

Los Angeles phonospirometry technique: creating a normogram that correlates with peak expiratory flow measurements in children

Kelly Ochoa, MD, Jeranil Nunez, MD, Vincent J. Wang, MD, MHA

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Abstract

Objective: Measurement of peak expiratory flow (PEF) is recommended in the assessment of patients with asthma. However, the use of PEF involves multiple barriers, which have limited its use. Phonospirometry, as assessed by a novel Los Angeles phonospirometry technique, has shown good correlation to standard PEF measurements in a pilot study on symptomatic patients with asthma. We sought to develop a normogram for phonospirometry, and to validate the PEF normogram.

Methods: A convenience sample of asymptomatic children ages 3-17 years old was approached for participation in the Emergency Department. Sample size calculations determined that at least 30 children per age group ($n=450$) were needed. Children were asked to perform PEF measurements and phonospirometry, measured as the length of time (in

seconds) the child was able to chant "lalala" in a single breath.

Results: 510 children were enrolled. Spearman's rho between PEF and phonospirometry was 0.722. Phonospirometry correlated with both age and height, with a spearman rho of 0.697 and 0.696, respectively. This was slightly lower than the correlation of PEF with age and height with spearman rhos of 0.877 and 0.902, respectively. A normogram was developed for phonospirometry based on age and height.

Conclusions: This study determined normal value ranges for the Los Angeles phonospirometry technique for age and height, and also showed that the technique has good correlation with PEF. This technique may be used to assess a pediatric patient with an acute asthma exacerbation.



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Running Head: Normal values for L.A. Phonospirometry technique

Key Words: Los Angeles technique, Phonospirometry, Children

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Introduction:

Asthma is a chronic disease characterized by intermittent, acute exacerbations. Objective techniques to determine the severity of an asthma exacerbation are necessary. Peak expiratory flow (PEF) measurement with a peak flow meter has been recommended^{1,2}, but is effort dependent, and requires an age-appropriate patient who is able to blow forcefully and effectively into a mouthpiece. In a previous study, Wang et al. showed that time-based phonospirometry using a novel Los Angeles technique showed good correlation with PEF measurements³. The Los Angeles phonospirometry technique is a simple technique which measures the amount of time a child is able to chant “la la la” in a single breath. This technique had the advantages of being independent of language and not requiring a peak flow meter. In this study, this technique had good correlation with PEF meter readings on children with asymptomatic and symptomatic asthma.

The PEF meter was introduced as a measure of pulmonary function in the late 1950's, and its values were validated in normal children in a few studies in the United States done in the early 1960s⁴⁻⁸. More recently, normal peak flow values have been studied and validated extensively in other countries⁹⁻³⁸. Since peak flow is typically expressed as percent ideal based on these normal values, it is necessary to determine a normal value range to express these phonospirometry measurements as percent of ideal. In this study, we sought to determine the normal value range in well children for the LA phonospirometry technique, including younger children. In addition, we sought to correlate the normal value range of phonospirometry to the normal value range of PEF.

Methods:

Children between the ages of 3 and 17 years were enrolled from the Emergency Department (ED) of Children's Hospital Los Angeles. Subjects included patients, siblings, and other visitors who did not have respiratory complaints. Children were excluded if they had a diagnosis of asthma, any chronic diagnosis known to have cardio-pulmonary manifestations, developmental delay, or an acute visit inhibiting their ability to breathe normally or cooperate fully (e.g., upper respiratory infection or pain). 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. All participants and their parents/guardians were verbally consented prior to participation. Parents, as well as participants over 7 years of age, were given an information sheet.

Subjects were primarily enrolled by one of the co-authors. In addition, several research assistants helped with enrollment. They were instructed and observed by the primary investigator (KO) prior to their autonomous enrollment, and were required to memorize a script explaining the study and technique. Children enrolled in the study were asked to perform the Los Angeles phonospirometry technique as well as standard PEF measurements.

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 children's weights were recorded using a portable scale, and their heights were recorded using a portable tape measure.

LA Phonspirometry Technique:

The LA technique is a simple phonspirometry 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 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:

This study sought to determine the normative value range for the Los Angeles Phonspirometry technique, as well as correlate these values with the subject's PEF measurement. Twenty to thirty values per stratum are generally considered a statistically adequate number to develop a normal range for a specified entity within that stratum. Therefore, a sample size of at least 30 subjects per age in years, from 3-17 years old, was targeted to enable us to establish a normal value range based on age for this technique. A normogram with a regression equation was established for phonspirometry based on the participant's age as well as height. The normogram for phonspirometry based on height was compared to the known normogram for

PEF based on height. Spearman's rho was used to determine correlations between phonspirometry and PEF. We also determined how well both phonspirometry and PEF correlated with a participant's age and height. A correlation is generally considered to be excellent if spearman's rho is above 0.8, good if between 0.6 and 0.8, fair between 0.4 and 0.6, and poor if less than 0.4. We considered our correlation to be statistically significant if the p value was <0.05 . The data analysis for this paper was generated using SAS version 9.2 (Cary, NC, USA).

Results:

A total of 510 subjects were enrolled from September 2012 through July 2013. The majority of subjects were enrolled after the winter season from May to July, 2013, since fewer eligible study subjects had upper respiratory infection symptoms after the winter season. At minimum, 30 children in each age group were enrolled. There were a total of 265 females and 245 males enrolled in the study, with similar numbers of each gender in each age group. Forty-eight (9.4%) of the study subjects were non-English speaking, and most of these were Spanish speaking.

Phonspirometry values ranged from 3.6 seconds to 50.3 seconds, and PEF values ranged from 60 L/min. to 680 L/min. The average phonspirometry and PEF measurements for each age group as well as the 5th – 95th percentile ranges are listed in Table 1. Twenty seven of the 180 children, (15%), 7 years old and under did not have PEF values recorded.

The correlation between phonspirometry and age, and phonspirometry and height amongst all age groups was 0.697 and 0.696, respectively. The correlation between PEF and age, and PEF and height amongst all age groups was 0.877 and 0.902, respectively. These four correlations all had p values <0.0001. Weight and BMI were also analyzed as is seen in Table 2. The spearman correlation between phonspirometry and PEF amongst all children enrolled was 0.722, p<0.0001.

Since correlation between phonspirometry and both age and height were good and nearly identical, a normogram was created for both as displayed in Figures 1 and 2. The regression

equations for the normogram for age is $4.18 + 1.05 \times \text{age (years)}$. The regression equation for the normogram for height is $10.5 + 0.46 \times \text{height (inches)}$.

Since the severity of an asthma exacerbation is considered moderate or severe based on PEF values of <80% of ideal and <50% of ideal, respectively, Table 3 lists the average phonospirometry measurement per age group as well as 80% and 50% of normal values.

We also correlated our PEF values to previously published normal values⁸. The regression coefficients for both the previously published PEF normal values and the normal values we obtained in our study are almost identical. The values we obtained, however, have a lower intercept, and less standard error. The previously published regression equation for PEF is $-397.17 + 4.9 \times \text{height (se 2.45)}$. The regression equation for PEF in our study is $-471.47 + 4.96 \times \text{height (se 0.17)}$. The graph shown in Figure 3 shows the 2 regression lines superimposed with nearly equal slopes, but overall lower values in our study. The previously published values are linear, as only the regression line based on the published regression equation is shown, not the individual values obtained in the previous study.

Discussion:

This study created normal value ranges based on age and height for the novel Los Angeles phonospirometry technique. We also showed that this technique has good correlation with a known and validated measure of lung function in children, the peak expiratory flow meter.

While the correlation of phonospirometry with a child's age and height was good, but not better than PEF, we can speculate that this technique may be a useful tool in the evaluation of a child suffering from an acute asthma exacerbation, in which a PEF meter is not readily available, or for which the PEF measurement is not easily performed.

Since its introduction, PEF has been used as a tool to evaluate children suffering from asthma, and is reported as percent ideal based on these published normal values². The absolute PEF value varies depending on the child's height, as was shown in these validation studies, and is more meaningful when reported in relation to the normal value for that child. As shown in our study, phonospirometry and PEF measurements were successfully obtained, but in the younger age population, some children were not able to perform a PEF measurement (see Table 2).

However, in the very beginning of enrollment we were only collecting PEF values for children with known PEF standards (over age 7 years) due to the known difficulty in obtaining this value in the younger age group, and decided shortly into enrollment to attempt obtaining PEF values in all children. Since 15% of these children had no PEF value recorded, we are unable to calculate the exact percentage of children under 7 years who were truly unable to perform PEF, as those enrolled in the beginning were not asked to try. This may introduce a bias, as those with unrecorded PEF values may have performed PEF better or worse than those that did have PEF values included in our analysis. Therefore, correlation with phonospirometry values in this age

group may have been affected. This is a limitation of our analysis in this specific age group. However, missing values in 27 out of the 510 total children enrolled is unlikely to change our results overall. We found there to be significant differences by gender in some age groups for both phonospirometry and PEF as is shown in figures 4 and 5, although less so for phonospirometry. In PEF literature, normal values are reported separate for males and females based on height for adults³⁸. Perhaps normal values for phonospirometry need to be determined for each gender in the older age groups as well.

In our study, we validated the previously published and accepted normal values for PEF. However, we had a lower intercept and less standard error than previously published. The lower standard error is likely due to our large sample size. The lower intercept shows that children in our study had a lower PEF value for any given height. The reason for this and its implication require further research. It is possible that the air quality in Los Angeles, where the children in this study reside, may have contributed to this³⁹⁻⁴¹.

In a similar manner, we sought to determine normal values for the Los Angeles phonospirometry technique in healthy children. We have shown that the Los Angeles phonospirometry technique has good correlation with PEF in healthy children. It also has good, and nearly identical correlation with both age and height of a healthy child. In the ED setting, when height is not routinely available, or must be additionally obtained, the normal values for phonospirometry can be determined based on age. Phonospirometry can now be reported as percent ideal (Table 3), as is done for PEF, which may improve the utility of the Los Angeles phonospirometry technique as a tool to evaluate children suffering from an acute exacerbation of asthma.

Lastly, PEF correlated with age ($\rho = 0.877$) almost as well as with height ($\rho = 0.902$). This may have unique implications in the acute care setting, in which height is not routinely known, and measurement of the patient is not possible. Age is generally known, and appears to be a reasonable proxy for height.

Limitations:

This study was designed as a convenience sample of children in the ED. While all subjects were screened for potential factors that may influence their ability to “breathe normally,” the location of the ED alone is an anxiety-provoking, occasionally loud place with many distractions. The normal values obtained in this setting may be shorter than those obtained in a quieter, non-distracting, and more comfortable setting. However, the ED would also be a site in which the phonospirometry technique is often used. Enrollment was also done at all hours, although the majority was done mid-day. Those subjects enrolled in the late evening/night hours may have been tired, and performed the techniques with less effort, compared with a daytime measurement. Also, PEF has diurnal variation and may be affected by time of collection⁴². However, having a mixed sample is more representative of typical clinical circumstances. There also may be variation in level of encouragement and enthusiasm displayed by the 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 by the PI before enrolling subjects independently. They also used a memorized script for enrollment. Obtaining accurate values for children under age 5 years was challenging due to their level of understanding and ability to accurately execute the measured techniques. Patient participation for children ages 3

and 4 years for this learned and effort-dependent technique was also a possible limitation for our study. The correlations between PEF and Phonospirometry specific to each age would be interesting data. However, we did not have a large enough sample size in each age group to report those correlations.

Future Direction:

This study provided normative values for phonospirometry. These values can now be used to determine percent ideal from normal values of phonospirometry during acute asthma exacerbations. Using the normogram we have created, a patient's acute measurement can now be compared with a child's expected phonospirometry value. In the best case scenario, the individual patient should have a non-ill phonospirometry measurement known, for which the patient can compare to the phonospirometry measurement when having an acute exacerbation of asthma. A previous study demonstrated correlation of absolute values of PEF and phonospirometry³. Future studies to determine correlation of adjusted percent ideal phonospirometry and PEF measurements in children suffering from acute asthma exacerbations could be performed. The Los Angeles phonospirometry technique is simple and does not rely on equipment, and therefore future studies could focus on investigating the utility of this technique in the home by a parent, as well as in clinic and ED evaluations of dyspnea. Normal values were also reliably obtained for children as young as 3 years old. Future studies should focus on the use of this technique in these younger age groups, as they are not able to reliably perform PEF measurements. Future direction also needs to investigate whether phonospirometry values and trends correlate with clinical outcomes.

Conclusions:

This study determined normal value ranges for the Los Angeles phonospirometry technique for age and height. We also showed that this technique has good correlation with a known and validated measure of lung function in children, the peak expiratory flow meter.

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Declaration of Interest:

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

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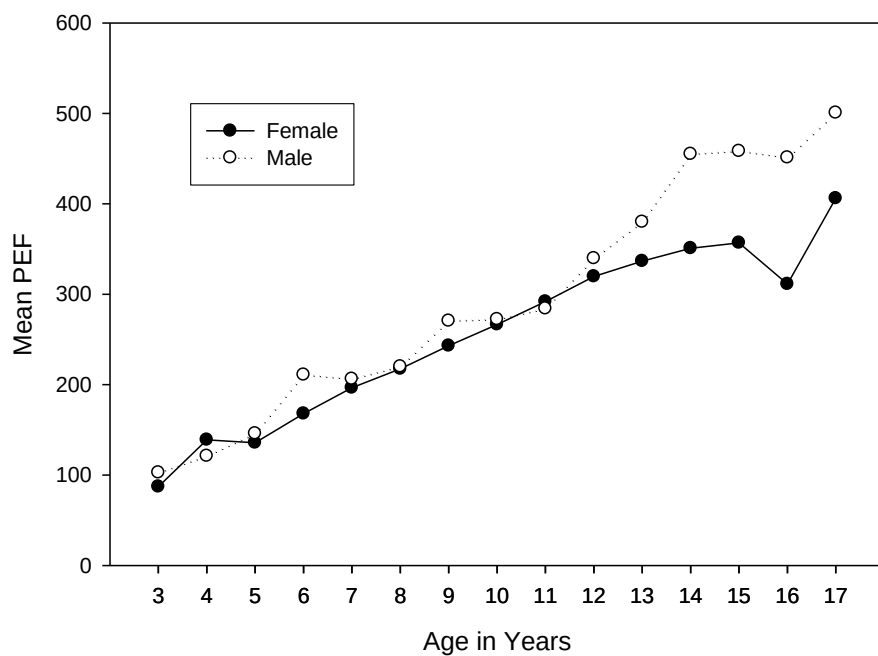
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Figure 1

PEF by Age and Gender



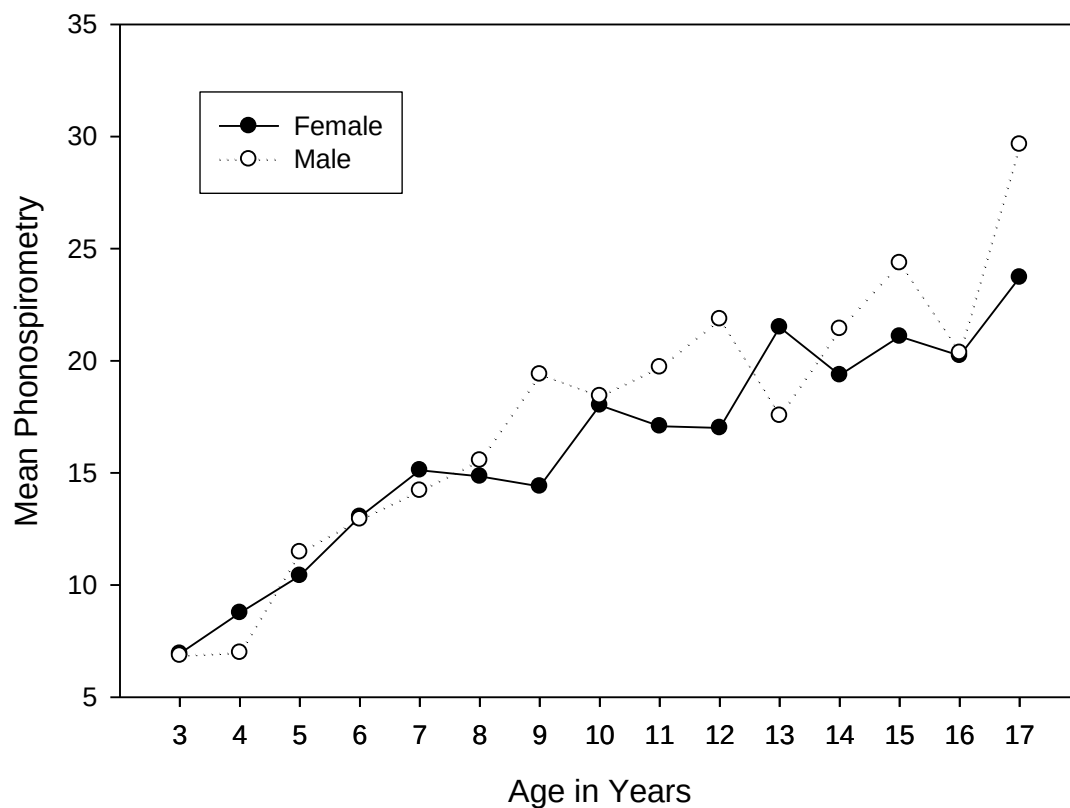
Significant differences

6 years $p=0.04$

13 years $p=0.04$

14-17 years $p < 0.01$

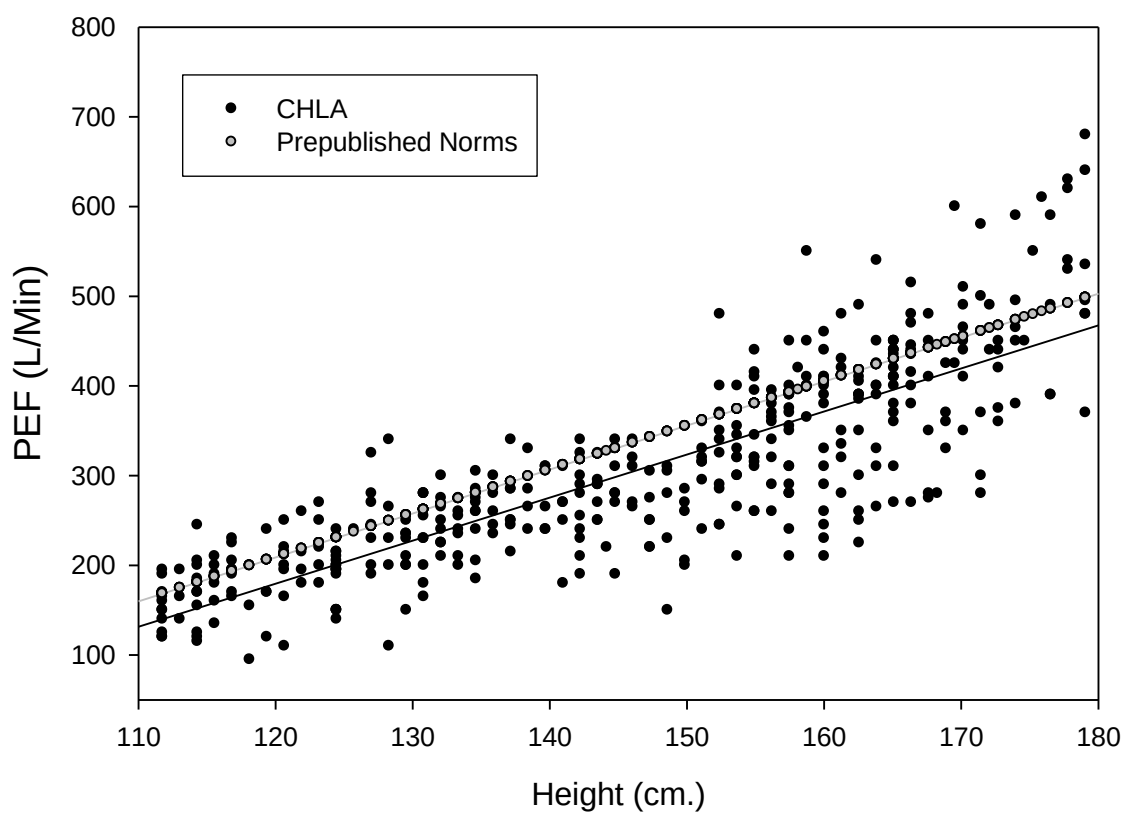
Phonspirometry by Age and Gender

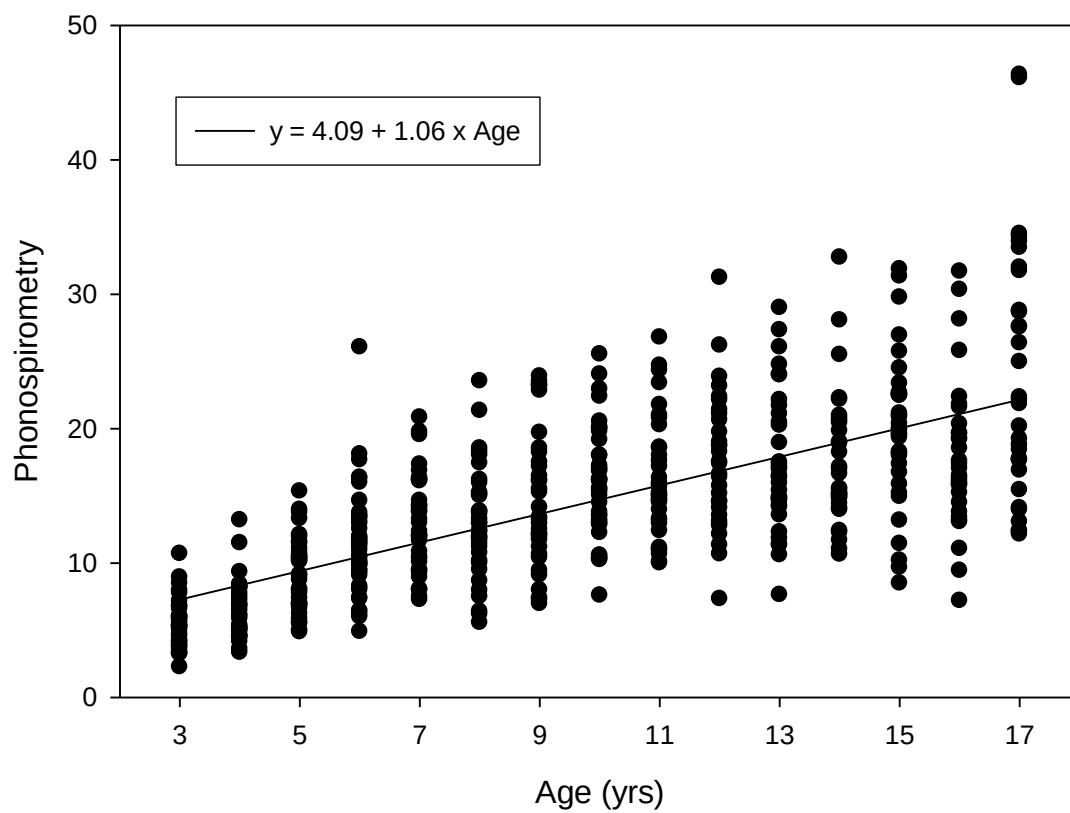


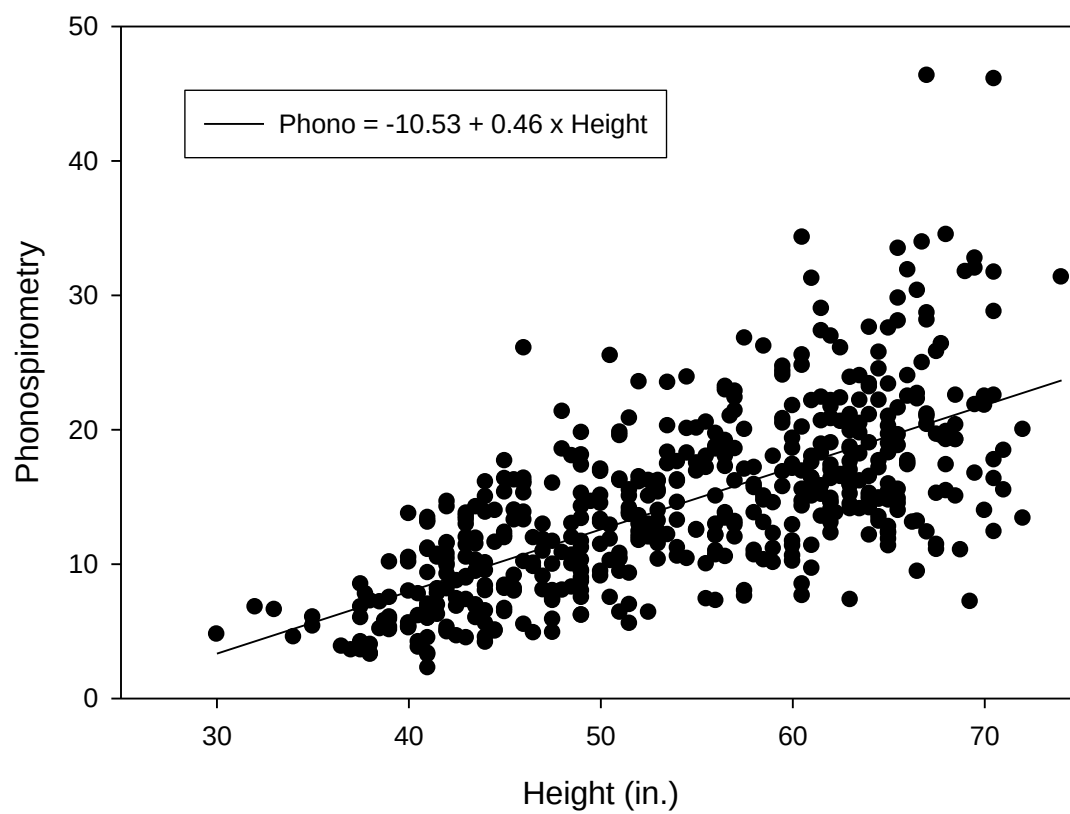
Significant differences

9 years	p=0.0074
12 years	p=0.0118
13 years	p=0.0385
17 years	p=0.0018

Normogram for Peak Expiratory Flow







Phonspirometry

Peak Flow

Age (Y)	N	Mean	5 th %ile	95 th %ile	N	Mean	5 th %ile	95 th %ile
3	32	6.9	3.6	11.3	27	94.6	60	120
4	31	7.8	4.0	13.1	27	130.4	95	170
5	34	10.9	6.2	17.0	29	141.4	95	195
6	45	12.9	6.7	19.4	33	188.8	125	245
7	38	14.8	9.0	23.4	37	200.8	135	260
8	34	15.0	9.7	23.9	34	218.4	150	280
9	33	16.8	8.0	29.0	33	256.4	165	310
10	39	18.2	11.0	27.8	39	268.3	200	340
11	36	18.8	11.2	30.4	36	286.9	200	360
12	31	19.5	13.0	29.3	31	330.0	245	440
13	33	19.9	11.7	32.0	34	353.2	240	450
14	32	20.2	12.6	36.2	31	391.1	210	530
15	34	22.8	11.9	34.1	34	410.6	265	620
16	31	20.3	10.3	33.5	31	396.9	210	610
17	32	26.9	13.3	49.1	32	456.3	320	640

	Spearman correlation with phonspirometry	Spearman correlation with peak expiratory flow
Age	0.697	0.877
Height	0.696	0.902
Weight	0.661	0.866
BMI	0.381	0.555

Phonspirometry Measurements

Age (y)	Mean (sec)	80%	50%
3	6.9	5.5	3.4
4	7.8	6.2	3.9
5	10.9	8.7	5.5
6	12.9	10.3	6.4
7	14.8	11.8	7.4
8	15	12.0	7.5
9	16.8	13.4	8.4
10	18.2	14.6	9.1
11	18.8	15.0	9.4
12	19.5	15.6	9.8
13	20	16.0	10
14	20.2	16.2	10.1
15	22.8	18.2	11.4
16	20.3	16.2	10.2
17	26.9	21.5	13.4