Methodologic Problems in Children's Spirometry

Technical problems encountered in the analysis of spirometry data collected on children aged 6-11 years in the United States, 1963-65, and the solutions are detailed in a narrative account. Data from other methodologic studies are presented and discussed. Behavioral and technical problems in the survey measurement of pulmonary function in children are discussed.

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METHODOLOGIC PROBLEMS IN CHILDREN'S SPIROMETRY

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INTRODUCTION

This report is a companion piece to Series 11, No. 164[1] and most profitably the reader should, at least, read the introduction and skim that report before reading this one. This report could be considered as playing the subordinate role of a series of very long technical footnotes to that report. The justification of two separate publications (in two different NCHS report series) is an attempt to maintain narrative flow of the primary report, to better handle unwieldy length, and to appeal to different sets of specialized readers.

However, these are not the only considerations. This report presents spirometry results on 6- and 7-year-olds from two small studies which have not been presented before; and this report, although presenting data and detailed arguments that support the Series 11 report, can be considered to have a narrative flow of its own.

While the primary function of the first report was to present and discuss data collected in HES Cycle II (and, subsidiarily, to take into consideration the methodologic complexities and limitations), this report, although presenting some new data, details the methodologic problems encountered in the collection and analysis of the HES Cycle II spirometry data, provides a narrative account of how some of them were solved, and touches on most of the problems and limitations involved in spirometry testing in children, especially in a survey setting.

This report does not simply expand the technical details of the companion Series 11 report. It has a different emphasis and provides the basis for the many refinements in spirometry data collection, data processing, and data analysis made in subsequent HES cycles of examinations that will appear in forthcoming spirometry reports on children and on adults.

BACKGROUND

The father of modern spirometry was John Hutchinson, an English physiologist, who was the first to name the subdivisions of lung volume and describe methods for measuring them.[2] In 1846 Hutchinson devised the first spirometer, an instrument to measure static lung volume. This closed circuit volume measuring device consisted of a cylindrical bell immersed in a reservoir of water into which air forcefully expired from the lungs could be blown by means of a connecting breathing hose. Using this instrument he was able to diagnose or exclude various forms of pulmonary disease. Only in recent years has this testing technique been developed to include measurements of the *rate* or *airflow*, which now form the basis of the most widely used test of lung function, the forced expiratory spirogram (FES). This advance was made by Tiffeneau and Pinelli, who connected a rotating kymograph to the spirometer (figure 1), permitting assessment of the dynamic, as well as the static, characteristics of the lung.[3] The kymograph, rotating at a constant speed, permits the display of a time-volume coordinate recorded by a pen attached to the spirometer bell.

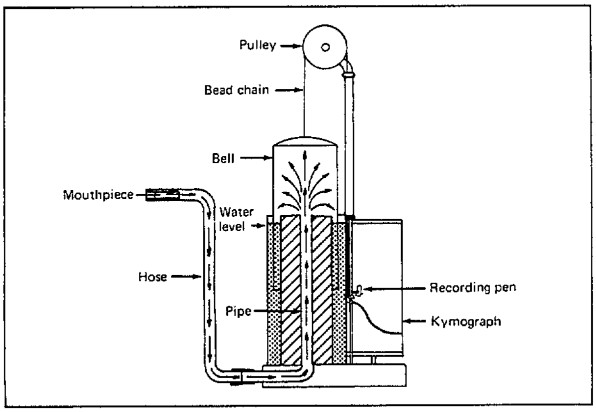

Figure 1. Schematic drawing of a wet system spirometer

The test instruction calls for a maximal inhalation, placing the cardboard mouthpiece (fastened to the air tube of the spirometer) into the mouth, carefully sealing the lips to prevent air leakage and then forcefully expiring as rapidly and as completely as possible. During the maneuver the attending technician verbally exhorts the standing subject to blow as hard as possible until no more air can be expired. A correctly executed maneuver provides a monotonically increasing volume curve which ultimately presents a plateau, and is free from inhalation artefacts (figure 2). From this wave form, calculations are made of numerous time and volume increments from which volume and flow-rate measurements are derived.

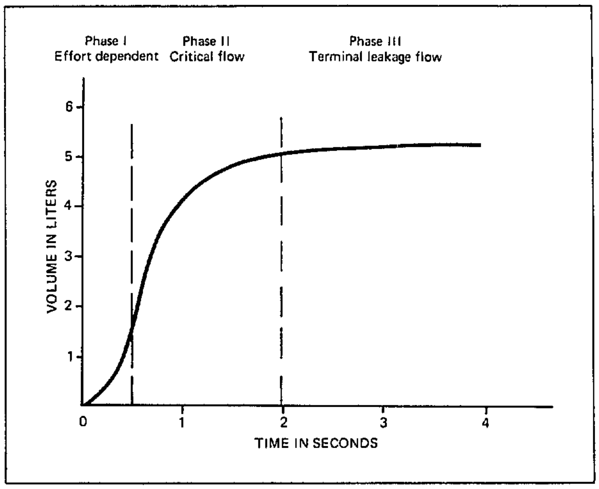

Figure 2. Normal time-volume spirogram showing the three component phases

The three most common measurements obtained from the FES and used in the assessment of pulmonary function are: (1) the forced vital capacity (FVC), defined as the maximal volume of air that can be forcefully expelled from the lungs from a maximal inhalation; (2) the forced expiratory volume during the first second ($FEV_{1.0}$); and (3) the forced expiratory flow rate (FEF) between 25 percent and 75 percent of the forced vital capacity ($FEF_{25\text{-}75\%}$). (See figure 3.)

Measurement of the FVC can reveal mechanical defects of the chest cage that prevent the full expansion of the lungs, i.e., chest wall deformity, loss of lung tissue, or loss of lung elasticity as in restrictive lung diseases. The flow-rate measurements, $FEV_{1.0}$ and $FEF_{25\text{-}75\%}$, provide an objective method of quantitating obstructive lung diseases, since in their presence these flow rates are impaired.

Volumes are calculated by multiplying the number of millimeters of bell movement as recorded on the kymograph by a bell calibration factor. This gives a volume correct to *a*mbient *t*emperature and *p*ressure *s*aturated with water vapor (ATPS). Because expired air is collected in a spirometer at room temperature (usually 25° C), gas expired from the lungs (at body temperature, 37° C) cools and subsequently contracts. This underestimate of gas volume is cor-

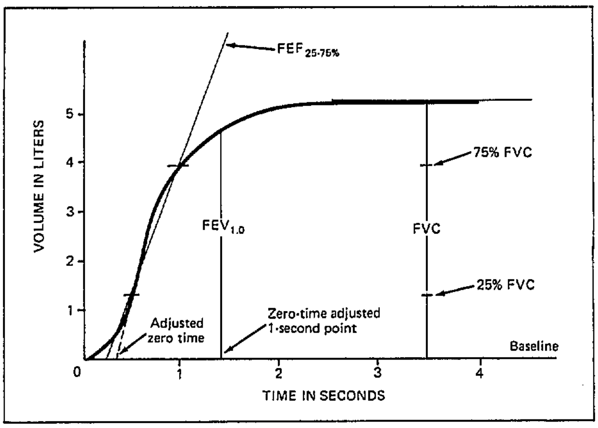

Figure 3. Forced expiratory spirogram illustrating measurements of FVC, $FEV_{1.0}$, and $FEF_{25\text{-}75\%}$ and identification of zero time

rectable to *b*ody *t*emperature and *p*ressure *s*aturated with water vapor (BTPS) by multiplying the ATPS measurement value by the BTPS correction factor obtained from a reference chart or calculated using the following equation:

$$\text{Volume (BTPS)} = \frac{273 + 37^\circ\ \text{C (body temp.)}}{273 + 25^\circ\ \text{C (spirogram temp.)}} \times \frac{750\ \text{mm Hg (BP)} - 24\ \text{mm Hg (pH 20 at } 25^\circ\text{C)}}{750\ \text{mm Hg} - 47\ \text{mm Hg (pH 20 at } 37^\circ\text{C)}}$$

PHYSIOLOGY OF AIRFLOW

Dayman has shown that during the performance of the FES, airflow can be divided into three components:[4] Phase I is effort-dependent flow culminating in the peak flow, the maximal flow velocity, for that breath. This is followed by a phase of constant deceleration of volume exhaled (phase II). A third phase is terminal leakage flow (figure 2). A correctly executed spirogram, therefore, demands that phase I begin at the total lung capacity (TLC), and end at the residual volume (RV) in phase III. Phase I is a measure of how fast the subject initiated the expiratory effort and is called "effort dependent" because it directly reflects the subject's understanding of the test instruction and his willingness and ability to cooperate. The dynamics of airflow are best demonstrated when the flow rate and the volume signals are displayed as a single graph (figure 4). Examination of a flow-volume spirographic loop illustrates how the volume signal abruptly leaves the volume baseline and rapidly culminates in *peak flow* and then shifts into phase II, the beginning of critical flow. This phase is believed to be most independent of effort variation, implying that both the constant of deceleration and the flows are regulated by airway size and not by the subject's effort. It is this phase of the spirogram that imparts disagnostic character and reproducibility. The point at which critical flow emerges is approximately 25 percent after the initiation of the FES while phase III occurs at approximately 75 percent of the FES and represents asynchronous emptying of various portions of the lung due to air trapping. Here flow rate is reduced and the volume of air expired is minimal and it is at this point in the test that the subject strains to exhale the last of his air and his face becomes red due to effort. A correctly executed spirogram must include phase III, since it is the portion of the curve that insures reproducibility of the FVC and all of those flow-rate measurements which are expressed as a proportion of the FVC. (Phase III is also of current interest for the early detection of obstructive lung disease.)

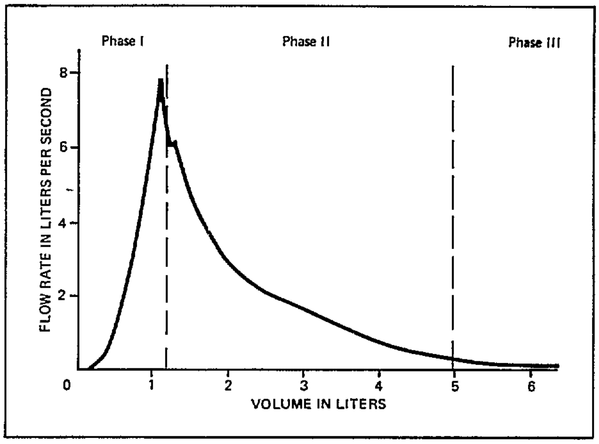

Figure 4. Maximum expiratory flow-volume curve

SOURCES OF SIGNAL VARIANCES

Three important factors contribute to the variability of the test maneuver: equipment accuracy, subject cooperation, and technician expertise. The spirometer should be accurate, linear, and have a frequency response of at least 8-10 Hz to permit capture of the highest frequency components present in the FES. Careful attention to the calibration of the kymograph speed and volume response of the instrument will permit accurate and reproducible data to be recorded. Subject cooperation depends on individual motivation and complete understanding of the test instructions. Contrarily, maximal effort may also be withheld in circumstances where this maneuver precipitates pain or coughing spasms or if the subject is a candidate for disability status and stands to gain financially by producing a positive test.

An astute technician can usually identify these problem areas and act appropriately either to correct a subsequent FES trial or to discard the data. Such a technician takes on the multiple roles of monitor, bully, cheerleader, and psychologist as he strives to elicit a maximal response from the subject. The end result of these skills is a strong interaction between technician and examinee which results in the collection of data that represents the best possible estimate of the physiologic capability of the lungs. Experienced technicians frequently vary in their performance. Day-to-day testing can be extremely boring and test subjects can be frustratingly uncooperative; therefore, the stamina to maintain the same level of expertise during a lengthy testing operation is variable.[5,6]

A correctly performed spirogram trial should embody the three phases described, even in the presence of disease. Those with an obstructive defect will have a reduced velocity in phases II and III, but can often achieve a normal vital capacity by greatly lengthening the duration of expiration. Conversely, in the presence of restrictive lung disease, flow rates can be normal and the vital capacity reduced. Testing without adequate quality control can result in spurious measurements. For example, should a subject with an obstructive lung defect prematurely terminate his expiratory effort before the emergence of phase III of the spirogram, the $FEF_{25\text{-}75\%}$ measurement will be artificially elevated since it will now fall between phases I and II of the spirogram, a steeper portion of the signal, as opposed to between phases II and III (figure 2). Likewise, the ratio $FEV_{1.0}/FVC$ will be artificially increased. Another serious procedural error occurs when a subject trumpets into the mouthpiece (pursing the lips in front of the mouthpiece as opposed to fully inserting the tube into the mouth). The incomplete lip seal can result in a Venturi defect in which air from the outside is drawn into the spirometer along with the expired air, resulting in spuriously large vital capacities. Such errors can be reduced by instituting a series of quality control checks upon the data; those used by this survey will be discussed in the section "Methodology" that follows.

A fundamental error is committed in spirometric evaluation when a composite spirogram is used in diagnosis, especially when inadequate quality control standards are operative. This occurs when, from a series of trials, the largest FVC is taken from one trial and the largest $FEF_{25\text{-}75\%}$ is taken from another of the trials. As already discussed, a subject with an obstructive lung disease could achieve a normal vital capacity but with low flow rates because of the obstructive defect. Then on a subsequent trial he could perform a maximal effort that encompasses phases I and II of the spirogram but prematurely ends prior to the emergence of phase III, therefore, artificially elevating the flow rate. Conceivably, by use of a composite trial, the FVC and $FEF_{25\text{-}75\%}$ could both be in a normal range when in fact moderate to severe obstructive lung disease is present, and so could result in a false negative test.

METHODOLOGY

The child entering the spirometry room was met by a trained technician who described and demonstrated the breathing maneuver.

The test instruction required that the subject inhale to maximal inspiratory capacity through the spirometer hose, then blast the air out as forcefully and rapidly as possible into the mouthpiece, sustaining the effort until no more air could be expelled. During the expiratory effort, the attending technician verbally exhorted the subject. During the test procedure the child was standing, and a nose clip was used to prevent air from escaping through the subject's nose.

Although the test procedure called for several practice attempts prior to executing the test, usually (because of the lack of time) only one practice trial was given; then at least two trials were recorded. Because of the physics of airflow when a maximal expiratory effort is achieved, it can be expected that the personal morphology of each subject's volume signal will be reproducible within the limits of biologic variation. Although no systematized procedures were devised in Cycle II to quantitate the degree of variability between trials during the test procedure, the attending technician visually monitored the spirographic wave forms to determine if the tracings were reasonably reproducible. Regardless of whether or not reliable data were demonstrated owing to a limitation of time the test was discontinued after two or three trials.

The forced expiratory spirogram was measured on a Collins 6-liter Vitalometer, a water-sealed, counterbalanced system. Volume displacements were recorded on a moving chart (kymograph) by a writing device connected to the bell by a pulley system (figure 1). The kymograph was driven by a motor at a constant speed (32 mm/s).

Prior to each day's testing, the barometric pressure and temperature were noted and recorded. During the day the temperature was rechecked periodically and recorded whenever change occurred. The water level in the spirometer was carefully maintained within 1½ inches of the top of the bell canister to prevent excessive spirometer dead space, which could cause an underreading of the recorded signal.

INITIAL LIMITATIONS OF DATA

Of the 7,119 subjects examined, no spirographic data were obtained for 187 examinees. Reasons for this data loss ranged from lack of the subject's physical coordination and/or his inability to follow any verbal directions, to the presence of pathology that precluded valid data collection. The spirographic tracings obtained on the other 6,932 subjects were initially measured by technically inexperienced clerks, whereby measurements of the FVC, $FEV_{1.0}$, and the $FEF_{25\text{-}75\%}$ parameters were made on the trial judged to represent the best spirometer effort. Ideally, both the best and second-best trial should have been measured to permit better assessment of data reliability; however, this could not be done because of the large amount of additional time and money involved. In addition, the maximum number of recorded trials per subject was, in most cases, two—occasionally three.

As a preliminary to analyzing the data, a reassessment of their overall quality and potential value was made by Palmer and Hamill. All of the spirometric tracings were reexamined and compared with the measurements originally performed by the unskilled clerks to determine the overall technical quality of the data (i.e., spirograms, morphology, and the recorded measurements). The quality of the spirograms ranged from good to technically unsatisfactory and the measurements, as recorded, were frequently unacceptable. The two most frequent measurement errors were the wrong choice of "the best trial" (on which all measurements are based) and the incorrect determination of zero time point. In addition, many of the actual measurements were underestimated and several hundred sets of spirograms, although measured, were obviously unacceptable because of technical errors in the original performance of the FES. Because of these problems, the decision was made to abandon the analysis.

However, one year later the decision to abandon Cycle II data was reversed because a large part of the HES Cycle III (youths 12-17 years old) spirometry recordings were lost. The Cycle III data were of much better technical quality: the testing situation was improved, more sophisticated electronic equipment was used, and the technicians were well instructed, supervised, and monitored. Most of the limitations just mentioned in Cycle II data on the younger children had been successfully corrected. In addition, the FES was recorded on magnetic tape which would have enabled greater scope and ease of data processing, minimized measurement and recording error, and allowed much greater range and flexibility of analysis.

However, when seven cartons containing most of these tapes were being moved from one location to another for "safekeeping," they were carelessly left on the building's loading platform and were carted off to the city's sanitary landfill. Despite enormous efforts made to recover, clean, and reprocess those tapes and parts of tapes which were recovered, more than half of the total data set proved irretrievable.

Subsequent to this disaster, a decision was made to go ahead and attempt to clean up the Cycle II data by culling the bad, remeasuring, reclassifying, and reassessing all the data. The two most serious limitations of the data about which nothing could be done had been built into the original design and test protocol: first, the failure to obtain four or five trials, and second, the complex of factors in the testing milieu that did not insure that enough children would come to maximal inspiration (TLC) immediately before the full expiratory effort. These limitations, although recognized at an early date, have become increasingly apparent as the analysis has proceeded.

The analysis and discussion of all the factors in the testing milieu that affect the data occupy much of this document. The consequences of the limited number of trials (i.e., practice trials, recorded trials, and measured trials) are also discussed under two general topics: (1) criteria development and tests of reliability of trials and (2) learning curves as they influence the performance of maximal voluntary, cooperative effort on the subject's part, especially in younger children.

Several investigators have demonstrated that learning occurs with practice.[7-10] Maximal values have been shown to occur most frequently on trials four and five, but because of the development of fatigue beyond trial five, values then tend to be attenuated. Since not more than three trials were ever attempted, it is evident that the observed "best" recordings were frequently underestimates of the child's true functional state.

One of the more limiting assessment errors made by the initial Cycle II readers, in addition to measuring only one trial, was the lack of documentation of the criteria used to judge the trial considered best and ascertain its reliability. Given this information, a more efficient assessment of the data might have been made. For example, if the original reader had used incorrect logic to identify the best trial, then those best trials considered by the reviewing reader to have been chosen correctly would have come under much closer scrutiny since then the correct choice would have been due to chance. The most valid method of judging reliability would have been to measure the best and second-best trials and compare the variance between them.

CRITERIA DEVELOPMENT

In view of the limitations of the data, a set of criteria was developed to evaluate the quality, reliability, and measurement precision of the spirograms.

Criteria for judging the quality of the spirogram required that an acceptable test demonstrate at least two trials with complete volume curves (i.e., phases I, II, and III) and be free from inhalation artefacts.

Reliability of the data was satisfied when the replicate trials of forced vital capacities, a measure of a sustained expiratory effort, agreed (within a range of ±100 ml) with the original trial. This "window" of variance has been established by pulmonary physiologists as the limit of biological variation in a healthy person when performing the test maximally.[11] The variance of the flow-rate measurement ($FEF_{25\text{-}75\%}$) has been given wider limits (±10 percent) and is considered a measure of expiratory thrust since the characteristics of critical flow will insure reliability.[12-14] Such limits of physiological variability were accepted as valid for this population of children with full knowledge that research data supporting such limits were developed on adults. In the absence of any such data for children, this decision appeared to be the only logical choice.

To lend precision to the measurement of $FEV_{1.0}$ the technique employed to identify true zero time was that described in a report by the American College of Chest Physicians.[12] A line was drawn tangent to the steepest portion of the volume curve and was extrapolated back until it intersected with the volume baseline (figure 3). The intersect is considered the point of true volume departure had there been no intervening variables such as equipment inertia or hesitation on the part of the subject at the initiation of the test. It is from this point that the 1-second volume measurement was made.

REMEASUREMENT PROCEDURE

After careful visual inspection of the 6,932 sets of measured spirograms, it was decided to separate them into three groups. One group of 3,506 were classed as valid, meaning that they were of acceptable quality by any conceivable set of criteria applied to them and also had been correctly measured. Group two consisted of almost 3,000 spirograms which obviously had been incorrectly measured and required careful perusal and remeasuring before final disposition was made. The third group consisted of spirograms considered of such poor quality that they were summarily discarded.

There were two primary reasons for remeasuring spirograms of apparently good quality. First were those tests which, although technically satisfactory, had measurements performed on the second-best trial. This measurement (or selection) error caused an underestimate of both the volume and rate measurements. Remeasurements were made on the best trial using the same technique employed by the original readers.

The second reason to remeasure the spirograms was to correct the improper selection of zero time. (This error would have consistently underestimated the $FEV_{1.0}$.)

The three measurements made on the forced expiratory spirograph (FES) were:

1. Forced vital capacity (FVC), i.e., the largest volume measured on complete forced expiration after the deepest inspiration.
2. Forced expiratory volume at 1 second ($FEV_{1.0}$), i.e., the volume of gas expired over the first 1-second time interval during the performance of the FES.
3. The forced expiratory flow rate between the 25-percent and 75-percent FVC ($FEF_{25\text{-}75\%}$), i.e., the average rate of flow during the middle half of the FES.

Measurements were made by determining the number of millimeters traveled by the kymograph pen from the baseline to the intersect of the volume line at defined points by use of a dividing caliper, and converting these distances to volume by multiplying by the spirometer bell factor. For example, the $FEV_{1.0}$ is the distance in millimeters from the 1-second point on the time baseline to the intersect of the volume curve. The FVC is measured from the baseline to the highest point reached by the volume curve. Measurement of the $FEF_{25\text{-}75\%}$ is determined by the volume and time increment between the FVC 25 percent and 75 percent, and is expressed as millileters per second. (Figure 3 expresses it in liters per second.)

In order to avoid introducing any computational error, all of the measured millimeter values were directly recorded and later were automatically converted to volume and flow rates at BTPS (i.e., the volume of gas as corrected for body temperature, barometric pressure, saturated with water vapor) by a programed digital computer.

CLASSIFICATION OF SPIROGRAMS

After the initial sorting into three groups and completing the necessary new measurements, all group one and two spirograms were reclassified according to the following criteria:

Class I

The prime group consisted of 5,155 records that demonstrated at least two trials in which the FVC's reproduced within a tolerance of approximately 100 ml, and the slopes of the spirograms were within approximately 10 percent of each other. Since maximum effort results in regulated airflow, a reliable spirometric test would demonstrate flow rates and volume measurements reproducible within acceptable physiological limits on consecutive tests.

It is a relatively easy task to choose the best trial from a series of trials when the largest FVC and $FEF_{25\text{-}75\%}$ flow rates occur on the same spirogram. A dilemma exists, however, when the largest FVC and $FEF_{25\text{-}75\%}$ values are split between different trials. At that time, for purposes of consistency, all component measurements in class I data were always made on the trial with the largest FVC. However, reconsidering this today, there is good reason to believe that rule need not have been so inflexibly applied.[a] Because current reliability criteria suggest that the differences within these ranges are due to normal physiologic variation and are not clinically significant, the best FVC and $FEF_{25\text{-}75\%}$ values could have been used regardless of the trial on which they occurred, as long as they were chosen from the best and second-best trials that did not exceed the stated reliability criteria.

Class II

Reliability was not as satisfactorily demonstrated in this group (n = 648) since only the

[a]The current *iso-volume technique* to better focus on phase III abnormalities violates these strictures, but only within tight quality limits of reproducibility.

volume criteria were met (±100 ml). The slope of the $FEF_{25\text{-}75\%}$ of the two best trials was found to fall within a range of 10-20 percent. In most cases the trial used for analysis contained both the best volume and flow rate, while in a few cases the best slope was measured from the trial with the smaller FVC.

To this class were also added 17 spirograms in which the comparison trial in the test had been terminated prematurely due obviously to a technician's error. If upon careful visual inspection, the reviewer determined the completed trial would have met "primary quality" criteria had the incomplete spirogram been permitted to run to completion, the test was classified as reliable. The judgment was made by comparing the slope of both curves and extrapolating the unfinished slope to determine if the flow-rate decay curve (phase III) of the spirogram appeared in the same position as the complete trial.

By limiting the sample to those data meeting the stringent criteria of class I, a response rate of 72.4 percent would have resulted which would have impaired the sample reliability of the HES data. However, relaxing the flow limits slightly, yet maintaining the important FVC criteria (see "Physiology of Airflow" for discussion on the FVC's effect on flow rate) permitted the inclusion of 648 class II spirograms. This raised the response rate to almost 82 percent.

Discarded Data

Class III

These data (n = 134) exhibited an intolerably large FVC variability, within the range of 100-200 ml, though the flow-rate slopes remained within ±10 percent of the best trial. In most cases the trial with the largest FVC contained the best flow rate, though several spirograms were included that definitely had the better slope on the trial with the smaller FVC.

Class IV

A total of 1,182 tests were eventually judged to have no clinical value. This included those initially discarded together with those subsequently discarded after further review and remeasurement. The most common faults were: tracings with inhalation artefacts, incomplete or nonreproducible set of tracings, only one spirogram recorded, and those trials where no two trials exhibited quality data equal to classes I and III spirograms. In addition, there were 187 examinees with no record of ever having taken a spirogram who were included in this group.

VERIFICATION AND VALIDATION OF THE DATA CLASSIFICATION SYSTEM

The first step in testing this classification system and the validity of the remeasured and reassessed data was its ability to be replicated by an independent expert observer. A systematic subsample of more than 700 spirograms, made up of samples from each class, was given to another highly experienced spirometrist to reclassify the spirograms using the same criteria as we had defined them, but without knowing how they had been previously classified. This project was performed by Gladys Dart, Senior Pulmonary Technician, under the direction of Dr. Giles Filley, at the University of Colorado Medical Center's Webb-Waring Lung Institute. This trial study was a success: it yielded a concordance greater than 95 percent between the two independently classified sets of spirograms. This was a critical stage in the life of the project: if this independent assessment had revealed a marked disagreement between the two expert readers, subsequent analyses would have been futile.

CRITERIA FOR MERGING THE DATA CLASSES

Having created the four classes of data, it was necessary to evaluate them in terms of acceptability: that is, which of the data classes were good enough to be considered as valid estimates of the best efforts (and/or true physiologic capacity) of the children?

At this point, the authors were faced with a problem of the cost/benefit nature which was a hallmark of the entire project. To have thrown out too large a portion of the available data would have severely weakened our confidence that the remaining sample represented the U.S. population of 6-11-year-olds. To have kept too large a portion of the available spirograms would have made the technical quality of that sample highly suspect; so the solution was to strike the most satisfactory balance between quality and quantity (i.e., spirometric quality and sampling quality).

In order to achieve an optimal balance for the best possible population estimates, a variety of distributions was examined to determine the kind and extent of differences between the classes. In particular, differences were sought between quality classes of FVC and $FEV_{1.0}$, by region, income, education, IQ (as measured by the Wechsler Intelligence Scale for Children), and stature. All of these distributions were further crossed by age, race, and sex to insure that any differences detected could be attributed as specifically as possible to their source. Partial tabulations for some of the more important variables involved in this massive effort can be found in tables 1-9.

The distributions by region, income, education, and IQ did not differ between classes in any regular fashion, nor did mean statures differ significantly. There were no consistent differences between means of the FVC's and $FEV_{1.0}$'s for any of the classes where these data existed.

The only important differences were found between the classes I, II, and III and class IV data (which contained cases with missing tests and tests of no clinical value) where substantial age, race, and sex effects were demonstrated. The percentage of each age group in class IV declined with increasing age, from a maximum of 26.4 percent for 6-year-olds to a minimum of 12.1 percent for 11-year-olds. Also, 22.3 percent of the black children fell in this class, while only 15.7 percent of the white children were included here. The difference in proportion by sex was small (17.0 percent for females versus 16.2 percent for males), but in the expected direction. This class was later subjected to an intense and lengthy scrutiny in an attempt to discover causative factors which might account for a subject's inclusion in class IV. Although class IV children differed from those in classes I-III on several variables (e.g., they were slightly shorter than their cohorts), no factor or combination of factors was found that exclusively identified class IV children. Consequently, it was not necessary to modify the imputation procedure to adjust for any unique characteristics of this group.

Classes I, II, and III were essentially alike demographically and physiologically. Class IV alone was different.

The final decision, then, was to combine classes I and II as our basic working data set. The data in class III were less than 2 percent of the original sample but evidenced a serious methodological failing. The spirometric values for these 134 subjects were discarded and later replaced by imputed values, as was the case for all class IV subjects.

STRENGTHS OF THE DATA

Despite the known deficiencies of these data the distributions of the component parameters of the forced expiratory spirogram are the most representative population estimates ever obtained on children. The 7,119 children examined in HES Cycle II are representative of 23,784,000 noninstitutionalized children, ages 6.0 to 12.0 years residing in the coterminous United States in 1963-65. In addition to the enormous sampling strengths of these HES data, a large battery of psychologic, physiologic, anthropometric, demographic, and sociologic data were also available for each person. This mass of additional information contributed immeasurable strength to the data analysis since it permitted the development of FVC and $FEV_{1.0}$ data using imputation techniques on those 1,316 subjects who did not have acceptable spirometric data; and, of course, these variables can be cross-tabulated and correlated in detailed analyses.

Several methods of imputation were considered, but stepwise multiple regression was chosen as most appropriate for FVC and $FEV_{1.0}$. The appendix in the Series 11-No. 164 paper on children's FVC[1] includes a detailed description of the rationale and details of this imputation process. The 5,803 cases with acceptable spirometric values were the data base upon which the imputed values were generated.

It was determined that from the many physiologic and demographic variables available as regressors, 37 of these (see section on imputation in appendix of reference 1) might manifest significant correlations with the spirometric parameters. The values for these 37 independent variables and the two dependent spirometric variables were input to a packaged multiple stepwise regression procedure, and the equations in the appendix of reference 1 were the result.

After the FVC's and $FEV_{1.0}$'s were imputed for the 1,316 subjects who did not have acceptable spirometric data, the validity of the imputation process was verified in the several ways just described. Distributions of the imputed values by age, race, and sex were compared with those of the basic data set of 5,803 (i.e., "acceptables" population) and no significant differences were shown by the sign test at the 5-percent level. Nor were there any significant differences when these distributions were further crossed by sitting height (the first variable to be included in both equations). There were no apparent differences in the relationships by age, race, and sex between the imputed and nonimputed data sets within classes.

Combining the data sets resulted in age-race-sex *specific* mean values very similar to those of the original nonimputed data set. However, the mean values for *combined* age or race or sex groups were reduced somewhat. This would be expected since younger children, females, and Negroes (all of whom tended to have lower values than their respective complements) were overrepresented in the "unacceptables" class. Consequently when the data sets were combined, more lower values were added to the final data set than higher ones, thus lowering any overall statistics that did not control for age or race or sex effects.

COMPARISON WITH OTHER DATA

Of course, comparison with data from other studies is one of the important steps in validating one's own data but such a comparison was almost impossible in 1970 and 1971. The published data on spirometry in children was then and remains now sparse, with conflicting estimated values and of quite uneven quality. Besides the paucity of solid comparative data, the important distinctions between data collected in a survey and those collected in a laboratory are sometimes ignored. (However, because of vast improvements in electronic equipment and development of spirometric technique in a survey setting, these differences are not as great now as they were before 1970.)

In general, spirometric data obtained in a clinical laboratory setting have two distinct advantages: a better motivated and more willing subject on the one hand, and time and opportunity to establish rapport, give more thorough instruction, with better opportunity of obtaining a valid test, on the other hand. Most people coming into a laboratory are usually there for a specific purpose and have something to gain by undergoing the tests. Time is available to individually explain and demonstrate the test procedure in as much detail as necessary and to run through several practice procedures. The subject may return another day for additional trials, if necessary. In addition, *the subjects are selected*: they self-select themselves to come to that particular laboratory and because the laboratories are not trying to obtain representative population samples they can simply discard bad data. They will exclude from their "normal" values people with very low IQ's, the hostile, the indifferent, the suspicious, the frightened, and any others who are either incapable or unwilling to give a satisfactory test response even after repeated attempts. Additionally, because most subjects' procedural errors give underestimates, and the errors are additive, especially in the parameters involving volume measurements, there is a general rule of thumb: all else being equal, the larger of two volume measurements on the same subject is likely to be the more accurate. (This special set of circumstances tends to increase the clinical laboratory spirometric values over those obtained in a survey setting.)

An unusually comprehensive and very useful handbook of laboratory techniques, "Pulmonary Function Testing in Children: Techniques and Standards," by Polgar and Promadhat was published in 1971.[15] However, in a section entitled, "Standard Values," Polgar and Promadhat ambitiously attempted to bring together most of the early literature on childhood spirometry and synthesize the findings into one set of composite standard values. They were prompted to such an effort by the realization that so-called "normal" values from the various individual studies could not be considered representative of general population values. By combining the various studies they had hoped that the composite normal predicted values might take on more of the characteristics of a representative sample that could be generalized to all children. This hope was not realized.

For vital capacity, data on 45,000 subjects between the ages of 3 and 19 years were assembled. Children comprising the test populations came from schools, orphanages, and hospitals, and originated from nine different countries of four continents. Although all measurements were made on wet systems, there were enormous and immeasurable variations in both the characteristics of the instruments, in testing methodologies, and measurement techniques among the various laboratories. Although the majority of measurements were made in a sitting position, several were made either in the semirecumbent or standing positions. All semirecumbent values were corrected to sitting position vital capacity values before being averaged with standing values. Data were corrected to BTPS. The composite mean FVC's are 100-150 ml higher than those observed by this survey for children of the same age and sex.

Polgar and Promadhat did not satisfactorily distinguish between survey and laboratory data nor did they consistently define important differences in technique when combining and adjusting data. This makes precise comparisons with their data very difficult. But more restrictive as reference data was the statistical handling and presentation of the data.

For example, when the mean FVC values from HES were directly plotted onto the graphs as taken from the book,[15] the HES means were at the line designated as 2 standard deviations below the "Polgar composite means." After several hours' work, we were able to reconstruct how the graphs were made: instead of using any estimate of variance from an actual study, the standard deviation was calculated using the summary means of the separate studies as data; consequently, rather than this being any measure of population variation, it was a standard deviation of means from various studies. Borrowing the standard error of FVC's from the HES data, it was then found that HES' mean FVC's were only 1 standard deviation less than Polgar's, rather than 2. Because of this evidence of a major statistical flaw and the fact that there is not enough documentation of other statistical techniques used attempting to arrive at the composite values, this section of the book cannot reliably serve for epidemiologic comparisons.

Polgar's published "normal values" would be more appropriately viewed as estimates representative of his own laboratory findings—for all their strengths and weaknesses. On the other hand, the remainder of the book has great value when used as a compendium of techniques employed in assessing all aspects of pulmonary function in children.

ANALYTIC PROBLEMS

The spirometric data obtained by this survey presented a series of problems so challenging and widespread in nature that a proper analysis required the use of a variety of analytic techniques and substudies and a great deal of time, patience, and effort to produce a report that might be both useful and informative. All of the various major problems were not immediately apparent; some only surfaced as the analysis proceeded.

Already detailed in this report was the problem encountered with initial measurement and review of the original 7,119 spirograms, and the remeasurement of several thousand spirograms that had been incorrectly measured. After careful development of volume and flow reliability criteria, all available spirograms were classified by quality. Verification of the classification system was accomplished by having a subsample of spirograms read and classified "blind" by a second expert spirometrist, as described earlier. The high level of concordance demonstrated (over 95 percent) encouraged the authors to continue with the analysis.

In spite of the care taken in this verification step, we knew that a residual group of procedural failings inherent in all the data would permanently defy adjustment. A practice trial, when done at all, had been frequently inadequate. Too few trials had been taken to insure a maximum effort. Since only the best trial was measured, intratrial comparisons were impossible. And finally, a strong possibility existed that some proportion of the subjects failed to reach their total lung capacity. (As will be discussed, the new visual criteria are vulnerable to this type of error; they are incapable of either detecting or adjusting minor errors of this type.) In the absence of further research in these areas, a quantification of these effects is impossible.

The next major project was the evaluation of the newly classified data set in order to optimize merging and to determine the validity of merging the classes. As described previously, this analysis revealed no marked differences between the groups where spirometric data were available. The greatest sample size (n = 5,803) was achieved with the least dimunition of quality by combining classes I and II. This data set was used to generate equations to impute spirometric values for the 1,316 subjects who didn't have acceptable spirograms. An earlier section has described the procedure used to impute the FVC, $FEV_{1.0}$, and $FEF_{25\text{-}75\%}$ measurements for the 1,316 subjects, and the verification of that procedure.

During the analysis and development of the spirometric population estimates, serious problems with the $FEF_{25\text{-}75\%}$ became evident. Regression lines of this variable against age were extremely unstable, particularly for blacks and younger children. No immediate explanation for this behavior could be found; but when digging deeper for answers, several more immediate problems with the two other parameters were uncovered: (1) A large proportion (28 percent) of the original sample (n = 5,803) had an FVC equal to $FEV_{1.0}$ (i.e., the forced expiratory spirogram was completed in less than 1 second and hence, for these subjects, the $FEV_{1.0}$ is a meaningless parameter because the required time duration is too long); this defect was sex-race-age related (i.e., girls, Negroes, and younger children were overrepresented). (2) The mean FVC's by age, race, and sex are probably underestimated. The effect of these problems on $FEF_{25\text{-}75\%}$ are explained in the following section, "Interaction of Volume and Flow," but their significance to the entire data set transcends their effects on $FEF_{25\text{-}75\%}$.

A study was immediately undertaken to determine if this FVC-$FEV_{1.0}$ phenomenon was the result of the subjects' failure to reach residual volume (RV) because of premature termination of expiratory effort, and, if so, to quantify its contribution to underestimating FVC for the data set. (A more detailed description of this and subsequent substudies follows in a later section.) To this end, a proportional sample of the available tracings was reevaluated by two expert spirometrists paying special attention to the terminal end of the curve.

Two more substudies were also performed to provide an accurate idea of the distribution of valid FVC_T's, particularly the proportion less than 1 second. The first, conducted on a very small sample, under optimal conditions, confirmed that a valid FVC_T of less than 1 second was possible in children of this young age. A second, larger sample provided a distribution of FVC_T's, and also provided FVC and $FEV_{1.0}$ data for comparison both with the HES estimates and Polgar's published values. Finally, a fourth substudy was performed to measure the effect on TLC of having used the "closed" versus the "open" system during inspiration in Cycle II.

Before describing the details of the substudies, it is necessary to understand some of the complex interactions of the lung function measurements that are produced by variations in the performance of the forced expiratory spirogram.

Literature dealing with the performance of the FES frequently ascribes certain component measurements as being either effort dependent or independent. Such statements need to be viewed with caution because specific dynamic test conditions must first exist before claims of effort independence can be made; viz, an FES maneuver performed by a normal lung gives a true measure of vital capacity only if the inspiratory phase is taken completely to the total lung capacity (TLC) *and* the expiratory phase to residual volume (RV). The failure to achieve either parameter causes an underestimate of the true vital capacity and distorts almost all of the component dynamic measurements of flow rate.

INTERACTION OF VOLUME AND FLOW

The morphology of the FVC curve is a sensitive indicator as to whether or not the RV was reached by the pattern described by airflow because it proportionally diminishes until residual volume is achieved. The airflow from the gradually smaller airways in the peripheral portions of the lung is characteristically displayed by a smooth decay curve that finally plateaus at RV. Absence of this terminal decay curve is strong evidence that the expiration was terminated prior to reaching RV (figure 5), caused either by abrupt closure of the glottis or by cessation of expiratory effort.

Unfortunately, no accepted criteria have been developed that permit a similar visual assessment to be made as to whether or not the TLC was achieved during the inspiratory phase of the test. Both errors (failure to reach TLC and failure to reach RV) not only reduce the FVC but may also reduce the forced expiratory volume at various time intervals (FEV_T). Either one of these procedural errors, in addition, effectively compresses the volume displacement between the onset of the curve and its termination, and spuriously elevates these FEV_T/FVC ratio measurements. Such distortions destroy the sensitivity of these measures of airway resistance.

In the section on technical background, the concept of critical flow and its importance to the validity of flow-rate measurements has been discussed. If the FES is correctly performed and critical flow is achieved, then measures of flow rate are accurate (i.e., $FEF_{25\text{-}75\%}$). However, if the FVC is attenuated due to failure to come to TLC or expire to RV, flow rates will be either erroneously high or low, even in the presence of critical flow (see figure 5). When the FES is performed correctly, the $FEF_{25\text{-}75\%}$ measurement falls within that part of the curve considered to be in critical flow (phase II). However, when RV is not achieved, this flow measure is pushed higher up the FES curve which includes a larger percentage of phase I of the spirogram. This now artificially elevated flow rate picks up another undesirable characteristic, that of variability, since it is computed using in part the highly variable (effort-dependent) portion of phase I. An opposite effect, however, takes place when fail-

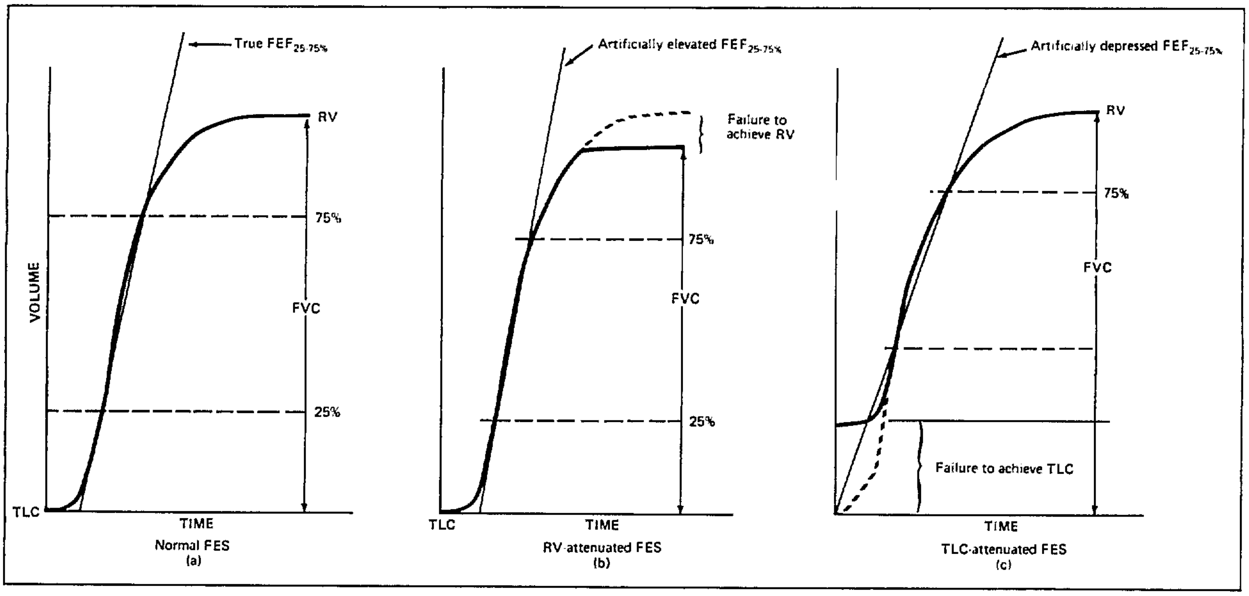

Figure 5. Effect of TLC and RV attenuations of FES on $FEF_{25\text{-}75\%}$ measure of flow rate. (Note increased slope of flow-rate line in (b) and decreased slope of flow-rate line in (c) as compared with (a))

ure to reach TLC causes an attenuated FES. The flow-rate measurement is pushed down the curve so that it now includes not only phase II, but some of phase III as well. This effectively reduces the flow rate, and also adds stability to the measurement since both phases II and III are included in the less variable effort-independent portion of the curve. Paradoxically the distortion to $FEV_{25\text{-}75\%}$ is less if *both* errors are committed on the same trial: in other words, these two effects are counterbalanced and somewhat neutralized when an attenuated FVC has equal components of both procedural errors.

Current practice attempts to get around this problem by use of an iso-volume curve whereby a resting vital capacity is obtained independently on one trial and then partial expiratory efforts are subsequently obtained and measured in the context of the resting vital capacity.

SUBSTUDIES

Miscellaneous Substudies

The first of the substudies was designed to closely examine the phenomenon of the $FVC = FEV_{1.0}$, and to determine its effect on the main body of the data.

A systematic subsample of 205 subjects from the 1,624 HES subjects with $FVC = FEV_{1.0}$ data was chosen and was found to be representative of its parent group for the variables of age, sex, and race. These data were intensively reviewed by Drs. Alan Palmer and David Discher to determine the extent and cause of the $FVC = FEV_{1.0}$ phenomenon. There was a working hypothesis based on the belief that all children should be able to maximally expire for more than 1 second. On this assumption, any spirogram with an $FVC = FEV_{1.0}$ would be prima facie evidence that the test effort had been incomplete due to failure to reach residual volume which prematurely truncated the decay curve and would therefore be technically unacceptable. The consequences of such a finding would have been threefold:

1. It would go a long way toward explaining the apparent FVC underestimates.
2. It would explain why $FEV_{1.0}$'s were more similar to FVC's than was reasonable, particularly for the younger ages.
3. It would partially explain the erratic behavior of the flow-rate data (as explained in the previous section). Conversely, such a finding would have had a very serious implication, so serious as to challenge the validity of the entire research effort to that date. Specifically, it would have discredited the entire spirometry classification system that had been created by evidencing that a high percentage of truncated spirograms had slipped by the rigorous screening procedures used to preclude invalid tests.

Prior to the reexamination and classification of the 205 spirograms, a set of morphologic criteria was developed that permitted consistent decisions on the technical quality of the terminal portion of the recorded FES. Pattern-1 spirograms included all of those which, upon visual inspection, contained all three spirometric phases, particularly a terminal section (phase III) that showed a smooth deceleration of volume over time, to an eventual plateau (zero change in volume). Figure 6(a) demonstrates two commonly seen decay patterns, both acceptable as pattern-1 spirograms.

Pattern-2 spirograms differed by having a premature termination of airflow during phase II or III of the curve indicating that the test subject had locked the glottis, thus forcing an abrupt deceleration of airflow to zero. The sudden plateauing of the volume signal with no intervening decay section was considered evidence that the residual volume (RV) was probably not attained; therefore, the test was declared to be artificially attenuated. Figure 6(b) shows the morphology of unacceptable pattern-2 spirograms. Pattern-2 morphology, of course, can also exist in spirograms with an FVC greater than 1 second, but because this subsample was limited to those spirograms with an FVC less than 1 second, none was encountered in this investigation. To extend the reexamination for all pattern-2 errors in the entire remaining data set (n = 5,598) would have been prohibitively expensive in time and cost.

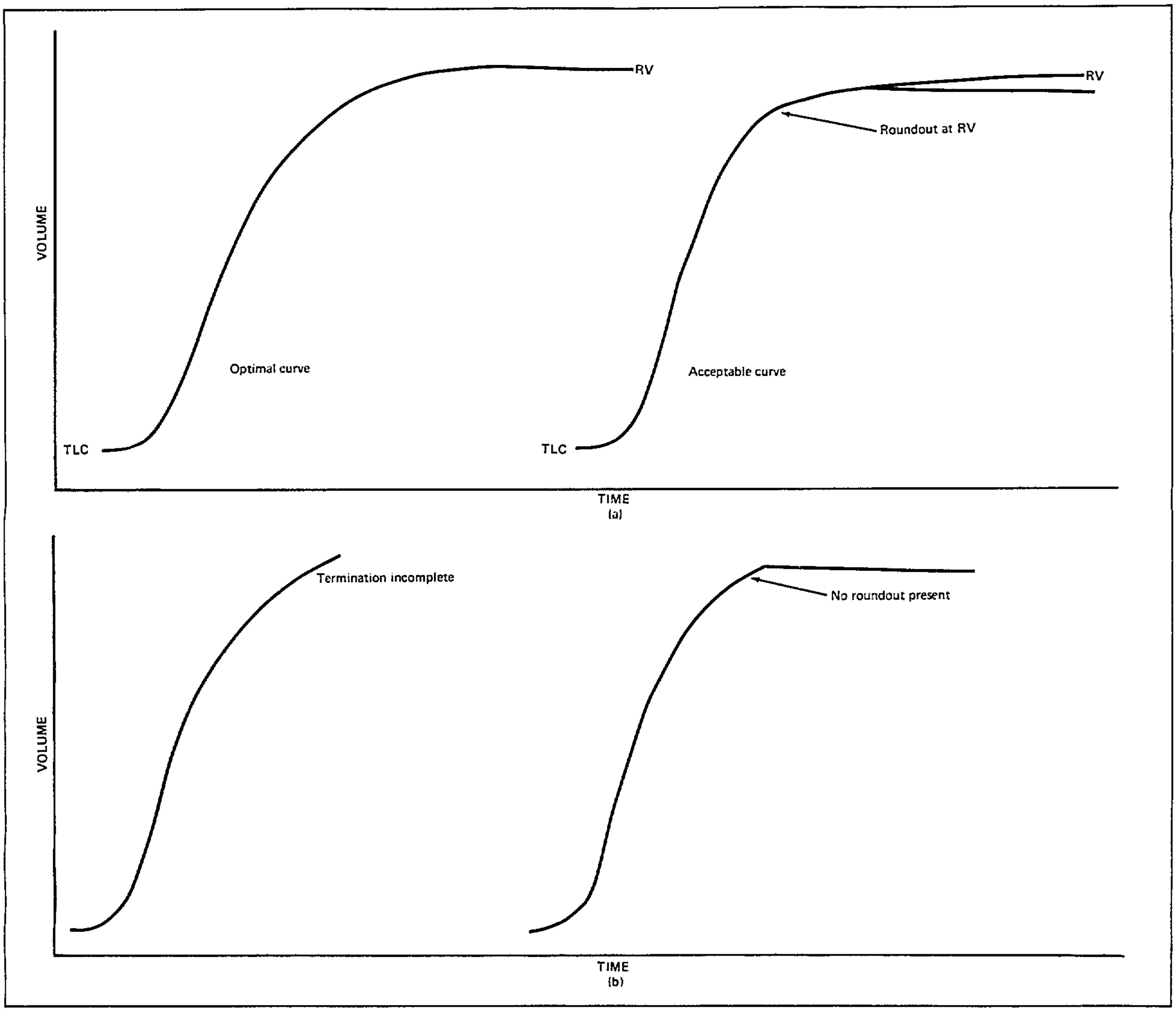

Figure 6. FES curves: (a) pattern 1—acceptable decay curves; (b) pattern 2—curves prematurely terminated. (Note that decay curves are incomplete or absent)

This investigation had surprising results: only 18 percent (n = 36) of the 205 subsample spirograms had a pattern-2 morphology! This unexpectedly small percentage of RV-deficient spirograms, although forcing a drastic reassessment of our assumptions and further investigations, did vindicate the visual classification system which we had devised. (The prevalence of the pattern-2, premature termination of expiratory flow error probably far exceeded 50 percent in the group of spirograms earlier discarded as technically unsatisfactory.) Because in larger spirograms it is easier to detect pattern-2 errors, and because the larger FES tends to indicate a better performance containing fewer technical errors, it would be unreasonable to assume a prevalence of greater than 18 percent in the larger part of the data set (i.e., in which FVC is greater than $FEV_{1.0}$ or 1-second duration). Therefore 18 percent (15-20 percent) appears to be a sound estimate of the prevalence of pattern-2 errors in the data set.

The pattern-2 curves were then reviewed to quantify the amount of underestimation of the FVC due to truncation by use of a technique known as the measurement of the "angle of incidence." This procedure required that at least three-fourths of the decay curve be present on the trial measured, and that another trial belonging to the same subject be present with a full decay. (The latter requirement is helpful in determining the shape of the estimated decay curve.) The difference in millimeters between the estimated (extrapolated) FVC and the observed FVC was determined and expressed as a percentage of the observed value (figures 6(a) and 6(b)).

This technique projected underestimated volumes ranging only from 3 percent to 7 percent, averaging about 5 percent.

A 5-percent underestimate occurring in approximately one-fifth of the data set at the most would result in the contamination of the final data set by pattern-2 errors causing only 1 percent or less underestimate of the average FVC.

The unexpectedly small frequency of pattern-2 curves and their small magnitude of underestimate strongly suggested that most of the problem was probably due to technical errors committed at the beginning of the spirogram rather than at the terminal part. This conclusion appears even more plausible after careful review of several separate items of data, i.e., the distribution of $FVC = FEV_{1.0}$, the distribution of pattern-2 obtained from this substudy, and the patterns of the regression lines of the flow rate. The most frequent occurrence of the $FVC = FEV_{1.0}$ phenomenon was seen to occur in the youngest age groups (6- and 7-year olds) in females and among Negroes. Since most of the pattern-2 data were seen to occur in 8- and 9-year-olds, in this subsample it can be conjectured that much of the attenuation of FVC values for 6- and 7-year olds seen in this main data set was caused by failure to achieve TLC.

Coefficients of variation derived from data in tables 10 and 11 show that flow rates for Negroes are extremely variable between the ages of 6 and 8, and this is also true, to a small extent, for white females. Because of the effect on flow rates of the reduced FVC (as discussed), the erratic pattern of the curves may be the result of both types of FVC errors perturbating the estimated flow rates.

The failure of this substudy to adequately explain the cause of the high percentage of data in which FVC equals $FEV_{1.0}$ and low FVC values in the HES sample indicated the need to pursue the following additional questions:

1. Is the assumption that almost all young children should be able to maximally expire for more than 1 second correct? In other words, is it possible to obtain an optimally performed FES, where all test criteria have been met (TLC, critical flow, and RV), with attainment of a proper FVC, in less than 1 second?

2. If so, what is the expected frequency of $FVC = FEV_{1.0}$ in the youngest children?

3. What is the expected distribution of FVC_T by age (i.e., the shape of the distribution curve and the actual time values as obtained under ideal testing circumstances)?

(To go back and remeasure each time duration accurately by hand on 5,803 Cycle II tracing would not only have been an enormous logistic task but it would have also begged the question: "Do these FES tracings in Cycle II represent ideal or even adequate testing circumstances—even after all of the work to screen out the bad trials?")

In order to answer the first question, we had to find one or more children over 6.0 years of age who, under optimal testing circumstances, and in the opinion of highly skilled spirometrists, completed a proper FES in less than 1 second. (Corollary: No matter how hard and effectively the children tried, their physiologic ventilatory capacity could not sustain an effective expiratory effort, even after maximal inspiration, for 1 second.) In testing 10 conveniently available children between 6 and 8 years old, one child was found to clearly and unequivocally meet these conditions. This finding, of course, negates the working hypothesis (stated above) that all spirograms with FVC_T less than 1 second are, prima facie, technically inadequate *spirograms* in children over 6 years of age.

Salt Lake City Substudy

With this information, a second study was devised to answer the second and third questions using an at-hand sample of 79 six- and seven-year-olds. The survey was performed by highly competent technicians on equipment capable of producing the same parameters that were earlier measured. A number of factors combined to make this testing situation almost unique: (1) The technicians who did the testing were very knowledgeable, very well trained, and highly skilled in administering the FES pulmonary test. (2) The equipment on which the FES was taken was of the most modern design, reflecting every advance in the state of the art. (3) Because the children were from two classes in the same grade at the same school, a lot of the anxiety which typically vitiates performance on the FES was absent; i.e., there was a good deal of peer support and friendly competition. (4) The data collected were analyzed by the most modern computer analysis program available, reflecting every advance in the science of spirometry up until the present. (5) All the data were collected in a very short time, a single day. This circumstance contributed to the overall quality of the data by providing a great deal of consistency insofar as barometric pressure, temperature, technician performance, and other factors were concerned. (6) Where only three trials, at the most, were taken in the HES, five trials were taken on the 79 children, and as might be expected, performance generally improved with the increased number of trials, due to a practice (or learning) effect.

Since the new spirometric data were to be compared with the HES spirometric data, it was important to eliminate (or at least quantify the effects of) differences in factors that might have influenced spirometric performance. For instance, the data indicated that the race and sex compositions of the two samples were different and it may or may not have been necessary to compensate for the dissimilarities.

Relevant factors may be of two general kinds, demographic or physiologic. While a large amount of this type of data was available for each of the HES subjects, relatively little was collected on the 79 subjects who were all white and residents of a Salt Lake City (SLC) suburb. Among demographic data available for the latter group were age, race, and sex, and some fairly substantial data concerning the socioeconomic status of the group as a whole. The only independent physiologic variable measured was stature. Preliminary demographic distributions for the SLC sample are given in table A.

It has been demonstrated that age, sex, race, stature, and to a lesser extent, socioeconomic

Table A. Frequency distribution of standing height, by age, sex, and sex and age: Salt Lake City, 1974

Age, sex, and sex and age	Standing height in inches											
	Total	42	44	45	46	47	48	49	50	51	52	53
Total	79	1	5	1	8	11	17	11	13	9	2	1
Age												
6 years	30	-	3	-	4	8	5	5	3	2	-	-
7 years	49	1	2	1	4	3	12	6	10	7	2	1
Sex												
Male	35	-	1	-	6	6	7	4	7	4	-	-
Female	44	1	4	1	2	5	10	7	6	5	2	1
Sex and age												
Male, 6 years	15	-	1	-	3	4	3	2	2	-	-	-
Male, 7 years	20	-	-	-	3	2	4	2	5	4	-	-
Female, 6 years	15	-	2	-	1	4	2	3	1	2	-	-
Female, 7 years	29	1	2	1	1	1	8	4	5	3	2	1

indicators are all related to spirometric performance.

Age.—It has been noted that for children there are positive relationships between age and FVC and age and $FEV_{1.0}$. The mean age of SLC and HES 6- and 7-year olds are:

Study	*6 years*	*7 years*	*6 and 7 years*
SLC	6.80	7.30	7.12
HES	6.50	7.50	7.00

Treating the two age groups separately would require estimating the adjustments necessary to make the two samples comparable. But the differences between the combined age groups were relatively slight, so the age groups were combined, and the comparisons were made between two groups rather than among four groups.

Sex.—The relationship between sex and spirometric performance (at least in adults) is that males have greater values than do females, given the same structure and age. The two samples are compared as follows:

Study	*Males*	*Females*
SLC	44.3%	55.7%
HES	50.8%	49.2%

The mean statures and ages by sex for the SLC sample were:

Age and stature	*Males*	*Females*
Mean age in months	85.1	85.6
Mean stature in inches	48.3	48.2

Although the proportions by sex for the two groups are not precisely comparable they are fairly close. Within the SLC sample the sexes are essentially identical as far as age and stature are concerned.

Race.—This variable was related to spirometric performance. Negroes did significantly less well than whites on both FVC and $FEV_{1.0}$. The SLC group was all white, but since the percent of blacks in the HES sample was relatively small (10 percent), no attempt was made to adjust for differing racial comparisons.

Stature.—This variable is highly and positively related to both FVC and $FEV_{1.0}$ ($r = 0.69$, 0.67, respectively). Although HES data indicate that sitting height may be a slightly better predictor of these parameters (and in fact may eliminate much of the race effect), it was not measured on the SLC children. The mean standing height of the SLC sample was 48.27 inches with a standard error of 0.243 inch, while that of the HES sample was about 47.68 inches with a standard error of about 0.103 inch. The two means were not significantly different at the 5-percent level, but the difference of about 0.6 inch is worth noting. The difference may be a function of the secular trend for mean heights of children to increase with the passage of decades[16] and there was a 10-year lag between the HES and SLC studies. Using a regression line published by HES earlier,[17] it is possible to estimate this effect to be about 0.5 inch. The differences may also be partially explained by considering that all the SLC subjects were volunteers, while some of the HES children were examined only after strenuous persuasion. Finally, standing height is significantly related to the last effect to be considered.[4]

Socioeconomic status.—Using published HES estimates,[17] we know that there is a positive relationship between height of child and parental income and between height of child and parental education.[5] For instance, the mean height of a 6-year-old whose family's income is \$500-\$999 is 45.2 inches, while that of a 6-year-old whose family income is \$15,000 or more is 47.1 inches. It is quite conceivable that much of the observed height difference between the two samples can be accounted for in this way, since the SLC suburban residents were somewhat more affluent than the general U.S. population, being composed primarily of professionals associated with the University of Utah and "corporate executives." It is known that the median income for the HES sample was in the \$5,000-\$7,000 range and that the 6- and 7-year-old boys and girls in this category had mean heights, respectively, of 48.03 and 47.34 inches.[17] On the other hand, the SLC sample would correspond best to the \$10,000-\$15,000 range, for which the mean heights were about 48.13 and 47.93 inches. The weighted HES mean for boys and girls combined was 47.71 inches, while that for the SLC distribution applied to the HES means was about 48.02 inches. The conclusion reached was that socioeconomic differences might account for about half the observed difference in standing height between the two samples.

Figures 6 and 7 in reference 1 show the regression of FVC against standing height. Although the values themselves may be suspect, the depicted slopes are probably near the truth, so that the graph can be used to determine what effect the various height differences have on the mean overall FVC's. Since the lines are nearly linear and parallel, any two height benchmarks uniformly applied to each line will describe the same difference in FVC. Using the overall mean heights for HES and SLC, 47.63 and 48.27 inches, respectively, a net difference of about 40 ml is noted.

Best trial selection, SLC.—Prior to displaying the distributions of the FVC_T's and FVC's, and $FEV_{1.0}$'s of the SLC sample, some mention should be made of the manner in which the best of the five trials of each SLC subject was chosen. Although the procedure has been described elsewhere,[6] a brief review follows to help the reader understand the subsequent discussion.

Predicted values for FVC and $FEV_{1.0}$ were calculated for each subject, based on equations found in the Journal of Occupation Medicine, September 1972, in an article entitled "Development of a New Motivational Spirometer."[6] Although these equations are intended for use with adults only, the use of any constant works equally well for the best trial selection procedure.

Standard deviations from the predicted values were calculated for the FVC and the $FEV_{1.0}$ of each of the five trials.

The two z values were summed for each reliable trial, and the trial with the most positive sum was declared the best.

Best trial selection, HES.—For the HES data, the better trial from the two (or best trial of three) available tracings was selected by a highly experienced spirometrist after being subjected to the consistency criteria described earlier in this report. Both the SLC and HES procedures evaluated the spirographic curves in terms of the same criteria; i.e., maximum FVC, maximum flow rate, and some measure of consistency, so that "best trials" were selected in a comparable manner.

The distributions of FVC_T's for the SLC sample are shown in table B. Only 4 of the 79 cases (or 5.1 percent) had an FVC time less than 1 second. This compares very unfavorably with the HES value of 709 out of 1,784 six- and seven-year-olds (39.7 percent). The z value of the significance test for the difference between the two proportions is 12.662, more than enough to reject the null hypothesis of no difference ($p < .0001$).

So, what has happened? The first conclusion that comes to mind is that a mass screening mechanism such as the Health Examination Survey fails to elicit the same quality performance from a group of examinees as did the optimal testing situation (SLC). But examination of other data suggests additional possibilities. Of particular interest is the possibility that a practice effect exists; i.e., a subject becomes more familiar with the test with repeat trials and con-

Table B. Frequency distribution of FVC_T (best of five trials), by age and sex: Salt Lake City, 1974

FVC_T	Age of children			
	6 years		7 years	
	Male	Female	Male	Female
Total	15	15	20	29
0.8-0.9 second	-	1	-	1
0.9-1.0 second	1	1	-	-
1.0-1.1 seconds	1	1	1	2
1.1-1.2 seconds	2	1	-	-
1.2-1.3 seconds	2	-	1	1
1.3-1.4 seconds	1	1	-	1
1.4-1.5 seconds	-	1	-	1
1.5-1.6 seconds	1	-	2	4
1.6-1.7 seconds	-	2	2	1
1.7-1.8 seconds	1	2	1	1
1.8-1.9 seconds	1	-	1	3
1.9-2.0 seconds	2	-	-	5
2.0 seconds and over	3	5	12	9

sequently does better on later trials. The distribution of the number of the best trial was tabulated to investigate the question:

Best trial	*Percent of occurrence*
1	6.3
2	19.0
3	12.7
4	22.8
5	39.2

Thus 74.7 percent of best trials were third, fourth, or fifth. And since the HES used only two or three trials, it is evident that as much as three-fourths of the time even the best of the recorded HES trials did not reflect the child's true capability, in spite of having achieved a visual level of reliability.

In the SLC data, the better of the first two trials was chosen by the "sum of z's" method (after all subjects with unreliable pairs of trials had been rejected), and FVC_T's were tabulated. (See table C.)

This resulted in 9 out of 59 (15.3 percent) subjects having FVC_T's less than 1 second. The z value for the difference of the SLC and HES proportions (39.7 percent and 15.3 percent) is 4.821, while the z value for the difference between the two SLC proportions (15.3 and 5.1 percent) is 1.924. The first is significant at the 1-percent level, while the second is significant at the 10-percent level.

Table C. Frequency distribution of FVC_T (better of first two trials): Salt Lake City, 1974

FVC_T	n	Percent	Cumulative n	Cumulative Percent
0.7-0.8 second	2	3.3	2	3.3
0.8-0.9 second	3	5.1	5	8.4
0.9-1.0 second	4	6.8	9	15.2
1.0-1.1 seconds	1	1.7	10	16.9
1.1-1.2 seconds	3	5.1	13	22.0
1.2-1.3 seconds	4	6.8	17	28.8
1.3-1.4 seconds	2	3.3	19	32.1
1.4-1.5 seconds	3	5.1	22	37.2
1.5-1.6 seconds	2	3.3	24	40.5
1.6-1.7 seconds	3	5.1	27	45.6
1.7-1.8 seconds	6	10.2	33	55.8
1.8-1.9 seconds	3	5.1	36	60.9
1.9-2.0 seconds	5	8.5	41	69.4
2.0 seconds and over	18	30.5	59	99.9

NOTE: n = sample size.

The mean values of FVC and $FEV_{1.0}$ also demonstrated that the SLC children were very unlike the HES sample in terms of spirometric performance. Using the better trial from only the first two of the five, the mean Salt Lake City FVC was 1,546 ml with a standard error of 30.38 ml. The mean Salt Lake City $FEV_{1.0}$ was 1,395 ml with a standard error of 49.05 ml. For the HES sample (n = 7,119), the mean values were 1,363 ml and 1,287 ml with respective standard errors of 6.3 ml and 5.8 ml. Significance tests comparing the FVC's and $FEV_{1.0}$'s both fell in the region of rejection, with z values of 5.89 and 2.18. It should be noted that the difference between the mean FVC's was almost 0.2 liter, while that between the mean $FEV_{1.0}$'s was nearer 0.1 liter. The greater difference in FVC's than $FEV_{1.0}$'s suggests that the HES trials were nearer termination by the time 1 second had elapsed.

Of primary concern in explaining the large differences between the HES and SLC spirometry means is the question of difference in testing milieu. Although the HES technicians were generally very competent and responsible, especially in body measurements and X-ray technique (by initial qualification they were all certified X-ray technicians), they were not highly trained spirometrists. In HES Cycle II, spirometry had not yet been given the importance it achieved in later HES work. Training and experience of technicians, sophistication and quality of equipment, and guidance-motivation monitoring were all at a much lower level than in SLC. Added to this, it seems likely that more than 7,000 examinations dulled the technicians' enthusiasm to some degree. In addition, the 2½-hour testing period (after a trip of from 15 to 45 minutes to the trailers) and the confusing and awesome array of examinations could bore, tire, and overwhelm the young child. Also, it became apparent, that, in spite of efforts to put the children at ease, they were sometimes intimidated by the new environment and the unfamiliar examinations. These effects were especially pronounced in the younger children.

The SLC children, on the other hand, were taken from their classes in school to the nearby examination unit, so were in more familiar surroundings. The children went in a school group so they had the enthusiasm and support of their peers. In fact, a good deal of competition developed among them, since the children entered the examination room in pairs, one to take the test and one to observe. They were spurred on by clearly excited, friendly, and extraordinarily knowledgeable and skilled technicians and a motivation mechanism called the "Motivational Assisted Spirometry System (MASS)," which was attached to the spirometer itself.[6] The spirometer used for the SLC study, although achieving the same end as that used in the HES, was by design more accurate and sensitive. Particularly, it minimized the initial mechanical inertia which tended to distort the early part of the curve, an important consideration since the curve tends to be rather short and of less mechanical force for 6- and 7-year-olds. These advantages and those mentioned earlier created an ideal testing situation.

In summary, it can be seen that the children in the Salt Lake City sample performed significantly better than those in the HES sample, both in terms of rate and volume-time-expiration. The comparison can be formulated in two ways: (1) the HES data versus the Salt Lake City "best of five trials" data (this is assumed to be an ideal condition because it permits each child to reach the maximum of his learning effect) and (2) the HES data versus the Salt Lake City "best of two trials" data (a more direct comparison because similar amounts of learning occur between the samples).

The first comparison demonstrates that the percentage of HES children having FVC_T's less than 1 second was almost eight times as great as that of Salt Lake City children having FVC_T's less than 1 second (39.7 percent versus 5.1 percent). Also, the mean Salt Lake City FVC (1,617 ml) was almost 19 percent greater than the mean HES FVC (1,363 ml), and the mean Salt Lake City $FEV_{1.0}$ (1,441 ml) was almost 12 percent greater than the mean HES $FEV_{1.0}$ (1,278 ml). Although the mean standing heights of the samples differed by about 0.6 inch, by the HES regression of FVC on height it is estimated that this difference accounts for less than 40 ml of the net FVC difference.

Using only two of the five Salt Lake City trials for the comparison reduced the differences somewhat. The percentage of HES subjects having FVC_T's less than 1 second (39.7 percent) was a little more than 2½ times as great as the percentage of Salt Lake City subjects having FVC_T's less than 1 second (15.1 percent). The mean Salt Lake City FVC was more than 13 percent greater than the mean HES FVC (1,546 ml versus 1,363 ml), and the mean Salt Lake City $FEV_{1.0}$ was more than 8 percent greater than the mean HES $FEV_{1.0}$ (1,395 ml versus 1,278 ml).

There seems to be little doubt, having found the samples quite similar in terms of relevant independent variables, that the spirometric differences are due almost entirely to differences in testing milieus. Perhaps the most important single factor is the greater opportunity available to the Salt Lake City subjects to achieve maximum learning, as demonstrated by the measurable and consistent differences between the "best of two trials" data and the "best of five trials" data just offered. This effect is more distinct in boys whose mean FVC increased from 1,543 ml to 1,649 ml with the three additional trials, than it is in girls whose mean FVC increased only from 1,549 ml to 1,594 ml, suggesting that girls in this age range either learn faster or fatigue earlier.

The Salt Lake City spirometry data collection was methodologically and mechanically superior to the HES spirometric operation in almost all respects: the equipment had less inertia and was more sensitive and accurate, the quality of encouragement, motivation and instruction was distinctly better, and the subjects had ample opportunity to achieve maximum learning. These factors all contributed to bringing the Salt Lake City children to a closer approximation of their true maximal effort and hence to a more accurate estimate of the physiologic parameter of interest, forced expiratory volume.

Annapolis Substudy

The methodology of the Salt Lake City substudy differed from that of HES Cycle II in one respect not yet evaluated. The HES subjects all inhaled through the spirometer hose after the bell was lifted to draw room air into the spirometer (called a "closed" system), while the SLC subjects all inhaled ambient room air (called an "open" system), which is the more commonly used technique. It was conjectured that the closed system might be inhibitory (a respiratory claustrophobia), because many children did not inhale maximally (and reach TLC) when they could not see the source of the inhaled gas. To test this hypothesis, a final substudy was performed on 22 six- and seven-year-old boys and girls enrolled in an Annapolis, Maryland, private school.

The children were first introduced to the subject of spirometry via a short classroom discussion of the objectives and a demonstration of the proper technique of the test. Pairs of children were then brought into the testing room, and the procedure was reviewed. Each child performed two complete sets of FES's, one with the open system and one with the closed. The spirometer used in this study was the same one used for almost half of the subjects in HES Cycle II, 1963-65. (After it was cleaned and recalibrated, its present performance was found to be identical to its Cycle II performance.) Half of the children did the open system first, and the other half did the closed system first. In all cases the children were allowed practice trials until Dr. Palmer, acting as the technician, felt that they understood the maneuver, and then up to four trials were performed. Measurements (in millimeters), from the tracings thus recorded and information on age and stature were the raw data of this study.

The mean age of the children was 6.71 years (many of the children were completing their second year of school). Their average stature was 124.2 cm, while for HES Cycle II the average stature for 6.7-year-olds was 119.4 cm. The mean FVC of all best trials on the open system was 1,528 ml, while the mean FVC of all best trials on the closed system was 1,541 ml. Of course, this minuscule difference is not significant at the $\alpha = 0.05$ level.

Males did slightly (but not significantly) better on the open than on the closed system, with mean FVC's of 1,643 ml and 1,637 ml. For females, the relationship was reversed, with the mean FVC for the open system (1,391 ml) insignificantly less than that of the closed system (1,428 ml).

The relationship of FVC and stature was very strong, $P < .01$, when the best trial by either system for each child was used. A 1-cm stature difference accounted for an FVC difference of about 35 ml. This value compares closely with that noted for HES of about 30-40 ml/cm.

A final observation concerns the difference between the mean male and female FVC values. Using the best observed trial for each sex (1,643 ml and 1,428 ml) a difference of 215 ml was obtained. However, there was also a 3.7-cm difference in mean statures (126.0 cm for males versus 122.3 cm for females), and applying the aforementioned 35 ml/cm adjustment factor reduces the mean FVC difference from 215 ml to about 85 ml. This value falls between the 55-ml difference estimated from the SLC study and the 150-ml difference estimated from the HES data.

This study provides the strongest possible demonstration that the difference in results from an open or closed system is totally negligible in children given an optimum testing environment and some preinstruction. Also, the similarity of mean FVC values between this substudy and the SLC substudy and the disparity between them and the mean FVC values of the HES provide further support for the hypothesis that the testing milieu is one of the most significant factors affecting FES performance in children (probably even greater than sophisticated electronic equipment).

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LIST OF DETAILED TABLES

Table 1. FVC of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65, unedited data

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
Total		Milliliters			Milliliters			Milliliters			Milliliters	
6 years	510	1,253	247	194	1,309	245	94	1,248	254	20	1,292	271
7 years	646	1,420	262	219	1,518	306	121	1,415	295	29	1,439	237
8 years	606	1,618	303	303	1,669	297	98	1,609	278	22	1,533	281
9 years	598	1,827	358	279	1,846	343	114	1,798	336	19	1,755	357
10 years	580	2,013	377	308	2,044	381	110	1,957	412	19	2,026	386
11 years	566	2,290	445	346	2,287	434	111	2,212	448	25	2,197	320
White												
6 years	446	1,268	247	171	1,309	242	80	1,270	255	19	1,296	278
7 years	554	1,446	259	195	1,538	303	112	1,435	290	27	1,429	242
8 years	512	1,653	296	263	1,694	294	77	1,642	272	18	1,568	297
9 years	513	1,847	353	246	1,877	345	104	1,826	328	18	1,788	335
10 years	502	2,050	368	269	2,070	374	100	1,987	392	17	2,041	392
11 years	496	2,332	437	289	2,335	422	96	2,259	431	21	2,195	344
Negro												
6 years	64	1,146	218	23	1,309	273	14	1,122	212	1	1,215	-
7 years	92	1,262	225	24	1,358	289	9	1,155	240	2	1,584	54
8 years	94	1,429	272	40	1,504	268	21	1,485	268	4	1,374	106
9 years	85	1,706	365	33	1,617	226	10	1,508	291	1	1,154	-
10 years	78	1,780	351	39	1,863	391	10	1,658	508	2	1,896	434
11 years	70	1,989	387	57	2.042	416	15	1,910	451	4	2,210	174
Male												
6 years	265	1,299	255	100	1,380	257	52	1,312	235	12	1,383	198
7 years	322	1,486	254	125	1,582	330	57	1,480	284	13	1,428	262
8 years	309	1,691	290	147	1,758	298	57	1,662	273	9	1,656	358
9 years	315	1,906	376	138	1,930	343	59	1,838	335	8	1,884	363
10 years	289	2,099	378	156	2,120	377	47	2,061	422	10	1,992	409
11 years	295	2,385	436	191	2,357	426	57	2,298	535	10	2,261	169
Female												
6 years	245	1,203	228	94	1,234	207	42	1,169	257	8	1,155	319
7 years	324	1,354	254	94	1,433	250	64	1,356	295	16	1,449	223
8 years	297	1,542	298	156	1,584	271	41	1,534	270	13	1,448	182
9 years	283	1,740	315	141	1,764	324	55	1,755	335	11	1,662	337
10 years	291	1,928	357	152	1,966	371	63	1,879	390	9	2,063	379
11 years	271	2,186	433	155	2,200	429	54	2,122	314	15	2,155	390

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 1. FVC of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65, unedited data—Con.

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
White male		Milliliters			Milliliters			Milliliters			Milliliters	
6 years	227	1,319	258	85	1,399	256	44	1,331	237	11	1,398	200
7 years	286	1,505	252	111	1,601	330	54	1,495	281	12	1,411	267
8 years	270	1,717	285	131	1,784	298	46	1,697	277	9	1,656	358
9 years	275	1,940	363	123	1,961	346	53	1,872	326	8	1,884	363
10 years	256	2,137	365	137	2,155	372	42	2,088	392	9	2,037	407
11 years	259	2,438	424	167	2,399	416	45	2,414	491	8	2,272	161
White female												
6 years	219	1,216	225	86	1,220	190	36	1,196	260	8	1,155	319
7 years	268	1,384	252	84	1,454	243	58	1,380	289	15	1,442	229
8 years	242	1,581	293	132	1,604	261	31	1,561	248	9	1,481	204
9 years	238	1,741	310	123	1,793	323	51	1,778	326	10	1,712	308
10 years	246	1,958	350	132	1,982	355	58	1,914	379	8	2,045	401
11 years	237	2,217	423	122	2,247	415	51	2,123	317	13	2,147	419
Negro male												
6 years	38	1,180	202	15	1,270	246	8	1,209	208	1	1,215	-
7 years	36	1,334	216	14	1,434	302	3	1,217	222	1	1,622	-
8 years	39	1,513	269	16	1,546	206	11	1,516	207	-	-	-
9 years	40	1,676	389	15	1,673	170	6	1,540	274	-	-	-
10 years	33	1,805	349	19	1,867	315	5	1,838	636	1	1,590	-
11 years	36	2,009	329	24	2,063	382	12	1,862	480	2	2,217	269
Negro female												
6 years	26	1,096	235	8	1,382	323	6	1,007	167	-	-	-
7 years	56	1,216	220	10	1,251	245	6	1,124	263	1	1,545	-
8 years	55	1,370	260	24	1,475	303	10	1,450	332	4	1,374	106
9 years	45	1,733	345	18	1,571	260	4	1,460	352	1	1,154	-
10 years	45	1,761	355	20	1,860	461	5	1,478	306	1	2,203	-
11 years	34	1,967	444	33	2,028	444	3	2,103	301	2	2,202	136

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 2. FEV_1 of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65, unedited data

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
Total		Milliliters			Milliliters			Milliliters			Milliliters	
6 years	510	1,188	238	194	1,229	226	94	1,160	232	20	1,216	253
7 years	646	1,344	244	219	1,423	275	121	1,351	262	29	1,380	211
8 years	606	1,513	272	303	1,544	268	98	1,494	257	22	1,441	236
9 years	598	1,684	321	279	1,713	307	114	1,636	327	19	1,594	281
10 years	580	1,839	344	308	1,844	353	110	1,805	345	19	1,770	399
11 years	566	2,062	406	346	2,073	389	111	1,961	389	25	1,888	444
White												
6 years	446	1,199	242	171	1,234	223	80	1,173	235	19	1,217	260
7 years	554	1,365	243	195	1,439	273	112	1,368	258	27	1,366	211
8 years	512	1,537	269	263	1,566	259	77	1,509	254	18	1,468	253
9 years	513	1,698	320	246	1,736	310	104	1,657	321	18	1,618	268
10 years	502	1,866	340	269	1,863	350	100	1,826	324	17	1,767	414
11 years	496	2,090	402	289	2,110	383	96	1,984	377	21	1,865	458
Negro												
6 years	64	1,113	186	23	1,195	250	14	1,087	209	1	1,192	-
7 years	92	1,220	211	24	1,287	263	9	1,138	225	2	1,572	38
8 years	94	1,380	250	40	1,401	283	21	1,438	266	4	1,324	50
9 years	85	1,597	312	33	1,544	219	10	1,422	321	1	1,154	-
10 years	78	1,665	318	39	1,719	350	10	1,600	485	2	1,796	355
11 years	70	1,862	378	57	1,887	364	15	1,811	446	4	2,010	389
Male												
6 years	265	1,227	250	100	1,279	237	52	1,202	227	12	1,296	128
7 years	322	1,400	237	125	1,475	302	57	1,408	245	13	1,375	242
8 years	309	1,576	260	147	1,621	246	57	1,542	242	9	1,498	316
9 years	315	1,733	336	138	1,782	294	59	1,676	315	8	1,720	291
10 years	289	1,901	344	156	1,880	348	47	1,903	342	10	1,658	425
11 years	295	2,124	390	191	2,103	381	57	1,958	451	10	1,753	541
Female												
6 years	245	1,146	215	94	1,176	202	42	1,109	231	8	1,096	348
7 years	324	1,289	238	94	1,353	219	64	1,300	269	16	1,384	190
8 years	297	1,447	269	156	1,472	268	41	1,427	265	13	1,402	164
9 years	283	1,629	294	141	1,645	305	55	1,593	336	11	1,502	246
10 years	291	1,776	332	152	1,808	355	63	1,732	332	9	1,894	350
11 years	271	1,994	413	155	2,037	396	54	1,964	315	15	1,978	357

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 2. FEV_1 of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65, unedited data—Con.

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
White male		Milliliters			Milliliters			Milliliters			Milliliters	
6 years	227	1,241	259	85	1,303	233	44	1,206	236	11	1,305	130
7 years	286	1,416	237	111	1,492	302	54	1,421	243	12	1,356	243
8 years	270	1,594	256	131	1,638	243	46	1,561	241	9	1,498	316
9 years	275	1,760	333	123	1,800	301	53	1,692	318	8	1,720	291
10 years	256	1,930	338	137	1,912	346	42	1,924	297	9	1,671	449
11 years	259	2,159	382	167	2,133	377	45	2,008	438	8	1,729	572
White female												
6 years	219	1,155	216	86	1,166	191	36	1,133	231	8	1,096	348
7 years	268	1,310	238	84	1,369	210	58	1,319	264	15	1,373	191
8 years	242	1,474	269	132	1,494	255	31	1,431	256	9	1,437	187
9 years	238	1,628	290	123	1,671	307	51	1,620	324	10	1,537	229
10 years	246	1,799	329	132	1,812	348	58	1,754	327	8	1,875	369
11 years	237	2,014	411	122	2,080	391	51	1,963	316	13	1,948	373
Negro male												
6 years	38	1,147	172	15	1,145	221	8	1,181	182	1	1,192	-
7 years	36	1,270	196	14	1,337	266	3	1,173	147	1	1,599	-
8 years	39	1,449	254	16	1,479	231	11	1,458	238	-	-	-
9 years	40	1,552	302	15	1,635	175	6	1,538	275	-	-	-
10 years	33	1,681	311	19	1,656	277	5	1,726	631	1	1,545	-
11 years	36	1,871	357	24	1,898	352	12	1,770	469	2	1,850	564
Negro female												
6 years	26	1,064	198	8	1,290	287	6	962	185	-	-	-
7 years	56	1,189	216	10	1,217	255	6	1,121	266	1	1,545	-
8 years	55	1,331	238	24	1,349	306	10	1,416	305	4	1,424	50
9 years	45	1,636	318	18	1,468	226	4	1,249	341	1	1,154	-
10 years	45	1,654	326	20	1,779	406	5	1,473	304	1	2,047	-
11 years	34	1,853	403	33	1,879	377	3	1,976	361	2	2,169	184

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 3. $FEF_{25-75\%}$ of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65, unedited data

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
Total		Milliliters			Milliliters			Milliliters			Milliliters	
6 years	510	1,769	497	194	1,742	530	94	1,746	515	20	1,757	554
7 years	646	1,973	523	219	1,917	507	121	2,012	517	29	2,009	557
8 years	606	2,122	557	303	2,068	577	98	2,065	536	22	2,075	470
9 years	598	2,263	628	279	2,272	666	114	2,159	640	19	2,167	650
10 years	580	2,413	665	308	2,335	689	110	2,432	599	19	2,207	711
11 years	566	2,651	762	346	2,579	682	111	2,508	746	25	2,464	817
White												
6 years	446	1,755	501	171	1,756	534	80	1,719	510	19	1,753	569
7 years	554	1,968	517	195	1,925	506	112	2,014	520	27	1,922	467
8 years	512	2,105	542	263	2,074	537	77	2,051	547	18	2,048	498
9 years	513	2,259	627	246	2,265	652	104	2,139	630	18	2,169	668
10 years	502	2,415	657	269	2,325	688	100	2,414	566	17	2,223	741
11 years	496	2,662	752	289	2,609	688	96	2,503	740	21	2,400	755
Negro												
6 years	64	1,868	461	23	1,639	502	14	1,896	535	1	1,842	-
7 years	92	2,003	559	24	1,852	517	9	1,992	499	2	3,182	252
8 years	94	2,215	628	40	2,031	799	21	2,114	503	4	2,196	333
9 years	85	2,289	637	33	2,320	770	10	2,368	739	1	2,137	-
10 years	78	2,400	717	39	2,400	700	10	2,604	882	2	2,070	536
11 years	70	2,574	830	57	2,429	635	15	2,543	813	4	2,797	1,167
Male												
6 years	265	1,798	495	100	1,782	614	52	1,836	504	12	1,859	367
7 years	322	2,002	537	125	1,987	526	57	2,110	508	13	2,018	543
8 years	309	2,167	525	147	2,170	593	57	2,123	537	9	1,887	481
9 years	315	2,245	623	138	2,287	532	59	2,116	601	8	2,423	778
10 years	289	2,428	635	156	2,313	734	47	2,515	512	10	2,036	855
11 years	295	2,659	750	191	2,540	659	57	2,457	776	10	2,294	1,010
Female												
6 years	245	1,738	499	94	1,700	424	42	1,634	512	8	1,604	759
7 years	324	1,945	508	94	1,825	468	64	1,926	513	16	2,002	586
8 years	297	2,075	587	156	1,972	546	41	1,984	531	13	2,205	432
9 years	283	2,283	635	141	2,257	776	55	2,204	682	11	1,981	495
10 years	291	2,397	694	152	2,357	641	63	2,370	653	9	2,397	488
11 years	271	2,642	775	155	2,627	708	54	2,562	716	15	2,577	672

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 3. $FEF_{25-75\%}$ of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65, unedited data—Con.

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
White male		Milliliters			Milliliters			Milliliters			Milliliters	
6 years	227	1,776	502	85	1,823	623	44	1,787	498	11	1,861	385
7 years	286	2,006	530	111	1,996	529	54	2,105	518	12	1,936	476
8 years	270	2,161	517	131	2,156	548	46	2,132	546	9	1,887	481
9 years	275	2,256	631	123	2,274	547	53	2,092	624	8	2,423	778
10 years	256	2,437	620	137	2,326	737	42	2,504	435	9	2,075	898
11 years	259	2,671	742	167	2,556	653	45	2,455	774	8	2,356	1,084
White female												
6 years	219	1,733	500	86	1,690	422	36	1,636	521	8	1,604	759
7 years	268	1,928	501	84	1,832	461	58	1,929	512	15	1,912	476
8 years	242	2,043	563	132	1,992	515	31	1,932	536	9	2,209	488
9 years	238	2,263	624	123	2,256	744	51	2,187	638	10	1,965	519
10 years	246	2,392	694	132	2,324	636	58	2,349	640	8	2,390	521
11 years	237	2,652	763	122	2,682	730	51	2,545	713	13	2,427	511
Negro male												
6 years	38	1,928	430	15	1,550	519	8	2,103	486	1	1,842	-
7 years	36	1,973	601	14	1,913	509	3	2,195	322	1	3,004	-
8 years	39	2,208	578	16	2,284	896	11	2,085	521	-	-	-
9 years	40	2,172	564	15	2,393	381	6	2,336	270	-	-	-
10 years	33	2,362	745	19	2,217	727	5	2,601	1,033	1	1,691	-
11 years	36	2,576	809	24	2,435	704	12	2,466	820	2	2,042	897
Negro female												
6 years	26	1,781	500	8	1,807	454	6	1,618	502	-	-	-
7 years	56	2,022	535	10	1,768	542	6	1,891	565	1	3,361	-
8 years	55	2,220	666	24	1,862	696	10	2,147	509	4	2,196	333
9 years	45	2,393	686	18	2,258	994	4	2,416	1,230	1	2,137	-
10 years	45	2,427	703	20	2,574	642	5	2,607	827	1	2,449	-
11 years	34	2,572	864	33	2,424	591	3	2,852	866	2	3,552	999

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 4. Number and percent of children 6-11 years of age, by education level of first-listed parent, quality group, and age of children: Health Examination Survey Cycle II, 1963-65, unedited data

Quality group and age	Education of first-listed parent																	
	Less than 5 years		5-7 years		8 years		9-11 years		12 years		13-15 years		16 years		17 years or more		Unknown	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
IA																		
6 years	22	4.3	45	8.8	53	10.4	112	22.0	167	32.7	39	7.6	39	7.6	26	5.1	7	1.4
7 years	36	5.6	58	9.0	60	9.3	140	21.7	206	31.9	61	9.4	57	8.8	21	3.3	7	1.1
8 years	33	5.4	68	11.2	67	11.1	134	22.1	169	27.9	51	8.4	36	5.9	38	6.3	10	1.7
9 years	48	8.0	65	10.9	69	11.5	110	18.4	186	31.1	38	6.4	48	8.0	24	4.0	10	1.7
10 years	43	7.4	61	10.5	69	11.9	101	17.4	165	28.4	51	8.8	46	7.9	35	6.0	9	1.6
11 years	42	7.4	57	10.1	77	13.6	110	19.4	180	31.8	30	5.3	37	6.5	32	5.7	1	0.2
IB																		
6 years	13	6.7	13	6.7	16	8.2	33	17.0	71	36.6	17	8.8	20	10.3	10	5.2	1	0.5
7 years	7	3.2	11	5.0	22	10.0	41	18.7	81	37.0	24	11.0	21	9.6	11	5.0	1	0.5
8 years	12	4.0	25	8.3	27	8.9	67	22.1	105	34.7	26	8.6	25	8.3	13	4.3	3	1.0
9 years	7	2.5	17	6.1	27	9.7	62	22.2	100	35.8	21	7.5	24	8.6	20	7.2	1	0.4
10 years	13	4.2	26	8.4	37	12.0	64	20.8	105	34.1	23	7.5	19	6.2	21	6.8	-	-
11 years	18	5.2	35	10.1	38	11.0	71	20.5	98	28.3	28	8.1	33	9.5	22	6.4	3	0.9
IC-IE																		
6 years	6	6.4	6	6.4	7	7.4	23	24.5	32	34.0	8	8.5	9	9.6	2	2.1	1	1.1
7 years	4	3.3	8	6.6	11	9.1	21	17.4	51	42.1	10	8.3	7	5.8	9	7.4	-	-
8 years	3	3.1	10	10.2	10	10.2	23	23.5	51	31.6	5	5.1	7	7.1	8	8.2	1	1.0
9 years	14	12.3	5	4.4	8	7.0	27	23.7	34	29.8	6	5.3	9	7.9	9	7.9	2	1.8
10 years	8	7.3	10	9.1	14	12.7	18	16.4	32	29.1	12	10.9	7	6.4	7	6.4	2	1.8
11 years	11	9.9	6	5.4	19	17.1	19	17.1	28	25.2	9	8.1	11	9.9	6	5.4	2	1.8
II																		
6 years	-	-	-	-	1	5.0	3	15.0	10	50.0	2	10.0	2	10.0	2	10.0	-	-
7 years	-	-	-	-	3	10.3	14	48.3	8	27.6	2	6.9	1	3.4	-	-	1	3.4
8 years	-	-	2	9.1	1	4.5	3	13.6	10	45.5	2	9.1	1	4.5	2	9.1	1	4.5
9 years	2	10.5	-	-	2	10.5	4	21.1	7	36.8	1	5.3	1	5.3	2	10.5	-	-
10 years	2	10.5	2	10.5	4	21.1	3	15.8	3	15.8	2	10.5	-	-	3	15.8	-	-
11 years	-	-	2	8.0	7	28.0	7	28.0	6	24.0	1	4.0	1	4.0	1	4.0	-	-
III																		
6 years	21	8.5	21	8.5	28	11.3	53	21.4	68	27.4	19	7.7	18	7.3	13	5.2	7	2.8
7 years	31	16.6	22	11.8	17	9.1	49	26.2	35	18.7	15	8.0	9	4.8	4	2.1	5	2.7
8 years	14	8.2	12	7.0	23	13.5	28	16.4	47	27.5	15	8.8	16	9.4	10	5.8	6	3.5
9 years	13	8.9	23	15.8	22	15.1	27	18.5	40	27.4	7	4.8	7	4.8	4	2.7	3	2.1
10 years	13	10.8	12	10.0	14	11.7	22	18.3	38	31.7	11	9.2	5	4.2	5	4.2	-	-
11 years	11	8.9	14	11.4	16	13.0	25	20.3	32	26.0	5	4.1	14	11.4	4	3.3	2	1.6
Deck 56 only																		
6 years	9	20.0	2	4.4	5	11.1	13	28.9	10	22.2	4	8.9	-	-	2	4.4	-	-
7 years	6	15.4	3	7.7	7	17.9	11	28.2	11	28.2	-	-	-	-	1	2.6	-	-
8 years	3	9.7	6	19.4	2	6.5	6	19.4	10	32.3	1	3.2	1	3.2	2	6.5	-	-
9 years	2	7.1	3	10.7	-	-	11	39.3	7	25.0	3	10.7	1	3.6	1	3.6	-	-
10 years	1	4.3	3	13.0	3	13.0	4	17.4	5	21.7	1	4 3	4	17.4	2	8.7	-	-
11 years	4	19.0	3	14.3	1	4.8	7	33.3	4	19.0	-	-	1	4.8	1	4.8	-	-

Table 5. Number and percent of children 6-11 years of age, by annual family income, quality group, and age of children: Health Examination Survey Cycle II, 1963-65, unedited data

Quality group and age	Annual family income									
	Less than $500		$500-$999		$1,000-$1,999		$2,000-$2,999		$3,000-$3,999	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
IA										
6 years	7	1.4	11	2.2	27	5.3	31	6.1	50	9.8
7 years	6	0.9	17	2.6	38	5.9	45	7.0	50	7.7
8 years	3	0.5	13	2.1	31	5.1	64	10.6	54	8.9
9 years	7	1.2	15	2.5	42	7.0	48	8.0	48	8.0
10 years	8	1.4	10	1.7	42	7.2	44	7.6	52	9.0
11 years	4	0.7	12	2.1	27	4.8	41	7.2	49	8.7
IB										
6 years	-	-	3	1.5	8	4.1	12	6.2	16	8.2
7 years	1	0.5	3	1.4	11	5.0	16	7.3	18	8.2
8 years	4	1.3	3	1.0	17	5.6	16	5.3	29	9.6
9 years	-	-	8	2.9	12	4.3	14	5.0	22	7.9
10 years	1	0.3	12	3.9	20	6.5	19	6.2	18	5.8
11 years	1	0.3	17	4.9	20	5.8	22	6.4	33	9.5
IC-IE										
6 years	1	1.1	3	3.2	6	6.4	7	7.4	9	9.6
7 years	1	0.8	-	-	3	2.5	6	5.0	12	9.9
8 years	2	2.0	3	3.1	9	9.2	1	1.0	11	11.2
9 years	1	0.9	6	5.3	3	2.6	6	5.3	7	6.1
10 years	-	-	1	0.9	8	7.3	10	9.1	9	8.2
11 years	-	-	2	1.8	8	7.2	5	4.5	12	10.8
II										
6 years	-	-	1	5.0	1	5.0	1	5.0	1	5.0
7 years	-	-	-	-	3	10.3	1	3.4	3	10.3
8 years	-	-	-	-	-	-	2	9.1	4	18.2
9 years	-	-	1	5.3	1	5.3	3	15.8	1	5.3
10 years	-	-	-	-	3	15.8	1	5.3	2	10.5
11 years	-	-	-	-	-	-	1	4.0	4	16.0
III										
6 years	4	1.6	9	3.6	24	9.7	31	12.5	25	10.1
7 years	3	1.6	6	3.2	18	9.6	19	10.2	24	12.8
8 years	1	0.6	8	4.7	12	7.0	16	9.4	14	8.2
9 years	2	1.4	9	6.2	11	7.5	11	7.5	14	9.6
10 years	3	2.5	2	1.7	11	9.2	11	9.2	8	6.7
11 years	-	-	-	-	9	7.3	12	9.8	9	7.3
Deck 56 only										
6 years	1	2.2	5	11.1	5	11.1	3	6.7	2	4.4
7 years	2	5.1	2	5.1	4	10.3	4	10.3	4	10.3
8 years	-	-	1	3.2	2	6.5	4	12.9	7	22.6
9 years	-	-	1	3.6	2	7.1	1	3.6	2	7.1
10 years	-	-	1	4.3	1	4.3	3	13.0	2	8.7
11 years	-	-	1	4.8	3	14.3	1	4.8	-	-

Table 5. Number and percent of children 6-11 years of age, by annual family income, quality group, and age of children: Health Examination Survey Cycle II, 1963-65, unedited data—Con.

Quality group and age	Annual family income											
	$4,000-$4,999		$5,000-$6,999		$7,000-$9,999		$10,000-$14,999		$15,000 or more		Unknown or refused	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
IA												
6 years	56	11.0	125	24.5	94	18.4	59	11.6	27	5.3	23	4.5
7 years	68	10.5	163	25.2	137	21.2	62	9.6	23	3.6	37	5.7
8 years	48	7.9	139	22.9	123	20.3	60	9.9	35	5.8	36	5.9
9 years	56	9.4	139	23.2	120	20.1	62	10.4	24	4.0	37	6.2
10 years	46	7.9	123	21.2	131	22.6	70	12.1	27	4.7	27	4.7
11 years	61	10.8	145	25.6	99	17.5	66	11.7	31	5.5	31	5.5
IB												
6 years	19	9.8	51	26.3	40	20.6	28	14.4	7	3.6	10	5.2
7 years	18	8.2	53	24.2	49	22.4	25	11.4	13	5.9	12	5.5
8 years	27	8.9	68	22.4	71	23.4	42	13.9	12	4.0	14	4.6
9 years	31	11.1	54	19.4	75	26.9	40	14.3	18	6.5	5	1.8
10 years	28	9.1	67	21.8	68	22.1	44	14.3	19	6.2	12	3.9
11 years	27	7.8	72	20.8	68	19.7	38	11.0	25	7.2	23	6.6
IC-IE												
6 years	10	10.6	24	25.5	21	22.3	8	8.5	2	2.1	3	3.2
7 years	11	9.1	32	26.4	33	27.3	16	13.2	2	1.7	5	4.1
8 years	11	11.2	23	23.5	21	21.4	10	10.2	4	4.1	3	3.1
9 years	7	6.1	32	28.1	21	18.4	16	14.0	5	4.4	10	8.8
10 years	10	9.1	22	20.0	21	19.1	15	13.6	5	4.5	9	8.2
11 years	9	8.1	21	18.9	28	25.2	15	13.5	4	3.6	7	6.3
II												
6 years	-	-	6	30.0	5	25.0	3	15.0	2	10.0	-	-
7 years	3	10.3	10	34.5	4	13.8	4	13.8	-	-	1	3.4
8 years	1	4.5	5	22.7	3	13.6	3	13.6	1	4.5	3	13.6
9 years	2	10.5	5	26.3	1	5.3	5	26.3	-	-	-	-
10 years	-	-	5	26.3	1	5.3	4	21.1	1	5.3	2	10.5
11 years	3	12.0	4	16.0	7	28.0	4	16.0	2	8.0	-	-
III												
6 years	22	8.9	43	17.3	44	17.7	21	8.5	11	4.4	14	5.6
7 years	11	5.9	46	24.6	32	17.1	14	7.5	6	3.2	8	4.3
8 years	13	7.6	39	22.8	32	18.7	22	12.9	5	2.9	9	5.3
9 years	13	8.9	29	19.9	31	21.2	13	8.9	4	2.7	9	6.2
10 years	17	14.2	24	20.0	24	20.0	12	10.0	5	4.2	3	2.5
11 years	12	9.8	40	32.5	18	14.6	13	10.6	3	2.4	7	5.7
Deck 56 only												
6 years	4	8.9	11	24.4	5	11.1	5	11.1	1	2.2	3	6.7
7 years	5	12.8	11	28.2	5	12.8	1	2.6	1	2.6	-	-
8 years	2	6.5	4	12.9	7	22.6	3	9.7	-	-	1	3.2
9 years	2	7.1	9	32.1	4	14.3	4	14.3	1	3.6	2	7.1
10 years	1	4.3	5	21.7	5	21.7	3	13.0	1	4.3	1	4.3
11 years	1	4.8	3	14.3	3	14.3	3	14.3	2	9.5	4	19.0

Table 6. IQ of children 6-11 years of age, by quality group and age: Sample size, mean, standard deviation, and selected percentiles, Health Examination Survey Cycle II, 1963-65, unedited data

Quality group and age	n	$\bar{X}$	SD	Percentile						
				5th	10th	25th	50th	75th	90th	95th
		IQ								
IA										
6 years	510	97.0	13.1	73.7	79.0	88.2	97.8	105.9	112.7	118.0
7 years	646	96.9	13.5	74.2	80.2	88.1	96.7	104.8	113.4	121.9
8 years	606	97.6	13.7	74.0	79.5	89.1	97.7	106.3	115.6	120.9
9 years	598	96.7	14.7	71.6	77.0	86.3	96.5	107.5	116.0	121.7
10 years	580	97.8	15.8	70.8	74.9	86.9	98.9	108.8	117.3	122.8
11 years	566	96.0	15.2	70.0	73.7	85.4	97.4	106.4	113.7	120.6
IB										
6 years	194	99.4	14.4	75.6	81.5	90.3	99.2	108.8	115.4	122.3
7 years	219	99.7	13.1	78.2	84.0	91.4	99.5	108.6	116.7	121.5
8 years	303	99.2	13.5	77.8	81.9	90.3	99.5	108.3	115.7	122.2
9 years	279	100.8	13.7	78.5	82.4	91.0	100.6	111.0	120.0	123.4
10 years	308	98.9	14.1	73.4	80.5	89.0	99.8	108.6	116.4	121.2
11 years	346	97.5	17.2	67.6	73.9	86.0	98.7	108.4	119.7	126.2
IC-IE										
6 years	94	96.1	13.1	72.3	75.5	87.4	96.6	104.7	112.8	117.1
7 years	121	99.8	13.6	75.7	80.1	91.8	100.1	108.4	116.6	122.4
8 years	98	100.3	15.1	76.5	82.0	89.7	98.6	110.7	119.2	123.3
9 years	114	98.3	15.1	72.1	79.2	90.4	97.7	107.7	119.5	124.3
10 years	110	98.8	16.2	71.2	75.8	90.2	98.8	108.1	121.6	128.7
11 years	111	98.1	16.1	68.1	75.2	89.8	98.6	108.8	115.7	121.1
II										
6 years	20	100.3	10.7	0.0	84.9	95.8	99.9	107.4	113.3	114.9
7 years	29	99.1	8.8	85.7	88.1	94.0	99.5	105.7	110.2	113.8
8 years	22	101.3	12.5	80.2	82.9	95.6	103.3	108.7	114.4	119.4
9 years	19	95.3	13.1	0.0	79.4	84.5	93.1	107.0	112.7	115.1
10 years	19	96.9	15.7	0.0	69.7	84.5	98.7	107.0	115.5	120.2
11 years	25	102.7	15.2	73.6	86.2	92.8	99.4	116.2	121.8	123.2
III										
6 years	248	92.8	13.2	70.7	74.5	82.7	93.0	102.5	109.0	114.7
7 years	187	91.3	14.4	67.3	72.3	80.9	92.3	101.2	109.1	114.0
8 years	171	95.1	15.8	68.1	75.0	83.6	95.6	104.7	114.4	123.4
9 years	146	93.9	15.1	68.8	75.3	82.8	94.0	104.8	112.6	116.7
10 years	120	93.7	15.6	66.4	71.2	83.4	94.9	104.6	112.1	119.9
11 years	123	94.7	16.9	67.8	72.6	82.9	95.9	106.2	115.9	122.8
Deck 56 only										
6 years	45	92.7	16.6	65.4	69.1	80.4	93.4	105.7	112.4	114.7
7 years	39	87.2	19.0	54.9	59.7	69.7	89.3	103.0	110.2	115.2
8 years	31	96.4	17.5	64.2	75.2	82.7	93.7	109.4	117.2	122.2
9 years	28	93.1	17.1	63.6	68.9	81.6	93.9	106.6	115.5	118.9
10 years	23	95.8	24.5	50.7	56.5	83.7	101.5	108.7	126.7	129.5
11 years	21	89.7	17.7	60.2	70.2	75.6	92.4	99.7	109.7	121.3

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 7. Number and percent of children 6-11 years of age, by geographic region, quality group, and age: Health Examination Survey Cycle II, 1963-65

Quality group and age	Geographic region							
	Northeast		Midwest		South		West	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
IA								
6 years	146	28.6	137	26.9	108	21.2	119	23.3
7 years	171	26.5	169	26.2	169	26.2	137	21.2
8 years	176	29.0	139	22.9	158	26.1	133	21.9
9 years	157	26.3	149	24.9	159	26.6	133	22.2
10 years	135	23.3	157	27.1	150	25.9	138	23.8
11 years	137	24.2	150	26.5	161	28.4	118	20.8
IB								
6 years	46	23.7	56	26.8	44	22.7	52	26.8
7 years	52	23.7	68	31.1	36	16.4	63	28.8
8 years	71	23.4	108	35.6	38	12.5	86	28.4
9 years	73	26.2	93	33.3	44	15.8	69	24.7
10 years	79	25.6	99	32.1	57	18.5	73	23.7
11 years	89	25.7	99	28.6	68	19.7	90	26.0
IC-IE								
6 years	18	19.1	24	25.5	23	24.5	29	30.9
7 years	37	30.6	36	29.8	21	17.4	27	22.3
8 years	14	14.3	24	24.5	27	27.6	33	33.7
9 years	26	22.8	30	26.3	29	25.4	29	25.4
10 years	22	20.0	34	30.9	30	27.3	24	21.8
11 years	25	22.5	26	23.4	27	24.3	33	29.7
II								
6 years	6	30.0	3	15.0	6	30.0	5	25.0
7 years	8	27.6	11	37.9	3	10.3	7	24.1
8 years	9	40.9	2	9.1	6	27.3	5	22.7
9 years	1	5.3	6	31.6	7	36.8	5	26.3
10 years	7	36.8	7	36.8	-	-	5	26.3
11 years	4	16.0	9	36.0	3	12.0	9	36.0
III								
6 years	62	25.0	50	20.2	76	30.6	60	24.2
7 years	41	21.9	51	27.3	54	28.9	41	21.9
8 years	48	28.1	38	22.2	46	26.9	39	22.8
9 years	35	24.0	32	21.9	47	32.2	32	21.9
10 years	21	17.5	32	26.7	28	23.3	39	32.5
11 years	29	23.6	28	22.8	37	30.1	29	23.6
Deck 56 only								
6 years	12	26.7	6	13.3	10	22.2	17	37.8
7 years	5	12.8	7	17.9	13	33.3	14	35.9
8 years	8	25.8	4	12.9	6	19.4	13	41.9
9 years	8	28.6	5	17.9	6	21.4	9	32.1
10 years	2	8.7	8	34.8	4	17.4	9	39.1
11 years	2	9.5	3	14.3	6	28.6	10	47.6

Table 8. Height in centimeters of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65

Age, race, and sex	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
Total		Centimeters			Centimeters			Centimeters			Centimeters	
6 years	510	118.4	5.29	194	119.0	4.99	94	118.5	5.09	20	122.0	6.33
7 years	646	123.9	5.63	219	124.8	5.40	121	123.8	6.22	29	123.1	4.51
8 years	606	129.7	5.57	303	130.2	6.22	98	130.0	6.34	22	128.5	4.92
9 years	598	135.2	7.05	279	136.0	6.01	114	135.6	6.38	19	134.0	6.13
10 years	580	140.5	7.12	308	141.2	6.97	110	139.4	7.00	19	141.4	6.95
11 years	566	146.3	7.76	346	146.8	7.07	111	146.3	6.89	25	150.9	6.23
White												
6 years	446	118.4	5.31	171	119.0	5.05	80	118.3	4.91	19	121.6	6.17
7 years	554	123.9	5.60	195	124.8	5.36	112	123.6	6.31	27	122.7	4.41
8 years	512	129.5	5.48	263	130.2	6.28	77	130.0	6.21	18	129.1	4.79
9 years	513	134.8	6.89	246	136.2	6.04	104	135.5	6.49	18	133.8	6.24
10 years	502	140.3	6.88	269	141.1	6.81	100	139.9	6.31	17	141.6	6.80
11 years	496	146.3	7.61	289	146.5	7.00	96	146.8	6.87	21	150.5	6.54
Negro												
6 years	62	118.8	5.15	21	119.9	4.57	13	118.4	5.28	1	130.6	0.0
7 years	89	124.0	5.67	21	126.3	5.03	9	126.3	4.39	2	128.4	1.48
8 years	94	130.5	5.99	37	130.0	6.06	20	130.3	7.04	4	125.9	5.29
9 years	78	137.0	7.67	33	134.5	5.62	10	136.7	5.31	1	137.5	0.0
10 years	76	142.2	8.44	37	141.0	8.01	10	134.5	11.18	2	140.1	11.24
11 years	68	146.6	8.92	54	148.8	7.21	15	143.5	6.51	3	151.5	4.20
Male												
6 years	265	118.8	5.29	100	119.5	4.91	52	119.1	4.79	12	123.1	5.62
7 years	322	124.4	5.30	125	125.2	5.22	57	123.5	5.47	13	122.3	3.30
8 years	309	129.8	5.27	147	130.5	6.28	57	130.3	5.32	9	131.6	3.27
9 years	315	134.9	7.05	138	136.5	5.82	59	135.3	6.37	8	133.3	4.52
10 years	289	140.3	6.97	156	140.8	5.92	47	139.4	8.14	10	140.3	8.01
11 years	295	145.8	6.94	191	146.2	6.60	57	145.1	7.20	10	148.6	3.53
Female												
6 years	245	118.1	5.28	94	118.6	5.06	42	117.6	5.37	8	120.4	7.39
7 years	324	123.5	5.92	94	124.3	5.61	64	124.1	6.84	16	123.7	5.32
8 years	297	129.6	5.87	156	129.8	6.17	41	129.5	7.58	13	126.5	4.86
9 years	283	135.4	7.04	141	135.5	6.18	55	136.0	6.43	11	134.5	7.25
10 years	291	140.8	7.28	152	141.5	7.91	63	139.5	6.09	9	142.7	5.78
11 years	271	147.0	8.53	155	147.5	7.57	54	147.6	6.36	15	152.5	7.22

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 8. Height in centimeters of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65—Con.

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
White male		Centimeters			Centimeters			Centimeters			Centimeters	
6 years	227	118.8	5.41	85	119.5	5.04	44	118.6	4.50	11	122.4	5.34
7 years	286	124.3	5.33	111	125.2	5.33	54	123.4	5.54	12	121.7	2.63
8 years	270	129.6	5.20	131	130.6	6.46	46	130.5	5.40	9	131.6	3.27
9 years	275	135.0	7.14	123	136.6	5.96	53	135.3	6.51	8	133.3	4.52
10 years	256	140.2	6.98	137	140.9	5.93	42	140.2	6.66	9	141.2	7.92
11 years	259	145.9	6.69	167	146.1	6.56	45	145.8	7.18	8	148.0	3.12
White female												
6 years	219	117.9	5.17	86	188.5	5.02	36	117.9	5.41	8	120.4	7.39
7 years	268	123.5	5.86	84	124.3	5.40	58	123.9	7.00	15	123.5	5.41
8 years	242	129.4	5.78	132	129.8	6.08	31	129.2	7.28	9	126.7	4.97
9 years	238	134.7	6.60	123	135.8	6.12	51	135.8	6.53	10	134.2	7.57
10 years	246	140.4	6.79	132	141.3	7.63	58	139.8	6.11	8	142.0	5.79
11 years	237	146.7	8.50	122	147.0	7.56	51	147.6	6.54	13	152.1	7.68
Negro male												
6 years	37	118.7	4.60	15	119.2	4.18	7	120.6	4.49	1	130.6	0.0
7 years	35	125.0	5.17	13	126.1	4.38	3	125.9	3.93	1	129.4	0.0
8 years	39	130.8	5.65	15	130.2	4.77	10	130.1	5.19	-	-	-
9 years	36	134.2	6.58	15	135.3	4.51	6	135.4	5.57	-	-	-
10 years	32	140.9	6.88	18	140.0	6.09	5	132.6	15.58	1	132.1	0.0
11 years	34	144.6	8.80	23	147.6	7.02	12	142.4	6.91	2	150.8	5.66
Negro female												
6 years	25	118.9	5.97	6	121.5	5.48	6	115.8	5.26	-	-	-
7 years	54	123.4	5.94	8	126.8	6.24	6	126.5	4.96	1	127.3	0.0
8 years	55	130.3	6.25	22	129.9	6.91	10	130.4	8.81	4	125.9	5.29
9 years	42	139.4	7.79	18	133.8	6.45	4	138.5	5.01	1	137.5	0.0
10 years	44	143.1	9.38	19	142.0	9.54	5	136.3	5.47	1	148.0	0.0
11 years	34	148.6	8.71	31	149.7	7.33	3	147.6	1.62	1	153.0	0.0

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 9. Sitting height in centimeters of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65

Age, race, and sex	IA n	IA $\bar{X}$	IA SD	IB n	IB $\bar{X}$	IB SD	IC-IE n	IC-IE $\bar{X}$	IC-IE SD	II n	II $\bar{X}$	II SD
		Centimeters			Centimeters			Centimeters			Centimeters	
Total												
6 years	510	64.4	2.89	194	64.7	2.82	94	64.5	2.54	20	66.7	2.79
7 years	646	66.5	2.92	219	67.0	2.95	121	66.8	3.18	29	66.2	2.37
8 years	606	68.7	2.97	303	69.2	3.14	98	68.8	3.01	22	68.3	3.06
9 years	598	71.0	3.37	279	71.4	2.94	114	71.1	3.06	19	70.2	3.25
10 years	580	73.1	3.33	308	73.4	3.22	110	72.8	3.57	19	73.8	3.49
11 years	566	75.8	3.76	346	75.8	3.48	111	75.5	3.61	25	77.8	3.91
White												
6 years	446	64.6	2.82	171	64.9	2.85	80	64.7	2.38	19	66.7	2.86
7 years	554	66.7	2.86	195	67.2	2.92	112	66.9	3.21	27	66.4	2.37
8 years	512	69.0	2.85	263	69.5	2.98	77	69.3	2.87	18	69.0	2.81
9 years	513	71.2	3.23	246	71.7	2.83	104	71.2	3.04	18	70.3	3.32
10 years	502	73.3	3.19	269	73.7	3.07	100	73.1	3.39	17	74.2	3.44
11 years	496	76.0	3.70	289	75.9	3.43	96	76.0	3.34	21	78.0	3.86
Negro												
6 years	62	62.7	2.87	21	63.5	2.32	13	62.9	2.57	1	65.7	0.0
7 years	89	64.9	2.79	21	65.8	2.95	9	66.3	2.88	2	64.0	0.07
8 years	94	67.1	3.12	37	67.1	3.53	20	67.2	3.04	4	65.5	2.71
9 years	78	69.4	3.71	33	69.2	2.80	10	70.3	3.37	1	68.3	0.0
10 years	76	72.0	4.00	37	71.4	3.38	10	70.0	4.22	2	71.2	3.61
11 years	68	73.9	3.75	54	74.9	3.73	15	72.7	4.07	3	75.2	3.65
Male												
6 years	265	64.8	2.76	100	65.1	2.62	52	65.1	2.30	12	66.6	2.02
7 years	322	66.9	2.65	125	67.6	2.83	57	67.0	2.60	13	65.7	1.66
8 years	309	69.1	2.80	147	69.7	3.07	57	69.0	3.15	9	70.0	1.88
9 years	315	71.1	3.43	138	71.7	2.87	59	71.2	3.11	8	70.5	2.96
10 years	289	73.1	3.28	156	73.3	2.86	47	73.1	3.40	10	73.2	4.15
11 years	295	75.5	3.26	191	75.5	3.08	57	74.6	3.72	10	76.2	2.39
Female												
6 years	245	63.9	2.97	94	64.3	2.96	42	63.8	2.67	8	66.8	3.83
7 years	324	66.1	3.12	94	66.3	2.94	64	66.7	3.64	16	66.6	2.81
8 years	297	68.4	3.10	156	68.8	3.16	41	68.6	2.82	13	67.2	3.25
9 years	283	70.9	3.30	141	71.2	2.99	55	71.0	3.04	11	69.9	3.57
10 years	291	73.2	3.39	152	73.5	3.56	63	72.6	3.70	9	74.6	2.60
11 years	271	76.1	4.23	155	76.1	3.90	54	76.5	3.24	15	78.9	4.42

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 9. Sitting height in centimeters of children 6-11 years of age, by quality group, age, race, and sex: Sample size, mean, and standard deviation, Health Examination Survey Cycle II, 1963-65—Con.

Age, race, and sex	Quality group											
	IA			IB			IC-IE			II		
	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD	n	$\bar{X}$	SD
White male		Centimeters			Centimeters			Centimeters			Centimeters	
6 years	227	65.1	2.71	85	65.4	2.61	44	65.1	2.17	11	66.7	2.10
7 years	286	67.1	2.64	111	67.8	2.86	54	67.0	2.65	12	65.8	1.64
8 years	270	69.3	2.70	131	69.9	3.09	46	69.6	3.20	9	70.0	1.88
9 years	275	71.5	3.27	123	72.0	2.75	53	71.3	3.15	8	70.5	2.96
10 years	256	73.3	3.16	137	73.7	2.63	42	73.4	3.18	9	73.7	4.06
11 years	259	75.8	3.22	167	75.6	3.05	45	75.4	3.31	8	76.5	1.76
White female												
6 years	219	64.1	2.86	86	64.4	3.00	36	64.1	2.53	8	66.8	3.83
7 years	268	66.4	3.04	84	66.4	2.84	58	66.7	3.68	15	66.8	2.82
8 years	242	68.7	2.98	132	69.1	2.84	31	68.9	2.30	9	68.0	3.30
9 years	238	71.0	3.17	123	71.5	2.90	51	71.1	2.95	10	70.1	3.72
10 years	246	73.3	3.24	132	73.7	3.48	58	72.9	3.55	8	74.7	2.76
11 years	237	76.3	4.15	122	76.4	3.86	51	76.4	3.32	13	78.9	4.54
Negro male												
6 years	37	63.2	2.58	15	63.6	2.20	7	63.9	2.04	1	65.7	0.0
7 years	35	65.6	2.45	13	66.3	2.27	3	66.5	1.72	1	63.9	0.0
8 years	39	67.5	3.02	15	67.8	2.37	10	66.8	1.69	-	-	-
9 years	36	68.4	3.56	15	69.4	2.87	6	70.2	2.81	-	-	-
10 years	32	71.2	3.66	18	70.7	3.34	5	70.6	4.55	1	68.6	0.0
11 years	34	73.0	2.53	23	74.6	3.30	12	71.6	3.75	2	75.2	5.16
Negro female												
6 years	25	62.1	3.19	6	63.2	2.78	6	61.9	2.87	-	-	-
7 years	54	64.5	2.93	8	65.1	3.88	6	66.2	3.47	1	64.0	0.0
8 years	55	66.8	3.18	22	66.5	4.11	10	67.6	4.04	4	65.5	2.71
9 years	42	70.3	3.66	18	69.1	2.83	4	70.5	4.57	1	68.3	0.0
10 years	44	72.6	4.18	19	72.0	3.39	5	69.3	4.26	1	73.7	0.0
11 years	34	74.8	4.53	31	75.2	4.06	3	77.1	1.20	1	75.2	0.0

NOTE: n = sample size, $\bar{X}$ = mean, SD = standard deviation.

Table 10. FEV_1 of children 6-11 years of age, by age, sex, and race: Sample size, weighted sample size, standard deviation, standard error of the mean, mean, and selected percentiles, Health Examination Survey Cycle II, 1963-65

Age, sex and race	n	N	SD	$SE_{\bar{X}}$	$\bar{X}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
Total			Milliliters									
6-11 years	7,119	23,784	429.6	9.06	1,594.7	947.3	1,071.7	1,283.4	1,564.0	1,872.4	2,172.0	2,345.0
6 years	1,111	4,098	256.0	13.19	1,172.2	730.3	858.1	1,007.3	1,172.3	1,339.7	1,504.7	1,598.9
7 years	1,241	4,084	263.7	11.44	1,353.1	923.3	1,008.2	1,186.6	1,351.2	1,521.5	1,679.0	1,786.8
8 years	1,231	3,986	284.1	11.01	1,520.7	1,043.5	1,147.5	1,326.1	1,528.1	1,711.6	1,884.3	1,980.3
9 years	1,184	3,957	328.1	12.24	1,682.1	1,140.2	1,268.6	1,463.7	1,682.6	1,905.4	2,096.6	2,215.0
10 years	1,160	3,867	345.5	13.58	1,831.4	1,253.1	1,404.3	1,615.0	1,821.3	2,058.6	2,270.7	2,385.1
11 years	1,192	3,792	389.0	14.26	2,059.0	1,433.2	1,570.9	1,805.1	2,054.1	2,308.3	2,541.0	2,701.8
Male												
6-11 years	3,632	12,081	425.1	11.43	1,648.9	994.2	1,130.1	1,344.2	1,622.5	1,929.5	2,213.6	2,373.1
6 years	575	2,082	254.9	16.54	1,223.9	819.0	905.2	1,054.9	1,227.4	1,386.3	1,558.6	1,639.2
7 years	632	2,074	267.6	16.24	1,407.0	966.3	1,077.9	1,235.1	1,411.1	1,581.2	1,728.5	1,817.8
8 years	618	2,026	268.5	15.82	1,589.3	1,160.1	1,244.3	1,398.1	1,589.3	1,775.7	1,929.1	2,010.2
9 years	603	2,012	331.7	19.71	1,745.7	1,202.3	1,335.7	1,523.7	1,751.7	1,967.8	2,165.7	2,261.2
10 years	576	1,963	344.6	15.35	1,878.5	1,276.0	1,447.5	1,663.1	1,868.3	2,114.9	2,309.0	2,409.7
11 years	628	1,924	384.6	22.84	2,098.0	1,458.3	1,619.0	1,855.3	2,096.3	2,330.3	2,578.3	2,728.4
Female												
6-11 years	3,487	11,703	427.2	8.14	1,539.2	911.6	1,023.1	1,227.9	1,509.3	1,808.0	2,114.0	2,295.3
6 years	536	2,016	246.0	13.01	1,118.9	677.6	792.9	966.4	1,129.4	1,284.4	1,417.1	1,535.2
7 years	609	2,010	247.6	11.22	1,297.5	893.5	968.3	1,150.6	1,295.1	1,458.9	1,598.8	1,698.0
8 years	613	1,960	282.5	14.34	1,449.9	974.9	1,073.5	1,259.3	1,470.0	1,628.3	1,790.1	1,917.1
9 years	581	1,945	311.1	14.06	1,616.4	1,111.2	1,209.6	1,388.8	1,624.5	1,814.8	2,018.3	2,138.6
10 years	584	1,908	339.7	16.97	1,783.0	1,230.5	1,372.5	1,567.6	1,772.8	1,988.4	2,224.6	2,360.4
11 years	564	1,868	389.5	16.04	2,018.9	1,383.6	1,550.1	1,765.7	1,997.1	2,274.8	2,486.6	2,646.8
White												
6-11 years	6,100	20,403	429.4	9.19	1,616.3	965.2	1,093.4	1,305.1	1,585.9	1,896.0	2,192.7	2,363.4
6 years	950	3,509	251.4	13.82	1,186.8	765.7	878.0	1,023.0	1,183.8	1,351.2	1,520.2	1,609.5
7 years	1,063	3,497	260.0	11.53	1,371.7	946.2	1,041.1	1,209.3	1,369.9	1,535.0	1,687.2	1,792.8
8 years	1,035	3,413	280.1	12.38	1,539.9	1,070.1	1,176.6	1,355.7	1,542.0	1,724.5	1,897.0	1,992.2
9 years	1,019	3,393	324.6	13.21	1,702.9	1,161.0	1,289.7	1,488.6	1,703.2	1,919.1	2,117.5	2,226.1
10 years	1,014	3,324	339.4	12.39	1,858.2	1,293.8	1,425.2	1,647.5	1,846.3	2,088.1	2,286.4	2,391.6
11 years	1,019	3,267	384.7	13.34	2,085.2	1,452.5	1,607.9	1,834.1	2,080.3	2,329.8	2,564.1	2,725.9
Negro												
6-11 years	987	3,272	404.2	13.36	1,459.7	854.2	967.8	1,170.5	1,435.5	1,728.2	1,980.5	2,139.8
6 years	156	570	265.0	17.97	1,076.4	660.1	722.2	914.9	1,095.1	1,240.7	1,400.5	1,491.8
7 years	172	570	259.2	27.19	1,241.8	852.7	924.4	1,076.4	1,211.1	1,413.0	1,612.9	1,698.4
8 years	192	560	282.1	21.94	1,403.9	951.2	1,030.8	1,207.3	1,396.4	1,593.1	1,788.3	1,897.4
9 years	158	534	315.8	20.78	1,555.2	1,057.2	1,171.6	1,330.6	1,541.2	1,760.3	1,997.5	2,083.5
10 years	142	530	330.3	30.33	1,665.1	1,123.6	1,262.6	1,483.8	1,661.2	1,841.8	2,050.3	2,230.3
11 years	167	507	371.9	35.73	1,882.5	1,267.6	1,466.9	1,634.2	1,893.5	2,098.4	2,324.3	2,480.5

NOTE: n = sample size, N = estimated number of children in thousands, SD = standard deviation, $SE_{\bar{X}}$ = standard error of the mean, $\bar{X}$ = mean.

Table 10. FEV_1 of children 6-11 years of age, by age, sex, and race: Sample size, weighted sample size, standard deviation, standard error of the mean, mean, and selected percentiles, Health Examination Survey Cycle II, 1963-65—Con.

Age, sex and race	n	N	SD	$SE_{\bar{X}}$	$\bar{X}$	Percentile 5th	10th	25th	50th	75th	90th	95th
			Milliliters									
White male												
6-11 years	3,153	10,391	427.0	11.74	1,672.7	1,012.9	1,155.5	1,365.2	1,647.5	1,956.6	2,240.0	2,391.5
6 years	489	1,787	257.6	18.69	1,238.3	829.6	912.1	1,067.2	1,250.3	1,398.0	1,580.2	1,648.3
7 years	551	1,781	263.5	16.55	1,425.6	989.0	1,112.8	1,257.4	1,428.0	1,592.2	1,738.8	1,824.5
8 years	537	1,739	268.9	16.93	1,604.0	1,166.2	1,254.4	1,423.5	1,610.0	1,789.9	1,938.4	2,017.8
9 years	525	1,730	327.9	21.55	1,773.2	1,262.2	1,370.7	1,557.8	1,768.6	1,984.3	2,183.6	2,294.8
10 years	509	1,692	336.1	13.94	1,911.9	1,326.3	1,476.0	1,710.7	1,921.3	2,134.0	2,327.6	2,427.5
11 years	542	1,662	376.2	22.11	2,129.4	1,471.1	1,674.7	1,892.8	2,134.3	2,348.3	2,597.0	2,744.8
White female												
6-11 years	2,947	10,012	424.2	7.92	1,558.2	932.2	1,047.6	1,250.9	1,525.4	1,823.9	2,133.2	2,314.1
6 years	461	1,722	233.1	13.02	1,133.4	695.7	846.0	987.5	1,137.4	1,291.9	1,420.0	1,529.8
7 years	512	1,716	244.0	10.88	1,315.9	910.1	985.5	1,167.4	1,316.3	1,471.9	1,615.3	1,715.9
8 years	498	1,674	276.0	16.59	1,473.3	1,002.1	1,104.7	1,293.1	1,494.6	1,645.3	1,797.6	1,924.6
9 years	494	1,663	304.3	14.42	1,629.7	1,123.5	1,231.2	1,417.0	1,635.7	1,824.1	2,015.0	2,138.4
10 years	505	1,632	333.7	17.39	1,802.7	1,254.2	1,396.5	1,606.1	1,789.6	2,009.0	2,234.7	2,362.2
11 years	477	1,605	388.0	16.85	2,039.6	1,433.2	1,570.0	1,790.8	2,021.8	2,293.2	2,498.6	2,677.6
Negro male												
6-11 years	464	1,642	379.7	17.70	1,497.0	922.9	1,030.1	1,217.2	1,480.7	1,745.8	1,978.5	2,115.4
6 years	84	289	217.2	22.06	1,131.2	736.5	866.8	991.9	1,138.7	1,271.7	1,407.1	1,472.9
7 years	79	286	266.5	36.37	1,291.0	906.2	951.7	1,115.4	1,268.1	1,448.9	1,646.1	1,776.9
8 years	79	279	249.6	35.75	1,496.4	1,084.6	1,211.5	1,323.3	1,491.1	1,681.4	1,852.5	1,921.3
9 years	74	269	295.7	25.08	1,568.9	1,046.1	1,171.2	1,364.2	1,561.8	1,783.9	1,975.8	2,068.5
10 years	65	264	325.7	45.42	1,675.1	1,118.1	1,238.7	1,509.1	1,695.7	1,808.6	2,040.0	2,226.0
11 years	83	255	371.4	55.21	1,884.4	1,294.8	1,491.2	1,642.0	1,901.9	2,079.1	2,304.6	2,475.1
Negro female												
6-11 years	523	1,629	424.2	14.26	1,422.2	776.2	921.3	1,128.2	1,373.5	1,708.9	1,981.9	2,165.0
6 years	72	281	296.1	36.60	1,019.9	550.4	673.1	804.9	1,006.3	1,206.7	1,344.1	1,573.1
7 years	93	284	241.6	26.98	1,192.1	827.1	903.6	1,036.9	1,180.0	1,335.9	1,501.5	1,613.8
8 years	113	281	282.5	19.88	1,312.0	920.2	975.6	1,085.7	1,269.3	1,501.1	1,718.9	1,862.1
9 years	84	265	334.3	38.36	1,541.3	1,062.6	1,172.1	1,295.8	1,515.6	1,730.0	2,027.1	2,153.5
10 years	77	266	334.6	36.62	1,655.1	1,200.5	1,271.1	1,446.6	1,624.3	1,874.8	2,053.8	2,235.4
11 years	84	253	372.3	39.00	1,880.5	1,245.2	1,372.8	1,627.9	1,866.8	2,117.1	2,378.0	2,483.7

NOTE: n = sample size, N = estimated number of children in thousands, SD = standard deviation, $SE_{\bar{X}}$ = standard error of the mean, $\bar{X}$ = mean.

Table 11. $FEF_{25\text{-}75\%}$ of children 6-11 years of age, by age, sex, and race: Sample size, weighted sample size, standard deviation, standard error of the mean, mean, and selected percentiles, Health Examination Survey Cycle II, 1963-65

Age, sex and race	n	N	SD	$SE_{\bar{X}}$	$\bar{X}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
			Milliliters									
Total												
6-11 years	7,119	23,784	671.4	18.45	2,173.6	1,152.2	1,348.3	1,704.5	2,138.1	2,589.9	3,036.5	3,317.0
6 years	1,111	4,098	529.8	22.51	1,762.0	926.3	1,119.9	1,407.9	1,752.1	2,100.5	2,419.7	2,599.0
7 years	1,241	4,084	539.4	24.11	1,968.6	1,085.2	1,298.9	1,582.0	1,959.2	2,310.3	2,672.6	2,888.2
8 years	1,231	3,986	573.5	21.53	2,090.3	1,168.1	1,346.0	1,677.0	2,109.0	2,459.5	2,801.7	2,970.2
9 years	1,184	3,957	635.9	26.94	2,259.3	1,245.8	1,463.8	1,830.7	2,233.4	2,652.3	3,094.4	3,314.6
10 years	1,160	3,867	652.8	22.94	2,387.1	1,356.4	1,574.5	1,937.1	2,372.6	2,821.9	3,202.3	3,468.0
11 years	1,192	3,792	719.8	30.47	2,621.7	1,420.1	1,697.1	2,140.2	2,623.3	3,067.4	3,519.4	3,768.4
Male												
6-11 years	3,632	12,081	657.2	21.65	2,190.9	1,179.5	1,384.1	1,743.1	2,158.1	2,605.5	3,025.8	3,300.7
6 years	575	2,082	542.4	26.23	1,793.9	931.8	1,144.4	1,444.5	1,796.0	2,143.3	2,429.1	2,633.4
7 years	632	2,074	559.4	29.98	2,006.1	1,067.7	1,304.6	1,623.5	1,986.1	2,368.3	2,752.5	2,942.5
8 years	618	2,026	568.5	28.29	2,152.7	1,244.3	1,418.8	1,774.7	2,154.9	2,503.2	2,837.1	3,012.3
9 years	603	2,012	591.7	37.86	2,265.6	1,332.9	1,519.6	1,853.4	2,244.5	2,644.4	3,060.4	3,306.8
10 years	576	1,963	657.5	29.35	2,385.6	1,369.0	1,588.8	1,932.4	2,360.5	2,812.7	3,174.5	3,457.2
11 years	628	1,924	708.1	50.34	2,584.1	1,382.8	1,648.0	2,105.7	2,592.1	3,045.6	3,479.5	3,731.0
Female												
6-11 years	3,487	11,703	685.3	19.85	2,156.2	1,127.9	1,310.1	1,662.9	2,115.2	2,576.0	3,046.7	3,335.5
6 years	536	2,016	514.5	27.46	1,729.2	922.4	1,100.8	1,364.2	1,708.5	2,059.5	2,415.4	2,582.4
7 years	609	2,010	515.2	26.58	1,929.9	1,108.4	1,292.6	1,547.3	1,932.9	2,267.0	2,567.8	2,762.4
8 years	613	1,960	571.5	33.37	2,026.0	1,097.7	1,269.8	1,593.4	2,046.6	2,416.9	2,756.0	2,940.9
9 years	581	1,945	678.7	31.47	2,252.8	1,202.0	1,402.3	1,793.1	2,222.8	2,665.4	3,122.9	3,328.8
10 years	584	1,904	648.1	29.44	2,388.7	1,344.7	1,563.0	1,942.7	2,389.1	2,834.4	3,239.1	3,475.7
11 years	564	1,868	729.7	42.82	2,660.4	1,468.0	1,753.3	2,169.9	2,661.3	3,091.5	3,569.1	3,794.2
White												
6-11 years	6,100	20,403	670.5	16.99	2,170.9	1,149.9	1,344.2	1,701.6	2,134.9	2,586.6	3,032.1	3,325.7
6 years	950	3,509	530.2	26.23	1,753.0	908.3	1,112.3	1,403.1	1,743.9	2,090.5	2,420.2	2,586.6
7 years	1,063	3,497	535.3	22.71	1,962.0	1,079.5	1,293.3	1,576.7	1,951.1	2,309.7	2,653.7	2,856.3
8 years	1,035	3,413	559.1	23.25	2,085.3	1,166.2	1,346.5	1,684.9	2,103.3	2,461.9	2,793.9	2,967.8
9 years	1,019	3,393	637.3	26.33	2,252.3	1,227.8	1,453.8	1,810.9	2,227.4	2,651.6	3,112.8	3,322.8
10 years	1,014	3,324	647.0	19.75	2,384.8	1,373.1	1,577.4	1,942.2	2,367.0	2,812.7	3,193.7	3,474.3
11 years	1,019	3,267	719.3	29.58	2,632.3	1,431.8	1,714.2	2,149.6	2,633.1	3,073.6	3,532.5	3,790.7
Negro												
6-11 years	987	3,272	676.6	50.75	2,194.7	1,166.5	1,370.6	1,741.6	2,159.2	2,615.0	3,061.8	3,274.8
6 years	156	570	529.5	46.88	1,816.2	1,027.4	1,183.4	1,438.9	1,798.2	2,163.2	2,454.4	2,772.2
7 years	172	570	564.7	60.66	2,017.8	1,112.3	1,322.2	1,645.9	2,006.8	2,332.8	2,771.0	3,071.6
8 years	192	560	653.1	56.74	2,121.9	1,187.1	1,349.3	1,617.4	2,144.7	2,451.1	2,838.0	2,991.5
9 years	158	534	622.2	58.35	2,315.6	1,428.4	1,576.9	1,934.4	2,274.9	2,652.3	3,054.5	3,248.8
10 years	142	530	680.8	81.17	2,405.1	1,214.0	1,588.0	1,911.5	2,429.6	2,886.3	3,222.9	3,375.7
11 years	167	507	724.5	73.23	2,552.4	1,356.9	1,579.6	2,061.4	2,555.8	3,038.2	3,447.2	3,664.2

NOTE: n = sample size, N = estimated number of children in thousands, SD = standard deviation, $SE_{\bar{X}}$ = standard error of the mean, $\bar{X}$ = mean.

Table 11. $FEF_{25\text{-}75\%}$ of children 6-11 years of age, by age, sex, and race: Sample size, weighted sample size, standard deviation, standard error of the mean, mean, and selected percentiles, Health Examination Survey Cycle II, 1963-65—Con.

Age, sex and race	n	N	SD	$SE_{\bar{X}}$	$\bar{X}$	Percentile						
						5th	10th	25th	50th	75th	90th	95th
White male			Milliliters									
6-11 years	3,153	10,391	658.3	20.27	2,189.9	1,180.7	1,388.4	1,740.9	2,154.2	2,602.8	3,023.9	3,315.6
6 years	489	1,787	538.6	29.60	1,780.1	920.6	1,140.3	1,438.2	1,784.7	2,113.7	2,411.2	2,594.6
7 years	551	1,781	551.5	28.29	2,004.7	1,063.7	1,298.5	1,629.0	1,985.5	2,366.2	2,745.5	2,925.6
8 years	537	1,739	558.2	30.28	2,143.4	1,228.2	1,420.8	1,765.7	2,152.8	2,506.9	2,824.9	2,996.7
9 years	525	1,730	607.7	39.87	2,261.2	1,315.3	1,504.2	1,832.5	2,225.6	2,653.9	3,091.9	3,331.9
10 years	509	1,692	652.8	25.03	2,398.3	1,411.9	1,603.6	1,948.7	2,369.0	2,816.5	3,180.9	3,480.2
11 years	542	1,662	704.9	48.71	2,592.4	1,409.0	1,666.9	2,110.8	2,594.8	3,047.2	3,487.0	3,748.5
White female												
6-11 years	2,947	10,012	682.5	18.83	2,151.5	1,125.0	1,295.9	1,658.7	2,112.0	2,571.5	3,039.7	3,337.2
6 years	461	1,722	519.8	31.06	1,724.9	900.1	1,084.8	1,346.0	1,703.8	2,067.6	2,424.5	2,576.2
7 years	512	1,716	514.3	27.05	1,917.7	1,102.5	1,288.0	1,535.2	1,919.5	2,263.5	2,555.0	2,716.7
8 years	498	1,674	553.7	33.69	2,025.0	1,116.0	1,273.0	1,607.5	2,036.2	2,417.0	2,756.9	2,942.2
9 years	494	1,663	666.7	27.88	2,243.2	1,183.8	1,388.1	1,775.5	2,228.9	2,648.3	3,123.7	3,307.2
10 years	505	1,632	640.7	28.50	2,370.9	1,335.9	1,554.3	1,935.3	2,364.1	2,807.2	3,215.7	3,470.4
11 years	477	1,605	731.7	46.99	2,673.7	1,461.9	1,771.2	2,181.7	2,688.0	3,102.5	3,589.6	3,953.4
Negro male												
6-11 years	464	1,642	651.2	58.29	2,197.5	1,177.7	1,363.4	1,761.3	2,182.4	2,619.2	3,037.2	3,250.4
6 years	84	289	561.2	70.31	1,872.9	996.8	1,164.1	1,496.6	1,861.3	2,258.1	2,572.9	2,928.7
7 years	79	286	609.3	82.61	2,017.7	1,085.6	1,323.3	1,592.9	1,986.6	2,404.2	2,792.4	3,169.4
8 years	79	279	630.0	93.11	2,200.8	1,306.8	1,393.2	1,847.3	2,152.2	2,481.6	2,877.4	3,126.5
9 years	74	269	465.0	66.98	2,315.6	1,532.3	1,635.7	2,034.8	2,353.5	2,630.0	2,927.1	3,082.5
10 years	65	264	680.9	95.86	2,312.4	1,152.5	1,403.6	1,843.8	2,248.4	2,762.9	3,146.5	3,295.6
11 years	83	255	725.7	128.45	2,520.8	1,202.0	1,436.7	2,058.2	2,552.0	3,032.5	3,387.4	3,639.5
Negro female												
6-11 years	523	1,629	701.3	49.35	2,191.8	1,147.9	1,379.1	1,721.5	2,138.1	2,609.1	3,089.1	3,325.6
6 years	72	281	487.8	46.63	1,757.8	1,042.3	1,209.2	1,415.1	1,747.6	2,007.0	2,359.5	2,687.4
7 years	93	284	515.9	70.53	2,017.8	1,126.9	1,319.3	1,738.0	2,039.1	2,292.3	2,721.8	3,004.4
8 years	113	281	666.0	65.09	2,043.4	1,005.2	1,260.3	1,543.0	2,137.4	2,421.6	2,756.6	2,935.4
9 years	84	265	748.7	74.86	2,315.5	1,362.5	1,467.3	1,889.7	2,171.3	2,718.5	3,144.4	3,633.7
10 years	77	266	668.1	90.64	2,497.2	1,477.7	1,669.7	2,040.1	2,542.0	2,968.0	3,264.7	3,467.3
11 years	84	253	721.8	86.74	2,584.2	1,482.0	1,640.6	2,062.8	2,560.9	3,046.7	3,483.6	3,685.9

NOTE: n = sample size, N = estimated number of children in thousands, SD = standard deviation, $SE_{\bar{X}}$ = standard error of the mean, $\bar{X}$ = mean.

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