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LA phonospirometry technique compared to pediatric respiratory assessment measure and peak expiratory flow measurement as a novel technique to assess the severity of an asthma exacerbation

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ABSTRACT

Objective: Asthma is a common chronic disease treated in emergency departments. The measurements of Peak Expiratory Flow (PEF) and Pediatric Respiratory Assessment Measure (PRAM) scores have been recommended as objective techniques in the assessment of acute asthma exacerbations, but have multiple barriers limiting their use. The Los Angeles phonospirometry technique is an easier, trans-cultural technique. The technique assesses dyspnea by measuring how many seconds a child is able to chant "LA LA LA" in a single breath. The objective of this study is to determine the correlation of this technique with PEF measurements and PRAM scores in children with acute asthma exacerbations, both before and after nebulized bronchodilator treatment. **Methods:** A convenient sample of children aged 5–17 years being treated for asthma in the ED was enrolled. Phonospirometry, PRAM, and PEF measurements were obtained through pre and post inhaled bronchodilator treatments. The highest values from each measurement were correlated using Spearman's correlation coefficient. **Results:** A total of 91 children were enrolled. The correlations at pre-treatment, after first, second, and third treatments between phonospirometry and PEF were 0.38 ($p < 0.001$), 0.60 ($p < 0.001$), 0.54 ($p < 0.001$), 0.52 ($p < 0.01$), respectively; between phonospirometry and PRAM were -0.37 ($p < 0.001$), -0.42 ($p < 0.001$), -0.26 ($p < 0.05$), and -0.06 ($p > 0.05$), respectively; and between PEF and PRAM were -0.6 ($p < 0.01$), -0.54 ($p < 0.001$), -0.38 ($p < 0.01$), and -0.36 ($p = 0.05$), respectively. **Conclusions:** This novel technique correlates mild to moderately with PEF, and shows promising aide in the assessment of children with acute asthma exacerbations.

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Introduction

Asthma is a common chronic disease characterized by intermittent, acute exacerbations in both adults and children. Peak Expiratory Flow (PEF) may be used in adults and children and Pediatric Respiratory Assessment Measure (PRAM) may be used in children to assess the severity of an acute asthma exacerbation. Peak flow meters are portable and inexpensive, and yield reproducible results. However, measurement is effort dependent and requires an age appropriate patient who is able to blow forcefully and effectively into a mouthpiece. Even in children 8 years old and older, the usual age range for whom this is recommended, PEF measurement is frequently unreliable [1]. In addition, a peak flow meter may not be readily available when an exacerbation occurs [2]. A

PRAM score is useful to assess the severity of an asthma exacerbation in the clinical setting, but requires the skill of a medical provider to auscultate the patient's lungs and assess for the presence or absence of retractions. This score also requires the use of a pulse oximeter. It is necessary to develop a technique to assess the severity of an asthma exacerbation that is easier, transcultural, does not depend on a device or medical provider, and can easily be done by a parent at home.

Several studies have looked at breathlessness and dyspnea as clinical correlates of a low PEF and respiratory distress. Roofe et al. attempted to assess a single breath counting (SBC) technique in the evaluation of children with acute asthma exacerbations and correlate it with percent predicted FEV1 and

PRAM scores. They concluded that this technique has limited validity as a measure of acute asthma severity [3]. Other studies have found contrary results. Ali et al. looked at this SBC technique in a pulmonary clinic and correlated it with the child's PEF, FEV1, FVC, forced expiratory flow 25–75%, and FEV1/FVC. They concluded that SBC correlates well with these standard measures of pulmonary function [4]. Wang et al. assessed a novel technique, the Los Angeles phonospirometry technique, in a pilot study on patients with asthma in the ED [5]. This technique simply required the child to chant “LA LA LA” for as long as they were able to in a single breath. This technique did not depend on counting ability and is trans-cultural. The study found good correlation when comparing this phonospirometry technique to PEF in children suffering from acute asthma exacerbations in the ED. A subsequent study by Ochoa et al. enrolled over 500 children to develop a normogram for this LA phonospirometry technique based on both age and height. A normogram is necessary to be able to report values as percent ideal, as is routinely done for PEF measurements. This study also demonstrated that this technique has good correlation with PEF in healthy individuals with a spearman's rho of 0.722 [6]. It is now necessary to assess this LA phonospirometry technique, recorded as percent of predicted ideal, in a larger study on patients with symptomatic asthma, and correlate it with PEF and PRAM, both routinely used and validated measures of asthma severity in children.

Methods

A convenience sample of patients' ages 5–17 years old presenting to a busy urban pediatric emergency department from December 2014 through May 2015 with the chief complaint of asthma exacerbation were approached for enrollment and given an information sheet on the study. To be enrolled in the study, patients had to be treated for an acute asthma exacerbation requiring at least one nebulized bronchodilator treatment. Children were excluded if they had any other chronic diagnosis known to have cardio-pulmonary manifestations, such as congenital heart disease or pulmonary hypertension, or if they had developmental delay. They were also excluded if they could not reliably perform any of the measurements, for example laughing too hard or obviously not trying. Their height, age, and gender were recorded. The children's weights were recorded using

a portable scale, and their heights were recorded using a portable tape measure. Measurements of PEF, PRAM, and phonospirometry were obtained prior to treatment with inhaled medication when possible. PEF and phonospirometry measurements were obtained by K. O., J. R., and trained research assistants in the ED. To reduce bias, the PRAM score was assessed at the same time as the other measurements were obtained, either by the registered nurse or respiratory therapist who were not involved in the study, and had previous training on the use of PRAM scoring. All three measurements were obtained after the patient's 1st, and when applicable, 2nd and 3rd bronchodilator treatments. The standard PEF measurements were made using a peak flow meter with disposable mouthpiece attachments (Mini-Wright, Clement Clark, Harlow, England). Since this is a learned technique, the study participants were given three attempts to achieve their maximum peak flow value. The study was approved by the hospital's institutional review board and was open to all children in the ED who met the inclusion criteria.

LA phonospirometry technique

The LA phonospirometry technique is a simple measurement. Subjects were asked to repeat the syllable “LA” (pronounced “lah”) continuously with a single breath. The subject was instructed to take as large a breath as possible, and then say “LA LA LA” until he or she needed to take a new breath, which was the end of the measurement. One of the investigators or research assistants initially demonstrated the technique, which had a time meter of approximately 180 syllables per minute, although minimally varying time meters were accepted. The length of time the subject was able to repeat “LA” was measured in seconds, usually using a smart phone, stopwatch, or other timing device that was able to measure seconds. This technique is a learned technique, so the subject was given three attempts to achieve their longest measurement.

Statistics

Sample size calculation was based on a previously reported Spearman's correlation of approximately 0.70 between PEF and phonospirometry obtained in healthy children [6]. A base calculation under the model of 80% power for a Pearson's correlation of 0.70 indicated that 13 children be enrolled per

Table 1. Spearman's correlations.

Phase	Spearman's correlations		
	Phono and PEF	Phono and PRAM	PEF and PRAM
Pre-treatment	0.38 [†] (N=76) CI: 0.17, 0.56	-0.37 [†] (N=74) CI: -0.16, -0.55	-0.60 [‡] (N=74) CI: -0.43, -0.73
After 1st treatment	0.60 [†] (N=84) CI: 0.44, 0.72	-0.42 [†] (N=83) CI: -0.23, -0.58	-0.54 [†] (N=84) CI: -0.37, -0.68
After 2nd treatment	0.54 [†] (N=60) CI: 0.33, 0.70	-0.26* (N=59) CI: -0.01, -0.48	-0.38 [‡] (N=60) CI: -0.14, -0.58
After 3rd treatment	0.52 [‡] (N=27) CI: 0.18, 0.75	-0.06 (N=27) CI: -0.43, 0.33	-0.36 (N=27) CI: -0.65, 0.02

CI: 95% confidence interval; Phono: phonospirometry measurement; PEF: peak expiratory flow measurement; PRAM: pediatric respiratory assessment measure.

[†]Statistically significant at $p \leq 0.001$.

[‡]Statistically significant at $p \leq 0.01$.

*Statistically significant at $p \leq 0.05$.

subgroup of the current study. However, since the current study required Spearman's correlation, which is a less powerful statistical test than Pearson's correlation, the sample size was set to 20 per subgroup to compensate statistical power.

Spearman's rho was used to determine the correlations between the patient's phonospirometry value and their PEF measurement and PRAM score. The patient's percent predicted ideal was calculated by using the patient's height in the regression equation from our previous study's normogram. The correlation between the patient's phonospirometry and percent predicted PEF was also determined using Spearman's rho.

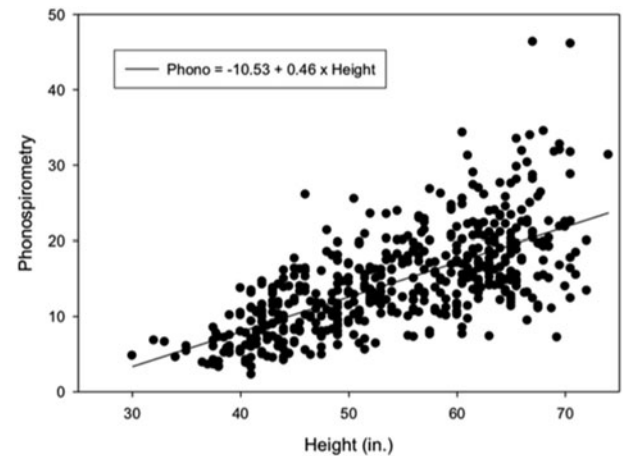
Wilcoxon test was used to examine the difference between median values of PRAM, PEF, and phonospirometry measurements before treatment and after the last treatment given.

Results

A total of 91 children were enrolled, of which 88% were 12 years and younger and 69% were 9 years and younger (mean = 8.73, SD = 2.87, median = 8). Seventy-six children were able to be enrolled pre-treatment, 86 had measurement obtained after one treatment, 61 after two treatments, and 27 after three treatments.

Spearman's correlation between phonospirometry, PEF, and PRAM pretreatment, after 1st treatment, after 2nd treatment, and after 3rd treatment are illustrated in Table 1.

PEF is typically reported as percent ideal, so correlations of the percent of ideal were also calculated. This could only be done for PEF and phonospirometry. The ideal (predicted) phonospirometry value was obtained using the child's height based on a previous normogram developed for the phonospirometry technique [6]. The percent ideal (predicted) PEF value was also calculated based on this same study. The normogram for phonospirometry is shown in Figure 1. The correlations between

**Figure 1.** Normogram for phonospirometry (in seconds) based on height.**Table 2.** Spearman correlation values for principal investigator, K. O.

Phase (N)	Spearman's correlations		
	Phono and PEF	Phono and PRAM	PEF and PRAM
Pre-treatment (N=14)	0.72 [‡]	-0.43	-0.52
After 1st treatment (N=13)	0.81 [†]	-0.46	-0.47
After 2nd treatment (N=8)	0.91 [‡]	-0.63	-0.59

Phono: phonospirometry measurement; PEF: peak expiratory flow measurement; PRAM: pediatric respiratory assessment measure.

[†]Statistically significant at $p \leq 0.001$.

[‡]Statistically significant at $p \leq 0.01$.

percent ideal PEF and percent ideal phonospirometry before treatment, after 1st treatment, after 2nd treatment, and after 3rd treatment were 0.41 ($p < 0.001$, $N=74$), 0.49 ($p < 0.001$, $N=81$), 0.52 ($p < 0.001$, $N=60$), and 0.20 ($p=0.31$, $N=27$), respectively.

Since the correlation values were not as high as expected based on the previous studies, subanalyses of the dataset, splitting it by research assistant, gender, and age, were performed. Measurements by K. O., principal investigator, can be viewed in Table 2. Correlations after the 3rd treatment are not reported

Table 3. Spearman correlations for age under 8 years.

Age under 8 year phase	Correlation of Phono to PEF	Correlation of Phono to PRAM	Correlation of PEF to PRAM
Pre-treatment	0.63 [†] (N = 26)	−0.61 [†] (N = 25)	−0.74 [†] (N = 25)
After 1st treatment	0.66 [†] (N = 29)	−0.64 [†] (N = 29)	−0.75 [†] (N = 29)
After 2nd treatment	0.65 [‡] (N = 18)	−0.73 [†] (N = 17)	−0.38 (N = 17)
After 3rd treatment	0.87 [‡] (N = 7)	−0.88 [‡] (N = 7)	−0.74 (N = 7)

Phono: phonospirometry measurement; PEF: peak expiratory flow measurement; PRAM: pediatric respiratory assessment measure.

[†]Statistically significant at $p \leq 0.001$.

[‡]Statistically significant at $p \leq 0.01$.

Table 4. Spearman correlations for age 8 years and older.

Age 8 year and older phase	Correlation of Phono to PEF	Correlation of Phono to PRAM	Correlation of PEF to PRAM
Pre-treatment	0.16 (N = 50)	−0.27 (N = 49)	−0.56 [†] (N = 49)
After 1st treatment	0.37 [‡] (N = 55)	−0.25 (N = 54)	−0.44 [†] (N = 55)
After 2nd treatment	0.38 [*] (N = 42)	0.06 (N = 42)	−0.24 (N = 43)
After 3rd treatment	0.32 (N = 20)	0.36 (N = 20)	−0.09 (N = 20)

Phono: phonospirometry measurement; PEF: peak expiratory flow measurement; PRAM: pediatric respiratory assessment measure.

[†]Statistically significant at $p \leq 0.001$.

[‡]Statistically significant at $p \leq 0.01$.

^{*}Statistically significant at $p \leq 0.05$.

Table 5. Wilcoxon test results comparing median values.

	Median		p value
	Pre-treatment	After last treatment given	
Phonospirometry (N = 76)	7.75	9.90	<0.001
Pediatric respiratory assessment measure (N = 76)	4	2	<0.001
Peak expiratory flow measurement (N = 76)	100	153	<0.001

in the following table, as not enough patients were enrolled after a 3rd treatment by KO.

The correlations were split by age under 8 years old and 8 years old and over, as this is the typical cutoff age for use of PEF. These values can be viewed in Tables 3 and 4.

We also split the data to analyze correlations based on gender. There were no differences in correlation between males and females.

We also looked at the change in values of PRAM, PEF, and phonospirometry measurements pre-treatment to after last treatment was given. All three had significant changes in the direction expected according to the Wilcoxon test based on median values (Table 5).

Discussion

The overall correlations of phonospirometry to PEF and PRAM scores were mild to moderate, and slightly less than the correlation values obtained in previous studies on this technique. The correlations of percent predicted values were similar to the correlations of the raw values. When splitting that data by researcher, data obtained by K. O. had higher correlations than the data obtained by the research assistants, and was

comparable with results from previous studies. Similar to PEF, the LA phonospirometry technique is effort dependent, often requiring coaching and encouragement of the participants to obtain their full potential measurements. The effort-dependent nature of the measurements likely contributed to the differences seen in the PI data as compared with the other data. Interestingly, there was a difference in the correlation values obtained in the younger children as compared with the older participants, with correlations being stronger in the younger age group. Many of the correlation values obtained in the older kids were not statistically significant, meaning the data were much more scattered. The reason that the data were more spread for older children, and correlated better in the younger children may be due to variations in effort as well. If a participant did not chant “LA LA LA” to their full potential, his/her data point would be much lower than others of the same age with maximal effort. This would cause a large variation in the data, and result in less significant and lower correlation values. Anecdotally, teenagers were often more difficult to encourage to reach their full phonospirometry potential than younger children, who could be motivated simply by giving them a sticker or cracker. Gender did not influence correlation values.

The Los Angeles Phonospirometry technique is easy, quick, does not rely on trained personnel or special equipment, and can be done in younger children. Since it had mild to moderate correlation with PEF and PRAM, which are currently used to evaluate asthma exacerbations, this could be considered as an alternative to evaluate the extent of a child’s asthma exacerbation when PEF and PRAM are not able to be

performed. Specifically, the data correlated better in younger children than older children. Younger children are often more difficult to evaluate using the PEF meter, so in this age group, perhaps the Los Angeles Phonospirometry Technique could be of use.

Limitations

As mentioned previously, there may be variation in the level of encouragement and enthusiasm displayed by the enrolling investigator, and, therefore, subject effort may have varied. In an effort to minimize differences due to investigator variation, all research assistants were trained and observed before enrolling subjects independently. However, quietness or shyness of the research assistant may have played a role in the final results. The overall correlations with PRAM were less. The PRAM score has some inherent limitations in this correlational study. The range in the PRAM score 0–12 is smaller than the numerical range of phonospirometry and PEF. The difference between a PRAM score of 5 and 8 is clinically more significant than a comparable change of 3 s in phonospirometry or a comparable peak flow difference. The inherent subjectivity of the PRAM score is also a limitation in its use. The PRAM score is also dependent on the RNs' and RTs' clinical auscultation skills. While not calculated, a confounder may be a low kappa agreement between the nurses and respiratory therapists. Also, although the nursing staff was educated on the PRAM scoring system, and PRAM had been established as a standard measure in our emergency department prior to this study, many nurses were unfamiliar with the score, such as what scalene muscle contraction meant. There are also a reasonably large number of “traveler” nurses from other institutions who care for children in our Emergency Department. If this single component of the PRAM score was not interpreted correctly, this accounts for 16% of the total score, which has the potential to change our results.

Future direction

Future studies on this technique may focus on the ability to use phonospirometry as a triage tool to assess the severity of an initial asthma exacerbation, as well as assess the improvement of the patient after treatment, and ultimately help to determine management and disposition. Phonospirometry can also be evaluated in the pre-hospital setting to help a caregiver decide how severe their child's asthma exacerbation is and what treatment is needed, similar to the expected home use of a PEF meter.

Conclusions

Phonospirometry had mild to moderate correlation with PEF and PRAM in patients presenting to the ED with symptomatic asthma, and can possibly be used as a substitute for these measurements if PEF or PRAM are not feasible to use. Future studies for the utility of this measurement at home or in triage may be a useful application of the technique.

Disclosure statement

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

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