50%	47%
Suprasternal retractions	76%	79%	74%
Scalene muscle retraction	95%	100%	91%
PRAM total score ^a	93%	100%	88%

^aHASS and PRAM total scores were collapsed into three severity categories (mild, moderate, severe). The HASS total score was collapsed to three categories: 0–6 mild; 7–10 moderate; 11–15 severe. The PRAM total score was collapsed to three categories: 0–4 mild; 5–8 moderate; 9–12 severe. Agreement on the total scores refers to agreement between raters on the severity category.

^bValues represent the percent of rater agreement between HASS severity categories.

^cValues represent the percent of rater agreement between PRAM severity categories.

Table 3. Intra-rater agreement between HASS and PRAM severity categories.

	Rater 1	Rater 2
All subjects	41/58 (71%)	37/58 (64%)
Under 7	16/24 (67%)	17/24 (71%)
7–18	25/34 (74%)	20/34 (59%)

Notes. Counts show the number and percent agreement between the HASS and PRAM severity categories (mild, moderate, and severe) for Rater 1 and Rater 2. HASS total score: 0–6 mild; 7–9 moderate; 10–15 severe. PRAM total score: 0–4 mild; 5–9 moderate; 10–12 severe.

variation in the air entry and wheezing components (Table 2). When intra-rater agreement between HASS and PRAM categories was examined, the HASS and PRAM agreement for Rater 1 was 71% and Rater 2 was 64% (Table 3).

The clinical assessment with HASS and PRAM were performed a median of 3.0 (range 0–11) minutes prior to spirometry. In total, 38 (66%) subjects performed spirometry, with 76% of those yielding acceptable results. There was a weak correlation between the

HASS total score and %FEV₁ ($r = -0.31$, $p = .11$). Also, there was a weak correlation between PRAM total score and %FEV₁ ($r = -0.30$, $p = .11$).

Discussion

There are a host of pediatric acute asthma severity tools available, however many of these have not been validated against other validated tools (6,17–20). Thus, there is an essential need for a valid asthma severity tool which provides a common language to describe the severity of illness and to determine proper treatment of and disposition for the child with asthma. This study demonstrated that the HASS works as well as the PRAM at determining asthma severity in children aged 2 to 18 admitted to the hospital with mild to moderate asthma exacerbations at a single point-in-time.

Our findings showed that the HASS and PRAM had comparable agreement (29% and 28% respectively) when examining continuous total scores; the HASS had better inter-rater agreement (79%) as compared to the PRAM (60%), when allowing for a one-point difference in score; while the PRAM had better inter-rater agreement for severity classification as compared to the HASS (62% and 93% respectively). When each component of the HASS was examined, dyspnea, retractions, and oxygen saturation had very minimal variation across raters (> 80% agreement). However, more variation was noted for auscultation of breath sounds and respiratory rate by independent raters.

When studying 25 children with asthma aged 1 to 12 years, Maekawa et al. (21) also demonstrated lower inter-rater reliability for specific components of the Modified Pulmonary Index Score, another pediatric asthma severity tool. These investigators found oxygen saturation ($\kappa = 1.0$), heart rate ($\kappa = 0.92$), and, respiratory rate ($\kappa = 0.74$) to have high inter-rater reliability overall. However, for patients aged 1 to 5 years, inter-rater reliability for respiratory rate was noticeably lower ($\kappa = 0.54$).

Interestingly, in the present study, inter-agreement was greater for the PRAM as compared to the HASS. However, the scalene muscle retraction component was rarely observed, with most subjects scoring zero, resulting in high rater agreement for that individual component. Inclusion of the scalene muscle retraction component artificially inflated the overall inter-rater agreement for the PRAM. In the original PRAM study by Chalut et al. (9), only 2% of the 217 preschoolers aged 3 to 6 years old with asthma had abnormal

scalene muscle retractions. This is consistent with our findings, only 2.6% of the 116 observations revealed scalene muscle retractions. Also as stated by Arnold et al. (22) in a discussion of the PRAM, inclusion of scalene muscle retractions may only be recognized by palpitation or electromyography, making this assessment difficult without special training. The HASS, as compared to the PRAM, includes easily attainable objective and subjective components that do not require special training or equipment to obtain the measures leading to a potentially more realistic description of the patient's severity of illness, with a corresponding score to guide management.

In the present study, there was acceptable intra-rater agreement between the HASS and PRAM severity categories (71% and 64% respectively), although as previously noted, the PRAM had better inter-rater agreement for severity categorization. This finding demonstrates that raters could consistently utilize the tools to determine severity of illness. Categorization of the scores into mild, moderate, and severe can help determine the management of patients with asthma. Categorization of severity assists the provider in determining the next course of action for the patient, such as admission and discharge, transfers between the acute inpatient and critical care unit, or increasing/decreasing the frequency of albuterol and other interventions. While categorization using a scale can be helpful in inpatient management of asthma, Schroeder et al. (6) found when comparing an asthma severity tool that yields a numerical score to an asthma severity tool that yields a category, numerical scores may be more useful in guiding patient management. Schroeder found a stronger correlation between the numerical asthma severity score and clinical assessment ($r = 0.80$; $p < .001$) as compared to categorization of asthma severity using a scale ($r = 0.57$; $p < .001$). These authors also showed that clinicians found the asthma severity numerical score more usable in the clinical setting as compared to categorization (3.68 vs. 3.38 respectively using a 5-point Likert scale). Categorization may limit the clinician's ability to trend scores. For example, categorization of "moderate" does not convey whether or not the asthma symptoms are trending toward less or more severe, however a series of actual scores would let the clinician know if the score is stable, improving, or getting worse, even if the score falls within the moderate severity categorization. For example, serial hourly HASS scores of 7, 9, 9, 9 indicate persistently concerning severity.

Categorization is also important to consider when conducting validation studies. A difference of one point can result in a different severity category and can influence the reported reliability of the tool. As shown in this study the HASS performed better as compared to the PRAM when the actual scores were analyzed, and not as well as the PRAM when the scores were categorized.

With regard to the HASS scores and %FEV₁, there was a small but not statistically significant correlation between these measures. Other studies show that asthma severity tools do not correlate with spirometry results (23–25). Studies have found that hospitalized children with asthma are unable to perform spirometry or cannot perform spirometry well enough to yield acceptable results (24,26).

A key component of providing care to the patient with asthma is the ability to assess and describe the severity of their illness at any point-in-time. While spirometry is used as an objective measure for asthma severity, it is not considered a practical tool for use during a child's hospitalization, which can range from several hours to several days. To achieve accurate measurements the patient must blow into the device, which can be difficult for a patient when they are experiencing an acute asthma exacerbation. Notably Smith et al. (27), while studying a sample of 46 children aged 5 to 17 years, declared that a measurement of airway obstruction (i.e. spirometry) cannot reliably serve as an asthma severity tool in the clinical setting. Scoring systems are based on physical exam findings and do not measure airway obstruction (27). As the clinical appearance of a child with asthma improves with treatment, the underlying obstruction may not normalize for several weeks. This delayed improvement of airway obstruction further explains why there is a lack of correlation between the HASS and spirometry in this study, and therefore spirometry should not serve as the basis for establishing validity of an asthma severity tool.

Limitations

During the course of the study, enrollment was confined to inpatient units, this along with improvements in the care of patients with asthma at the study site led to a decreased number of patients eligible for enrollment (3,4). This, along with the exclusion of children on continuous albuterol, advanced airway protective therapies, and/or a diagnosis of bacterial or viral lung infection, chronic lung disease, cardiac or kidney disease resulted in a small sample size for this

study. However, decreased variability of the study sample had the benefit of limiting the number of potential confounding variables.

Evaluation of subjects throughout the course of their illness or specific interventions in relation to asthma management was not undertaken. Routine use of the HASS at the study site could be perceived as a bias, however findings demonstrated acceptable intra-rater agreement when scoring both HASS and PRAM. Also, since patients could not be assessed with spirometry when experiencing severe asthma, such as those managed with continuous albuterol or advanced airway protective therapies, patients with more severe asthma exacerbations were not included in the study sample.

In this study, raters did not auscultate the lungs or obtain the respiratory rate at the same time, which could have resulted in lower inter-rater agreement. A cough or change in positions between raters could have impacted scores for the auscultation component. Also, it is possible that inconsistencies occurred when obtaining respiratory rates. Some raters may have counted respirations for 15 s and multiplied times four, while others may have counted respirations for a full minute. This variation in auscultation and respiration scores was not anticipated therefore obtaining measurement for these components was not standardized. Recommendations for future utilization of the HASS include a standardized measurement approach for obtaining auscultation and respiratory rate components. Lastly, the total number of spirometry tests and the number of unacceptable spirometry tests were also limiting factors in this study.

Conclusion

The focus of this study was to examine the validity of the HASS asthma severity tool at a single point-in-time. Findings demonstrate the intra-class correlation coefficient of the HASS was higher than the PRAM. Both the HASS and PRAM demonstrated acceptable inter-rater and intra-rater agreement. Validation of the HASS was limited by using spirometry as a comparison. Future validation efforts should be limited to comparisons with validated tools that are used for assessment of patient's physical exam findings.

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Declaration of interest

Inventor of the HASS, Dr. McBride, was a member of the study team. She did not participate in data collection, analysis, or interpretation of findings. Her role was to serve as an expert for review of the protocol prior to study implementation, and development of the manuscript, specifically characterizing the history of the HASS. The remaining authors have no disclosures to report related to this body of work.

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References

- Centers for Disease Control and Prevention, National Center for Environmental Health. Most recent national asthma data. Washington (DC): U.S. Department of Health and Human Services. Available from: https://www.cdc.gov/asthma/most_recent_national_asthma_data.htm [last accessed 1 November 2020].
- McBride S, McCarty K, Wong J. Development of a Pediatric Hospital Asthma Severity Scoring System [HASS]. (forthcoming).
- Wong J, Agus MS, Graham DA, Melendez E. A critical asthma standardized clinical and management plan reduces duration of critical asthma therapy. *Hosp Pediatr*. 2017;7(2):79–87. doi:10.1542/hpeds.2016-0087.
- Melendez E, Dwyer D, Donnelly D, Currier D, Nachreiner D, Miller DM, Hurlbut J, Pepin MJ, Agus MSD, Wong J. Standardized protocol is associated with a decrease in continuous albuterol use and length of stay in critical status asthmaticus. *Pediatr Crit Care Med*. 2020;21(5):451–460. doi:10.1097/PCC.0000000000002239.
- Chacko J, King C, Harkness D, Messahel S, Grice J, Roe J, Mullen N, Sinha I, Hawcutt D. Pediatric acute asthma scoring systems: a systematic review and survey of UK practice. *JACEP Open*. 2020;1(5):1000–1008. doi:10.1002/emp2.12083.
- Schroeder SK, Samady W, Kolaitis IN, Smith CM, Palac H, Shreffler L, Nevin MA. Comparison of two assessment tools for hospitalized subjects with asthma. *Respir Care*. 2020. doi:10.4187/respcare.07761.
- Eggink H, Brand P, Reimink R, Bekhof J. Clinical scores for dyspnoea severity in children: a prospective validation study. *PLoS One*. 2016;11(7):e0157724. doi:10.1371/journal.pone.0157724.
- Bekhof J, Reimink R, Brand PL. Systematic review: insufficient validation of clinical scores for the assessment of acute dyspnoea in wheezing children. *Paediatr Respir Rev*. 2014;15(1):98–112. doi:10.1016/j.prrv.2013.08.004.
- Chalut DS, Ducharme FM, Davis GM. The Preschool Respiratory Assessment Measure (PRAM): a responsive index of acute asthma severity. *J Pediatr*. 2000;137(6):762–768. doi:10.1067/mpd.2000.110121.
- Ducharme FM, Chalut D, Plotnick L, Savdie C, Kudirka D, Zhang X, Meng L, McGillivray D. The Pediatric Respiratory Assessment Measure: a valid clinical score for assessing acute asthma severity from toddlers to teenagers. *J Pediatr*. 2008;152(4):476–480.e1. doi:10.1016/j.jpeds.2007.08.034.
- Miller MR, Hankinson J, Brusasco V, Burgos F, Casaburi R, Coates A, Crapo R, Enright P, van der Grinten CP, Gustafsson P, et al. Standardisation of spirometry. *Eur Respir J*. 2005;26(2):319–338. doi:10.1183/09031936.05.00034805.
- Quanjer PH, Stanojevic S, Cole TJ, Baur X, Hall GL, Culver BH, Enright PL, Hankinson JL, Ip MS, Zheng J, et al. Multi-ethnic reference values for spirometry for the 3–95-yr age range: the global lung function 2012 equations. *Eur Respir J*. 2012;40(6):1324–1343. doi:10.1183/09031936.00080312.
- Pellegrino R, Viegi G, Brusasco V, Crapo RO, Burgos F, Casaburi R, Coates A, van der Grinten CP, Gustafsson P, Hankinson J, et al. Interpretative strategies for lung function tests. *Eur Respir J*. 2005;26(5):948–968. doi:10.1183/09031936.05.00035205.
- Zec S, Soriani N, Comoretto R, Baldi I. High agreement and high prevalence: the paradox of Cohen's Kappa. *Open Nurs J*. 2017;11:211–218. doi:10.2174/1874434601711010211.
- Feinstein AR, Cicchetti DV. High agreement but low kappa: I. The problems of two paradoxes. *J Clin Epidemiol*. 1990;43(6):543–549. doi:10.1016/0895-4356(90)90158-I.
- Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med*. 2016;15(2):155–163. doi:10.1016/j.jcm.2016.02.012.
- Johnson MD, Nkoy FL, Sheng X, Greene T, Stone BL, Garvin J. Direct concurrent comparison of multiple pediatric acute asthma scoring instruments. *J Asthma*. 2017;54(7):741–753. doi:10.1080/02770903.2016.1258081.
- Bekmezian A, Fee C, Weber E. Clinical pathway improves pediatric asthma management in the emergency department and reduces admissions. *J Asthma*. 2015;52(8):806–814. doi:10.3109/02770903.2015.1019086.
- Kaiser SV, Johnson MD, Walls TA, Teach SJ, Sampayo EM, Dudley NC, Zorc JJ. Pathways to improve pediatric asthma care: a multisite, national study of emergency department asthma pathway implementation. *J Pediatr*. 2020;223:100–107.e2. doi:10.1016/j.jpeds.2020.02.080.
- Boeschoten S, de Hoog M, Kneyber M, Merkus P, Boehmer A, Buysse C. Current practices in children with severe acute asthma across European PICUs: an ESPNIC survey. *Eur J Pediatr*. 2020;179(3):455–461. doi:10.1007/s00431-019-03502-9.
- Maekawa T, Oba MS, Katsunuma T, Ishiguro A, Ohya Y, Nakamura H. Modified pulmonary index score was sufficiently reliable to assess the severity of acute asthma

- exacerbations in children. *Allergol Int.* 2014;63(4): 603–607. doi:[10.2332/allergolint.13-OA-0681](https://doi.org/10.2332/allergolint.13-OA-0681).
22. Arnold DH, Saville BR, Wang W, Hartert TV. Performance of the Acute Asthma Intensity Research Score (AAIRS) for acute asthma research protocols. *Ann Allergy Asthma Immunol.* 2012;109(1):78–79. doi:[10.1016/j.anai.2012.05.007](https://doi.org/10.1016/j.anai.2012.05.007).
23. Tan CC, McDowell KM, Fenchel M, Szczesniak R, Kercsmar CM. Spirometry use in children hospitalized with asthma. *Pediatr Pulmonol.* 2014;49(5):451–457. doi:[10.1002/ppul.22854](https://doi.org/10.1002/ppul.22854).
24. Arnold DH, Gebretsadik T, Hartert TV. Spirometry and PRAM severity score changes during pediatric acute asthma exacerbation treatment in a pediatric emergency department. *J Asthma.* 2013;50(2):204–208. doi:[10.3109/02770903.2012.752503](https://doi.org/10.3109/02770903.2012.752503).
25. Schneider WV, Bulloch B, Wilkinson M, Garcia-Filion P, Keahey L, Hostetler M. Utility of portable spirometry in a pediatric emergency department in children with acute exacerbation of asthma. *J Asthma.* 2011;48(3): 248–252. doi:[10.3109/02770903.2011.555036](https://doi.org/10.3109/02770903.2011.555036).
26. Arnold DH, Johnson DP, Yang CL, Hartert TV. Forced expiratory values in 1 second corresponding to Pediatric Respiratory Assessment Measure and Acute Asthma Intensity Research Score values during pediatric acute asthma exacerbations. *Ann Allergy Asthma Immunol.* 2017;119(6):561–562. doi:[10.1016/j.anai.2017.09.003](https://doi.org/10.1016/j.anai.2017.09.003).
27. Smith SR, Baty JD, Hodge D 3rd. Validation of the pulmonary score: an asthma severity score for children. *Acad Emerg Med.* 2002;9(2):99–104. doi:[10.1111/j.1553-2712.2002.tb00223.x](https://doi.org/10.1111/j.1553-2712.2002.tb00223.x).