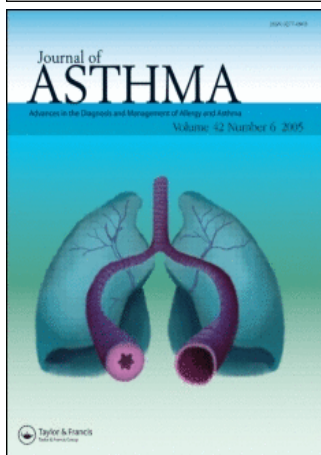


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Wheeze Detection: Recordings vs. Assessment of Physician and Parent

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ORIGINAL ARTICLE

Wheeze Detection: Recordings vs. Assessment of Physician and Parent

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ABSTRACT

Background. Parental and professional agreement as to the presence of wheezing in infants and preschool children has been shown to be poor. Agreement on the absence or presence of physical signs on chest examination in these populations is far from perfect, even among experienced physicians. *Objectives.* We sought to compare the assessment of a parent, nurse, and physician with the “gold standard” of acoustic analysis for the presence of wheezing in infants and preschool children attending a hospital clinic. *Setting and Subjects.* Urban district general hospital in North London, England. Wheezy children under 6 years old attending a “walk-in” emergency pediatric ambulatory care unit. *Results.* Comparisons were completed on 31 children (age range 4–62 months). The severity of wheeze was independently evaluated by a parent, nurse, and experienced pediatrician, and these were compared with breath sounds recorded and analyzed by acoustic techniques for the presence and severity of wheezing. In only 10 of 31 (32%) children did the parent and the physician agree on the wheeze severity score. In 13 infants, the parent scored higher than the doctor and in 8 the parent scored lower. In 16 (52%) of the children, there was complete agreement as to the severity of wheezing by the nurse and the physician. In 24 of the 31 children (77%), the acoustic wheeze score agreed with the physician wheeze score;

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#C.S. Irving was an employee of and Professor S. Godfrey was a paid medical adviser for Karmel Medical Acoustic Technologies at the time the study was undertaken.

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in 6 children the acoustic score was lower and in 1 it was higher. *Conclusions.* The physician was able reliably to judge the severity of wheeze measured objectively, whereas nurses and parents were not. This study has important implications for the interpretation of parental questionnaire studies of asthma prevalence and severity.

Key Words: Childhood asthma; Pre-school; Wheeze; Recording; Acoustic.

INTRODUCTION

The wheezy infant presents one of the commonest and greatest diagnostic and management problems in pediatrics. In a prospective cohort study from the United States, Martinez et al. (1) found that approximately 20% of all infants had transient wheezing before 3 years of age, another 14% of infants had continued to wheeze until 6 years of age, and some 15% had begun to wheeze after the age of 3. Similarly, Young et al. (2) reported an incidence of wheezing of 50% in Australian infants in the first 2 years of life. A large Italian survey, however found an approximately 17% lower incidence of wheezing in children aged 6–7 years (3). Prospective studies of populations of children with a history of wheezing during the first three years of life, and those with a history of viral bronchiolitis in early infancy reveal that some 30–40% will continue to wheeze over the next two to four years (1,3–6).

These studies, like many others conducted in older children, rely on parental reporting of the symptom of wheeze in children to estimate symptom prevalence. Keeley and Silverman (7) noted some of the possible biases inherent in epidemiological studies that rely on data obtained by using nonobjective measures that may show poor validity and reliability. This issue has recently been investigated by Cane et al. (8) who undertook a study to determine what the parents of “wheezy children” understood by the term “wheeze.” In a group of predominantly preschool children (median age 2.5 years), agreement between the parents and the physician as to the presence of wheezing or asthma was only 45%. This finding reflects the problem that there are a variety of abnormal sounds that are generated by the airways at different levels, and agreement on the presence of physical signs in the chest is thus far from perfect, even among experienced physicians (9,10).

Recent understanding of the acoustic analysis of breath sounds and the detection of wheezing from the observation of computer-generated images provides objective evaluation of abnormal breath sounds both in the nature of the sound and its intensity. This study was undertaken to compare the opinions of a parent, nurse, and physician with acoustic analysis of wheezing in wheezy infants and preschool children attending a hospital clinic.

METHODS

Subjects

We obtained ethical approval from the institutional ethics committee at Northwick Park Hospital, Harrow. The study was undertaken during late 2000 on wheezy infants and preschool children (termed “children” hereafter for simplicity) attending a “walk-in emergency” clinic at Northwick Park Hospital, London. Most had already been treated with an inhaled bronchodilator by their parents or general practitioner before arriving at the clinic. The children were referred to the clinic by their family practitioner who considered that further evaluation and treatment were indicated. The criteria for inclusion in the study were 1) that the child was under 6 years old; 2) the parents and the receiving nurse believed that the child was currently wheezing; 3) the child was not suffering from an acute severe attack of asthma requiring immediately necessary treatment; and 4) the parent(s) gave informed consent for the child to participate.

After enrollment into the study, parents completed a questionnaire concerning the history of the present illness and any previous respiratory problems. The child and a parent (in most cases, the mother) were taken to a quiet room where the sensors of the acoustic monitor (PulmoTrack[®]1010; Karmel Medical Acoustic Technologies, Yokneam Ilit, Israel) were attached to the chest. One sensor was placed over the right upper chest anteriorly to record breath sounds, and one was placed into each axilla to record respiration by impedance. A pulse oximeter was placed on a finger to record oxygen saturation and heart rate. The acoustic monitor was started and recorded continuously until the completion of all evaluations of the child. Acoustic analysis of data was not displayed in real time apart from the respiratory rate. Once the equipment was attached and functional, and the child was breathing regularly, the parent was asked to grade the intensity of the wheeze and of any respiratory distress each on a scale of 0–3 recording the answers on a piloted data-recording chart. The clinic nurse then also recorded her grading of wheeze by using a stethoscope to auscultate the chest and evaluated extent of the distress of the child by direct observation using scales of 0–3 on another chart; clinic

Table 1. Scores used for respiratory and heart rate and oxygen saturation.

Age (years)	Score=0 (normal)	Score=1 (mildly abnormal)	Score=2 (moderately abnormal)	Score=3 (markedly abnormal)
<i>Respiratory rate</i>				
<1	<35	35–44	45–54	≥55
1–3	<25	25–34	35–44	≥45
3–6	<20	20–24	25–34	≥35
<i>Heart rate</i>				
<1	<140	140–159	160–179	≥180
1–3	<120	120–134	135–159	≥160
3–6	<100	100–109	110–129	≥130
<i>Oxygen saturation</i>				
All ages	≥95%	92–94%	90–92%	<90%

nurses did not have access to the parental grades. Seven different nurses, currently working in the unit, were involved in this study.

A staff pediatrician (WH), a specialist in ambulatory paediatrics with 10 years' experience (but not a specialist in pediatric pulmonology), then examined the child and in a few instances supervised the examination by other nonspecialist doctors working in the pediatric department. The doctor recorded the grades on a third chart without reference to either the opinion of the parent or the nurse. Finally, a composite severity score was recorded in the chart based on the sum of the wheeze and distress scores of the physician together with scores for respiratory rate, heart rate, and oxygen saturation (Table 1).

Because of the variation in age of the children and, therefore, the variation in the significance of respiratory rates and heart rates, a table was prepared on the basis of deviations from age-adjusted normal values from which to score the changes in respiratory rate and heart rate. A similar score was used for saturation so that the maximum total score was 15.

After completion of the study, data were downloaded from the acoustic monitor onto compact discs for manual analysis by technicians trained in the interpretation of acoustic data who were totally blinded as to the opinions of the parent, nurse, and physician. The technicians analyzed the record obtained during the period in which the physician was examining the child, and the first 20 complete breaths for which there were technically acceptable data were used to calculate the severity of wheezing. The record was scanned for the presence of abnormal continuous adventitious sounds defined in accordance with the European Task Force report on computerized breath sounds (11–13) as musical monophonic or polyphonic sounds with a duration of at least 100 msec. These sounds were classified as "asthmatic wheeze" if they fell in the frequency range

of 200–800 Hz, provided they were expiratory polyphonic or monophonic or inspiratory polyphonic in character. The phase of respiration was determined by the changes in chest impedance recorded from the sensors placed in the axillae. All other continuous adventitious sounds (CAS) outside this range were not considered to be asthmatic wheeze. The wheeze rate ($Twz/Ttot$) was calculated for the total period of observation where Twz was the sum of the duration of wheeze in all the breaths and $Ttot$ was the total duration of the 20 breaths. In addition, for the purposes of comparison analogous to the other scoring systems, the acoustic wheeze rate was also classified arbitrarily into four grades of severity: score 0=no wheeze; score 1= $Twz/Ttot \leq 10\%$; score 2= $Twz/Ttot > 10\%$ but $< 50\%$; score 3= $Twz/Ttot \geq 50\%$.

Analysis and Statistical Methods

The results of the studies were entered into a computer database, and comparisons were made between the scores of the parent, the physician, and those derived from the acoustic analysis of the data. Multiple linear regression was performed separately with the acoustic wheeze rate and the acoustic wheeze score as dependent variables and physician wheeze score, physician distress score, respiratory rate, heart rate, and oxygen saturation independent variables.

RESULTS

Studies were completed on 31 children aged 4 months to 5 years and 2 months (mean age 2 years 3 months). Another 7 children were initially recruited for the study, but 1 was excluded because she was too old (8 years), and in 6 the acoustic data were unsuitable for analysis because the sensor had not been placed

Table 2. Individual scores for observed wheeze (Wz), observed respiratory distress (Dst), composite severity score (physician Wz+physician Dst+respiratory ratescore+saturation score+heart rate score), and acoustic wheeze rate (Twz/Ttot).

No.	Parent		Nurse		Physician		Composite score	TWz/Ttot
	Wz	Dst	Wz	Dst	Wz	Dst		%
1	1	2	2	1	1	0	3	0
2	1	2	2	2	2	2	9	26.8
3	1	1	2	1	2	2	8	5.34
4	2	1	2	2	0	1	2	0
5	2	2	2	2	2	2	10	23.3
6	1	2	3	2	2	1	6	33.5
7	1	2	1	2	1	1	5	4.3
8	1	1	0	0	0	0	6	0
9	2	2	1	0	2	1	9	16.4
10	1	1	0	1	1	1	7	0
11	1	1	0	0	2	2	8	5.9
12	1	2	1	1	2	2	8	30.8
13	1	1	1	0	2	2	7	3.3
14	2	1	1	2	1	1	4	4.3
15	2	3	1	1	1	1	4	7.9
16	3	3	2	2	2	2	11	18
17	1	1	1	1	0	1	4	0
18	1	1	0	0	0	0	5	0
19	1	2	3	3	3	1	8	29.3
20	2	3	3	3	2	2	9	16
21	2	3	2	2	2	2	10	39.4
22	3	3	2	0	2	2	10	48.7
23	2	3	2	2	1	1	6	3.6
24	2	2	3	2	2	2	9	15.8
25	2	3	3	2	1	2	8	42
26	1	1	2	2	2	2	10	31.2
27	2	2	2	2	1	2	9	1.7
28	1	1	1	1	1	2	7	4.1
29	2	2	2	1	2	1	6	39.8
30	2	2	1	1	1	2	9	4.9
31	2	1	0	1	1	1	5	5.3

correctly. No child refused to allow the measurements to be made.

Individual results for the parental, nurse, physician, and composite severity scores and the acoustic analysis are given in Table 2. Of the total of 31 children 4 were considered by the physician to have no wheeze (score 0), 11 mild wheeze (score 1), 15 moderate wheeze (score 2), and 1 severe wheeze (score 3). In terms of the composite severity score (maximum=15), 5 children scored 4 or less, 21 scored 5–9, and 5 scored 10–11.

Opinion of Parent Compared with Physician

The severity of wheezing reported by the parent varied between 1 and 3, and unlike the physician, none of the children were considered by the parent to be free of wheeze at the time of examination. The relation

between the wheeze scores of the parent and the physician are shown in Fig. 1. There was a wide scatter of the data, and the correlation between the scores was not significant (Table 3). In only 10 of the 31 children (32%), the parent and the physician agreed on the wheeze severity score. In 13 infants, the parent scored higher than the doctor, and in 8 the parent scored lower. The same applied to the comparison of the severity of respiratory distress recorded by the parent and the physician and the composite severity score (Table 3).

Opinion of Nurse Compared with Physician

The agreement as to the severity of wheezing between the nurse and the doctor was better than that between the parent and the doctor, and the correlation between the scores was significant (Table 3).

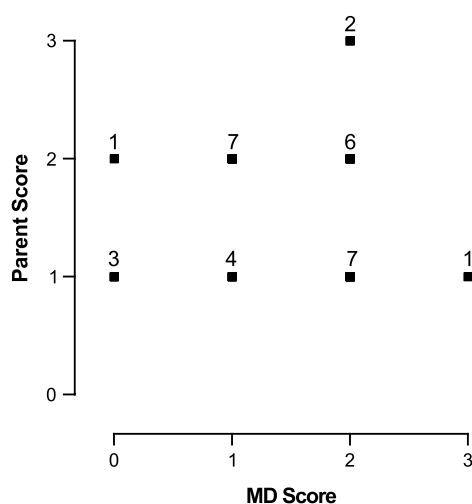


Figure 1. Wheeze score of parents compared with wheeze score of physician. The numbers above the points indicate the number of points falling on the same place on the plot.

In 16 (52%) of the children, there was complete agreement as to the severity of wheezing by the nurse and the physician. Correlation between the nurse and the physician as to the severity of respiratory distress was not significant, and neither was the correlation between the severity of wheezing recorded by the nurse and the composite severity score (Table 3).

Acoustic Analysis of Wheezing Compared with Physician

The severity of wheezing measured acoustically (Twz/Ttot) varied from 0 to 48.7%, with a mean of 14.9%. In 6 children no wheeze was detected acoustically, in 11 mild wheezing was recorded (Twz/Ttot 1–10%), and in 14 moderate wheeze was recorded (Twz/Ttot >10%). The relation between the acoustic wheeze rate and the wheeze score of the

physician is shown in Fig. 2A and the relation between the acoustic wheeze score and the wheeze score of the physician is shown in Fig. 2B. In both cases, the correlation was highly significant (Table 3) with considerably less scatter ($r=0.83$; $p<0.0001$) when the scores were compared (Fig. 2B). In 24 of the 31 children (77%) the acoustic wheeze score agreed with the physician wheeze score, in 6 children the acoustic score was lower, and in 1 it was higher. There was also a significant correlation between both the acoustic wheeze rate and the acoustic score with and the composite severity score (Fig. 3A and B; Table 3). It is of interest that if heart rate was omitted from the composite severity score, then the correlation between the acoustic score and the amended total score was even greater ($r=0.80$; $p<0.001$). In the multiple regression analysis, acoustic wheeze rate and the acoustic wheeze score were taken as dependent variables and physician wheeze score, physician distress score, respiratory rate, heart rate, and oxygen saturation as independent variables. The adjusted R^2 values with all the variables showed that 43% of the variability of wheeze rate and 69% of wheeze score were accounted for by the independent variables. However, in both cases once the physician wheeze score was added to the regression, none of the other variables contributed significantly. The regression accounted for 71% of the variability if the heart rate was omitted as a variable.

DISCUSSION

We have shown that wheezing in infants and preschool children graded by an experienced pediatrician agrees closely, but not completely, with the independent objective evaluation of wheeze by acoustic analysis of the breath sounds. The acoustic analysis also agreed with the overall severity score, which included the evaluation of distress, respiratory rate, heart rate, and oxygen saturation. In contrast, the

Table 3. Correlations.

	r	p
Parent wheeze score vs. MD wheeze score	0.10	0.585
Parent distress score vs. MD distress score	0.25	0.156
Parent wheeze score vs. Total severity score	0.30	0.099
Nurse wheeze score vs. MD wheeze score	0.49	0.005
Nurse distress score vs. MD distress score	0.25	0.178
Nurse wheeze score vs. Total severity score	0.32	0.083
Acoustic wheeze rate (Twz/Ttot) vs. MD wheeze score	0.64	<0.0001
Acoustic wheeze score vs. MD wheeze score	0.83	<0.0001
Acoustic wheeze rate (Twz/Ttot) vs. Total severity score	0.54	0.002
Acoustic wheeze score vs. Total severity score	0.71	<0.0001

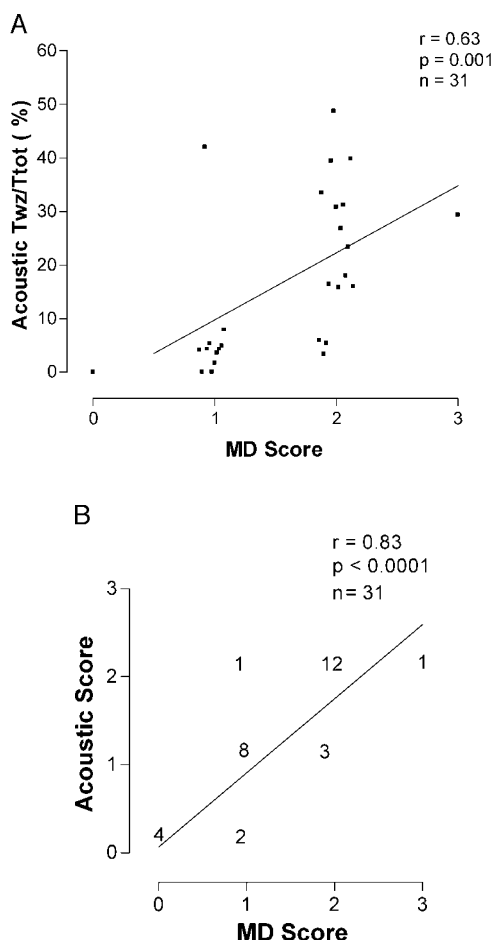


Figure 2. (A) Acoustic wheeze rate (Twz/Ttot) and (B) acoustic wheeze score compared with physician wheeze score. To improve clarity due to overlapping data points in (A), if displayed vertically, the data points have been slightly offset. The numbers above the points in (B) indicate the number of points falling on the same place on the plot. The solid lines are the regression lines.

evaluation by the parent agreed with that of the physician in only a minority of patients, and the evaluation by a nurse agreed with that of the physician in only half the children. This study was conducted in relatively well children (only requiring nebulized bronchodilator and oral steroid), and the agreement between our clinical severity score and acoustic analysis may not apply to more critically ill children. It is also possible that the relationship may be different in chronic wheeze, and further studies are needed to address this point.

Acoustic analysis is equivalent to an intelligent stethoscope, which records information very precisely, but has the same limitations as the stethoscope if used as the sole tool for assessing the child. A weakness of

this study is that we do not have recordings from normal infants, to exclude the possibility that acoustic analysis is oversensitive and that some noises recorded are of no clinical consequence. We consider this very unlikely, and in any case the conclusions about the poor agreement between physician and parent diagnosed wheeze are still valid. We quantified wheeze by the Tw/Ttot index, which is the fraction of the breath sound occupied by wheezing and does not necessarily reflect the loudness of the wheeze. We know of no studies that have assessed the relative contributions of duration and loudness of wheeze to the physician assessment of "clinical wheeze severity." In addition, we acknowledge that wheeze intensity, or its change with treatment, is only one factor to be taken into account when assessing the child. Indeed, disappearance of wheeze could mean recovery of the child or reflect that due to deterioration of disease, respiratory flow rates and tidal volumes have fallen too low to generate an audible wheeze, and urgent intervention is required. Other factors that the pediatrician would routinely consider include work of breathing, pulse rate, and levels of exhaustion, which acoustic analysis could not be expected to quantify. However, we do believe these results could have implications for the common hospital practice of nurse triage, as well as for questionnaire-based epidemiological studies where parents are asked to assess their child's wheezing and respiratory distress. Separate comparisons between acoustic analysis and the opinions of the parent or nurse were not undertaken, but it is extremely unlikely that they would have been better than the agreement with the physician. The children were examined over a relatively short period of time—some 10–15 minutes—and were thought to be in a stable state so that it is unlikely that variability in their condition accounted significantly to the poor correlation between the parent and nurse compared with the physician. The poor evaluation of wheeze severity by parents in comparison with the physician is not unexpected. Cane et al. (8) recently found less than 50% agreement between parents' and physicians' reports of wheeze and asthma, and in a subsequent study in which they showed parents video clips, only 59% correctly recognized wheezing (14). Even when parents were trained to recognize wheezing, Lee et al. (15) found that although obvious wheeze was recognized by parents, when the wheeze was faint, it was only noted in 68% of observations. No distinction was made between first time wheezers or recurrent wheezers or whether asthma had ever been diagnosed, because the objective of the study related to the evaluation of the severity of wheezing. We considered the possibility that more experienced parents may have performed better in comparison with the physician and looked at the data

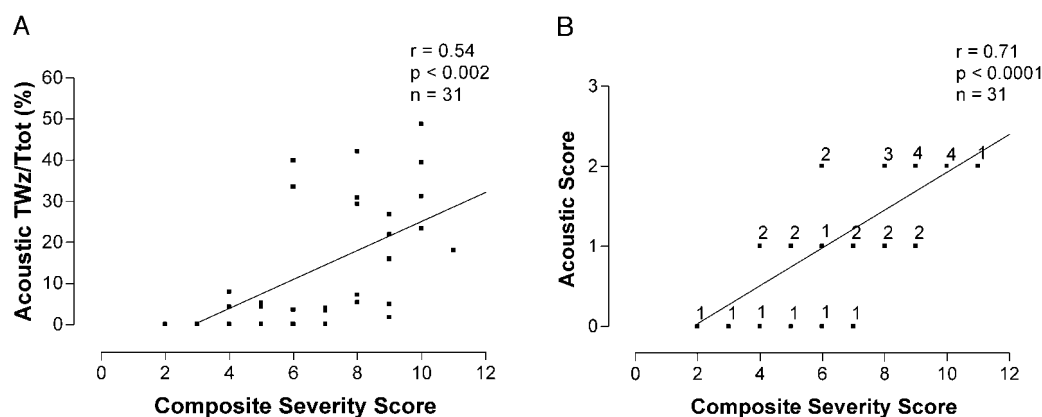


Figure 3. (A) Acoustic wheeze rate (Twz/Ttot) and (B) acoustic wheeze score compared with composite severity score. The numbers above the points in (B) indicate the number of points falling on the same place on the plot. The solid lines are the regression lines.

from the 8 children who were recurrent wheezers compared with the 23 who were first time wheezers. If anything, the “first time” parents performed a little better in that 8 of 23 (35%) agreed with the physician compared with 2 of 8 (25%) of those with recurrently wheezy children, but the numbers are too small to hope to achieve a statistically significant result.

To the best of our knowledge, no previous data are available on the objective acoustic measurement of wheeze in infants and young children comparing this with parental and professional evaluation. Attempts have, however, been made to evaluate the severity of airways obstruction in acutely wheezy infants of this age using the forced oscillation technique. For example, in a study of acutely ill asthmatic patients (which included preschool children), Ducharme and Davis (16) did not find any correlation between the wheeze recorded by a nurse and resistance, but they were only able to obtain reliable results of resistance in 19% of 3 year olds and 40% of 4 year olds. In a later study from the same group (17), some 40% of preschool children refused or were unable to perform the resistance measurements. They did find a correlation between an overall clinical index, which included wheeze, and resistance, but they do not give details of the individual physical signs. Even in older asthmatic patients able to undertake tests of lung function there are very few objective data relating the physical sign of wheeze to the severity of airways obstruction. McFadden et al. (18) studied 22 adults attending the emergency room because of acute asthma. The patients were examined initially and at intervals after the administration of an inhaled bronchodilator for the next 5 hours. At the start of the study when the patients were acutely ill and wheezing, the mean FEV₁ was

31% predicted, and when they had become totally wheeze-free and symptom-free, the mean FEV₁ was 63% predicted. Commey et al. (19) investigated 62 asthmatic children with a mean age of 11 years. In 40 children there was no objective wheezing, and their mean FEV₁ was 72% predicted, whereas in 22 children unstated severity, wheeze was present and their mean FEV₁ was 60% predicted. In the study by Shim and Williams (20), 93 adult asthmatic patients aged 16–67 years were evaluated on multiple occasions by one examiner, and wheeze was graded in its intensity and duration. Patients who were not wheezing had a mean PEF of 60% predicted. Patients with expiratory wheezing alone had a mean PEF of 49.4% predicted, and patients with inspiratory and expiratory wheezing had a mean PEF of 35.8% predicted. Kerem et al. (21) investigated 71 children with a mean age of 10 years who presented to the emergency room with an acute attack of asthma, and the wheeze was graded similarly. Although individual data or mean values are not given numerically, from their Fig. 2 it appears that children with their wheeze score of 0 had a mean FEV₁ of approximately 55% predicted, and children with their wheeze score of 1 had a mean FEV₁ of approximately 37% predicted. Taking all these studies together, we estimate that mild wheezing is heard when the FEV₁ was approximately 55% of predicted, moderate wheezing when it was approximately 40% predicted, and severe wheezing when it was approximately 25% of predicted but with marked individual variation.

Agreement about physical signs in the respiratory system by experienced clinicians has been shown to lie approximately midway between complete agreement and chance (9,10,22). The fact that the opinion of the physician differed from the objective acoustic

measurements in some 23% of children may help explain why there is considerable disagreement between observers about physical signs. We tried to determine whether there was any effect of the age of the child on the relationships we noted and found none. However, the narrow age range of the children studied and the relatively small numbers enrolled meant that we would have been highly unlikely to detect such an effect even if it did exist. If we take the objective acoustic measurement as the "gold standard" with which the performance of the parent, nurse, and the physician could be compared, the agreement between the parents and the acoustic score was nearly as poor (39%) as that between the parents and the physician (32%). Thus, parents were no better compared with an "independent" objective measure of wheeze than they were compared with the physician. The agreement of the nurse with the acoustic score (52%) was identical to that between the nurse and the physician. If it is possible to develop a simple method of measuring wheeze acoustically on an ambulatory basis, this could be of benefit to parents trying to determine the severity of their child's breathing problem.

CONCLUSIONS

In conclusion, there is good but not perfect agreement as to wheeze severity in infants and preschool children between an experienced physician and objective acoustic measurements. In almost a quarter of examinations, an experienced pediatrician differed in opinion as to the severity of wheezing compared with an objective acoustic measurement. There is less agreement between a nurse and the physician or the acoustic measurement and an even poorer agreement between the parent and the physician or acoustic measurement. In this study, parents were not trained in detecting wheeze; furthermore, most of their children were first time wheezers and, therefore, were not good judges of the severity of wheezing in their young children. Therefore, there is scope for objective acoustic measurement in diagnosing the presence and severity of wheezing in young children. In addition, further studies should address whether the degree of airway obstruction is more closely related to pitch, intensity, or duration of wheeze.

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