ON-LINE COMPUTERIZED SPIROMETRY IN 738 NORMAL ADULTS[1, 2]

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SUMMARY

A completely automated method of on-line computerized spirometry has been described. For forced vital capacity (FVC) and one-second forced expiratory volume (FEV_1), the mean difference between manual and computer measurements of the same spirogram was less than 13 per cent of the mean difference between manual measurements of successive spirograms obtained from the same subject.

The computer method was used to measure the FVC, FEV_1, maximal expiratory flow (MEF), and maximal mid-expiratory flow (MMF) of 604 normal men and 134 normal women. The age, height, and weight of each subject were also recorded. Means, standard deviations, and correlation coefficients were calculated for each variable. Reliable equations were derived for predicting the FVC and FEV_1 of both men and women as functions of age and height. The coefficient of correlation between observed and predicted values was 0.63 or more. The equations developed for MEF and MMF showed low correlations between observed and predicted values.

The data for FVC and FEV_1 were expressed as per cent of predicted value. Means and standard deviations were computed for these normalized data, and frequency histograms were constructed. The probability density function for a normal distribution was used to generate normal density curves with the appropriate means and standard deviations. These theoretical curves showed good fit with the frequency histograms. It was concluded that the FVC and FEV_1 were normally distributed in this population of healthy subjects.

INTRODUCTION

The patient with chronic obstructive airway disease is frequently unable to recognize significant symptoms before irreversible pathologic changes have developed. Early detection is, therefore, of prime importance. Objective measurements of pulmonary function are required, and spirometry is accepted as the logical and practical method for these measurements (1). This technique is basic, not only in diagnosis of individual patients, but also in surveys undertaken to screen large populations for disease.

Since the initial study of Hutchinson (2), many workers have collected spirometric measurements in normal subjects. The current accepted standard is based on the cooperative Veterans Administration study of Kory and associates (3). Scandinavian workers and others have since added additional observations (4, 5).

Unfortunately, the widespread use of spirometry as a practical tool has been limited by the scarcity of trained technicians, the cost involved, and the time required to measure and calculate the spirometric tracings.

Recently many workers have taken the manual measurements from spirometric records and used a computer to perform the calculations. Curtis and associates (6) originally attached a potentiometer to the spirometer and recorded an electrical output that was proportional to volume changes. Other electronic spirometers have since been devised.[3] However, it was Schonfeld and associates (7) at the U. S. Department of Health, Education, and Welfare Instrumentation Field Station who combined the two techniques with nearly complete automation of spirometry. Their method has proved successful, and the precision, accuracy, and speed of the technique has been established (8).

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[2] Supported by the Intermountain Regional Medical Program Computer Monitoring Project and by Grant FR-00012 from the National Institutes of Health.

[3] Wedge Spirometer, Med-Science Electronics, Inc., St. Louis, Missouri.

The purpose of this paper is to report a method of on-line computerized spirometry that is completely automated and to compare it with the techniques of other workers. The method was used to obtain spirometric measurements from 738 normal subjects. From the data collected, several prediction formulas for spirometric measurements were developed and are presented. The frequency distribution of these measurements as observed in this population of normal healthy subjects also is reported.

MATERIALS AND METHODS

Computerized spirometric technique: All pulmonary data reported in this paper were collected with an on-line computer system that is part of the Intermountain Regional Medical Program Computer Monitoring Project. The system has been described in detail by Pryor and associates (9). A photograph of a typical remote computer terminal with spirometer and data set (10) is presented in figure 1. This terminal connects into a time-shared computer system called MEDLAB, which allows multiple operators immediate access to a real-time digital computer. This system is controlled by re-

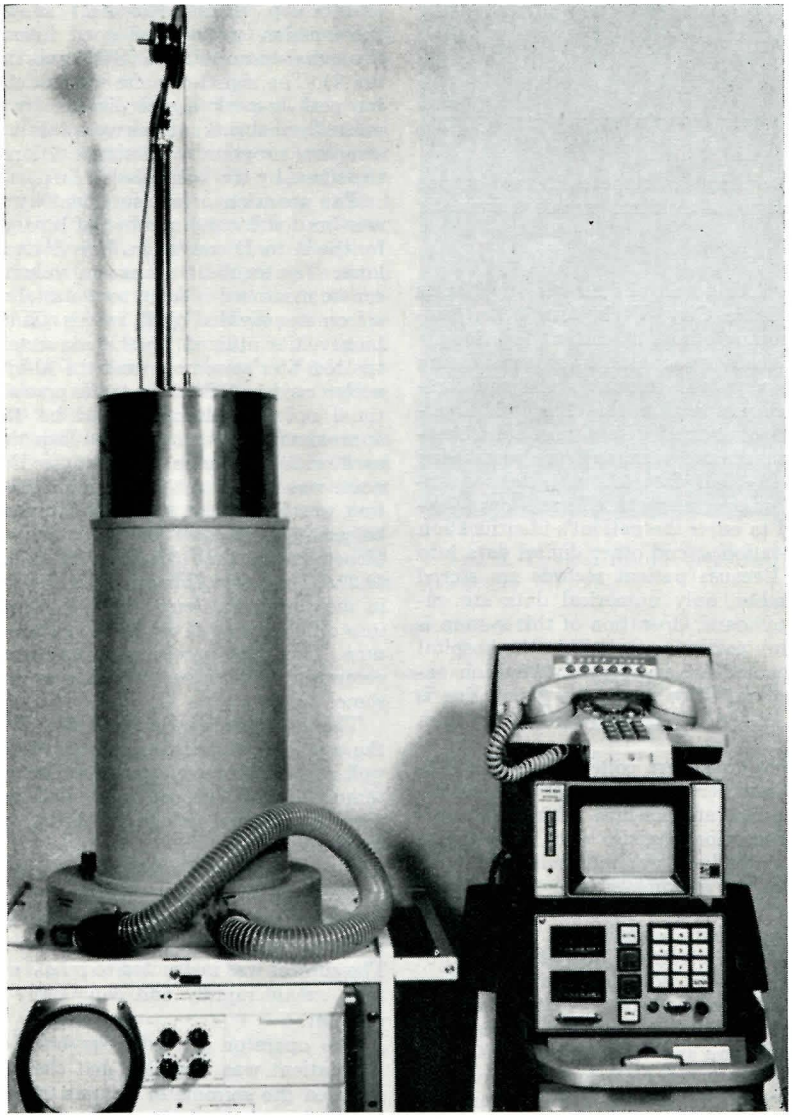

FIG. 1. Remote computer terminal with spirometer and data set.

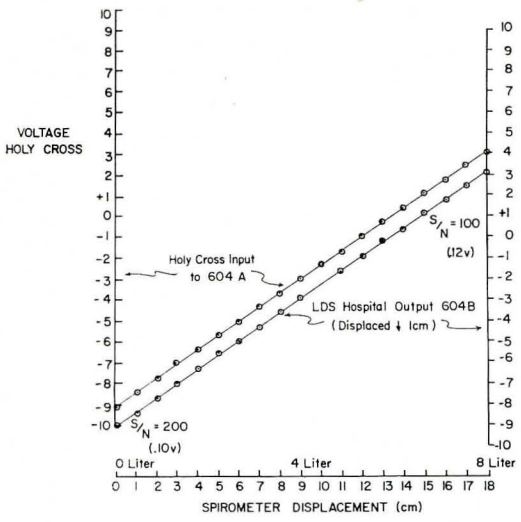

FIG. 2. Input voltages at remote site and output voltages at computer terminal versus spirometer displacements.

mote terminals located in the Latter-day Saints Hospital, Salt Lake City, Utah, four other hospitals, and screening clinics at distant locations.

There are basically two methods for transmitting information between the terminals and the computer. For terminals within this hospital, transmission is made over fixed wire connections. Analog signals from remote terminals are sent using Bell System 604A–604B data sets with the conventional dial telephone network. Touch-tone keyboards are used to enter the patient's identification number, vital statistics, and other digital data into the computer. Because patient records are stored by patient number, only numerical data are entered via the keyboard. Operation of this system is possible from any patient room within the hospital using a data set and the in-hospital television entertainment system. Only one input phone line is required from either the patient's room or from the remote site.

All spirometric data were collected with a 13.5-liter Collins spirometer using 0.75-inch Collins disposable mouthpieces and 1.5-inch tubing. The carbon dioxide absorption canister and valves were removed. The water level was maintained at 4 cm below the top of the spirometer, and the bell was maintained in a vertical free position. The spirometers were equipped with a single-turn potentiometer that provided an electrical output signal proportional to spirometer volume. Calibration was accomplished by sending the computer signals representing spirometer displacements corresponding to a zero base line and to a volume of 4 liters of gas (ATPS). After appropriate amplification, the electrical signal was sent to a 10-bit binary analog-to-digital (A to D) converter either by direct wire or via data sets and telephone lines.

Linearity of the single turn potentiometer is important in determining over-all accuracy. The potentiometer used was accurate to 0.1 per cent. The voltage input at a remote terminal located at Holy Cross Hospital, Salt Lake City, Utah, was measured over the range of spirometer displacements corresponding to volumes between 0 liters and 8 liters. The relationship between input voltage and spirometer displacement indicated clearly that the potentiometer signal was linear (figure 2). For data set communications, two other factors were also involved: (*1*) linearity of the transmission system, and (*2*) addition of noise to the real signal. Measurements of the input voltages at the remote terminal (Holy Cross Hospital) and the corresponding input voltages at the computer terminal (Latter-day Saints Hospital) showed that the transmission system had good linearity but that the signal-to-noise ratio (S/N) was important (figure 2). The signal-to-noise ratios determined were for peak-to-peak signal divided by peak-to-peak noise. Special precautions were taken with the data sampling program to minimize the noise added to the signal by the transmission link.

The precision of measurement by the computer was limited by the number of binary bits utilized by the A to D converter. This is explained as follows: The smallest change in volume of air that can be measured is equal to the total volume of the spirometer divided by 2^n, where n is the number of binary bits utilized by the converter. Thus, with the 13.5 liter spirometer and the 10-bit A to D converter used in this project, the precision under optimal noise conditions would be 13,500/1024, or approximately 13 ml of gas. When the system was used with telephone data set facilities, however, noise was added to the volume signal, and resolution was limited to about 50 ml of gas. It should be pointed out that the ratio of volume to displacement of the 13.5-liter Collins spirometer is 41.27 ml per mm. Therefore, a difference of 1 mm in measuring the length of the ink tracing results in a difference of 41 ml in the calculated ATPS volume. Thus, the precision of measurement by the computer and manual techniques was about the same.

The operator entered via the input keyboard the age, height, weight, and sex of the subject, as well as the barometric pressure and spirometer gas temperature. These data were used to compute the predicted normal values for the spirometric measurements.

The purpose of the testing was explained to each subject. All tests were performed with the subject sitting erect on a chair. The mouthpiece was placed in the patient's mouth and the nose was occluded. The subject was instructed to inhale maximally and then exhale rapidly and completely into the spirometer.

The operator pressed a keyboard switch while the patient was inspiring and the computer then sampled the spirometer volume 120 times per second and performed the necessary pattern recognition to identify the beginning and end of expiration. All calculations were performed on the

segment of the spirometric curve between the maximal inspiration and the end of expiration. The measured values (ATPS) were converted to BTPS. The results were immediately displayed at the remote terminal for evaluation by the operator. A typical output of results is shown in figure 3. The number on the upper right displays this value as a percentage of predicted value for a normal subject of the same sex, age, and height (3, 11). The immediate display of the percentage of predicted value achieved for each spirometric measurement enabled the operator to make a quick judgment as to whether the subject's performance was substandard. The subject repeated the test. With each successive repetition the computer compared the most recently obtained values with the best of those obtained previously in each category and retained the maximal values. At least three measurements were made on each subject.

After the calculations were performed, information was stored temporarily on a magnetic disc and later transferred to magnetic tape for a permanent record and statistical analysis. If requested, a printed report of data on any individual patient was available on either a high speed line printer or a teletype centrally located in the remote hospital. Alphabetic information such as the patient's name and physician's name were added at this time, either by punching a card or by entering it on the teletype. An example of such a report is illustrated in figure 4. It will be observed that this report includes a summary of abnormal findings as well as a computerized tentative interpretation.

Four spirometric measurements were made in this study: (*1*) forced vital capacity, (*2*) maximal expiratory flow, (*3*) forced expiratory volume at one second, and (*4*) maximal mid-expiratory flow. They were defined as in the Veterans Administration-Army Cooperative Study (3) (figures 5 and 6).

A preliminary study compared simultaneous computer and manual measurements of FVC and FEV_1. Three successive spirograms were obtained from each of 37 patients admitted to Holy Cross Hospital, Salt Lake City, Utah. The spirometer used provided an ink tracing as well as simultaneous on-line computer values of the spirometric functions. An experienced technician measured the ink tracings and computed the FVC from these 111 spirograms. For 26 subjects (78 spirograms), the FEV_1 was also calculated from the tracings. These manual measurements were compared with the corresponding computer values, and the significance of the measurement differences was analyzed by applying the *t* test. For FVC, the average differ-

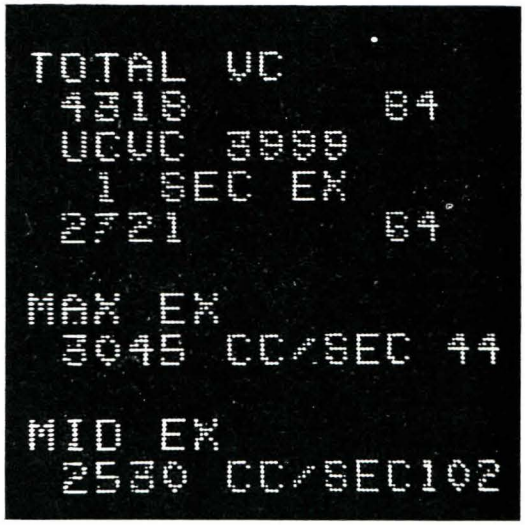

FIG. 3. Typical results displayed on oscilloscope at remote terminal.

U.S. HOSPITAL SCREENING SPIROMETRY

CASE 1433 NAME FOY,ARTHUR K DATE 9-17-68

PHYSICIAN TALMAGE NIELSEN ROOM NO. 0 HOSP. NO.OPD SERIES PS

AGE 56 SEX MALE HEIGHT 72 IN WEIGHT 135 LBS

CC - BTPS

TEST	PRED.	MEASURED		% PRED.
FORCED VITAL CAPACITY (TOTAL)	4662	1865	CC	40
MAX. EXPIRATORY FLOW RATE	6420	321	CC/SEC	5
1ST SEC. EXPIRATORY VOLUME	3587	574	CC	16
MID. EXPIRATORY FLOW RATE	2200	284	CC/SEC	13

QUESTIONS ANSWERED YES ON QUESTIONAIRE

1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14,

INTERPRETATION

VERY SEVERE OBSTRUCTIVE AIRWAY DISEASE

FIG. 4. Example of printed report of computerized spirometry.

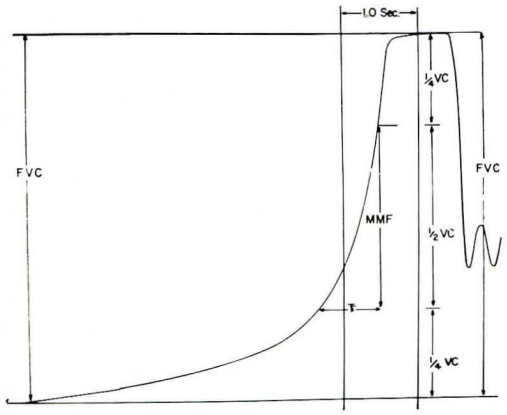

FIG. 5. Tracing of a spirogram showing definition of FVC and MMF.

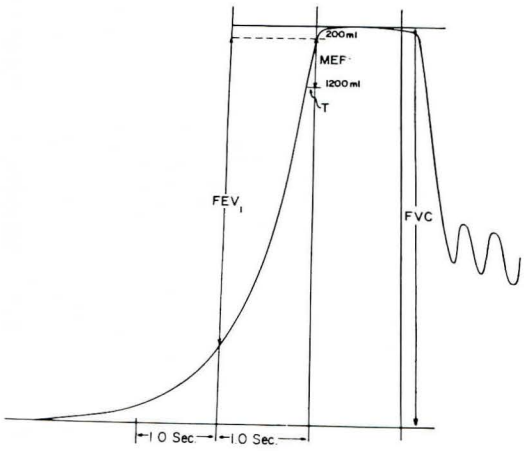

FIG. 6. Tracing of a spirogram showing definition of FEV_1 and MEF.

ence between the manual and computer means was 7 ml, with a standard deviation of 127 ml. For FEV_1 the average difference between the means was 13 ml, with a standard deviation of 221 ml. The t test indicated that neither of these differences was significant.

An analysis of the values obtained from three successive spirograms on each subject showed that the mean difference between successive measurements on the same subject was much larger than the mean difference between manual and computer measurements on the same spirogram. For example, the mean difference between the first and second FVC obtained from the same subject was 63 ml when measured manually and 70 ml when measured by the computer. This difference was about ten times the 7 ml mean difference between manual and computer measurements of the same spirogram. The mean difference between the first and second FEV_1 obtained from the same subject was 108 ml (manual) and 130 ml (computer), approximately eight to ten times the 13 ml mean difference between manual and computer measurements of the same spirogram. It was concluded that the small differences between manual and computer measurements were not clinically significant.

Population: Pulmonary data were obtained from a normal population of 604 men and 134 women. Donors to the blood bank at the Latter-day Saints Hospital, Salt Lake City, Utah (elevation, 4,500 feet above sea level) were asked to cooperate in the study and most (422 men, 119 women) of the subjects were from this source. The rest were volunteers in a respiratory disease screening program offered in Kamas, Utah (elevation, 6,500 feet) in June 1967 under the auspices of the Utah Thoracic Society, the Utah Tuberculosis and Health Association, and the Utah State Health Department. Each subject selected was at least 18 years of age and weighed more than 100 pounds. Only those who stated that they were currently in good health were included in this study of spirometric measurements of normal subjects.

Statistical methods: Pulmonary data were collected by the computerized spirometric technique. Data were recorded for age, height, weight, FVC, FEV_1, MMF, and MEF.

The statistical analysis used was a modification of the BMDO2R stepwise regression program (12). For a given dependent variable, the program computes a sequence of multiple linear regression equations in a stepwise manner. At each step one variable is added to the regression equation. The variable added is the one that makes the greatest reduction in the error sum of squares. Additional output includes means and standard deviations and a correlation matrix for all variables involved.

RESULTS

The subjects were separated by sex, and mean values and standard deviations were calculated for the variables (table 1). Each of the seven measurements was correlated with the other six, and a correlation matrix was developed (table 2). In general, the values for the correlation coefficients (r) are considerably lower for females than for males, except that the correlations of the spirometric measurements with height were slightly higher for females. Correlations of these measurements with age, however, were dramatically lower for females than males. Correlations with weight were low. Of the four spirometric measurements, FVC and FEV_1 showed the highest correlations with the other variables. These two variables were very strongly correlated with each other, and each showed a strong negative correlation with age and a strong positive correlation with height. In general, MMF and MEF showed low correlations with the other variables, with the ex-

ception that MMF showed a high correlation with FEV_1.

Prediction formulas were derived for each of the four spirometric measurements. For each of these dependent variables, a regression with age, height, and weight was developed in stepwise fashion. The coefficients of the equations obtained at the second and third stages of the regression, together with the coefficients of correlation between predicted and observed values, are displayed in table 3. The standard error of estimate is also presented for each equation.

Except in the case of MEF (females), the second stage of the regression expressed the predicted value of the spirometric measurement as a function of age and height:

$$\text{Equation II: } \hat{Y} = A_1 \times (\text{age in years}) + A_2 \times (\text{height in inches}) + C$$

Equation III expressed the predicted value of Y in terms of all three anthropometric measurements:

$$\text{Equation III: } \hat{Y} = A_1 \times (\text{age in years}) + A_2 \times (\text{height in inches}) + A_3 \times (\text{weight in pounds}) + C$$

A comparison of the correlation coefficients obtained with Equation II and Equation III demonstrated that when weight was included as one of the independent variables, the equations developed showed negligible improvements over those involving only age and height. For this reason the prediction formulas used in this study for establishing normal values are those expressed by Equation II.

The equations for both FVC and FEV_1 showed a very high correlation between predicted and observed values. For FVC: $r = 0.66$ (males); $r = 0.63$ (females). For FEV_1: $r = 0.70$ (males); $r = 0.64$ (females). However, in the case of MMF and MEF, the correlations between observed and predicted values were low ($r \leq 0.42$), and these equations were not regarded as useful formulas.

Equation II was used to compute the expected normal values of FVC and FEV_1 for each subject. The observed data could then be normalized. The experimentally determined value of the spirometric measurement was expressed as a percentage of the predicted value for a normal subjects of the same sex, age, and height.

TABLE 1

MEAN VALUES AND STANDARD DEVIATIONS OF MEASUREMENTS OF PULMONARY FUNCTION IN 3 GROUPS OF NORMAL SUBJECTS

Measurements	Group*	Mean	Standard Deviation
Age, years	1	35.4	10.9
	2	38.7	12.0
	3	37.3	10.5
Height, inches	1	65.3	2.8
	2	69.8	2.8
	3	69.5	2.9
Weight, pounds	1	144.4	26.7
	2	176.1	24.4
	3	170.5	24.5
FVC,† ml	1	3,411	572
	2	4,585	795
	3	4,810	760
FEV_1, ml	1	2,951	465
	2	3,834	711
	3	3,930	670
MMF, ml/sec	1	3,847	783
	2	4,712	1,186
	3	4,490	1,300
MEF, ml/sec	1	5,354	1,311
	2	7,453	2,323
	3	7,020	2,400

* Group 1 = 134 females; group 2 = 604 males; group 3 = values reported by Kory and associates in the Veterans Administration Cooperative Study (3).

† The Veterans Administration data presented here are for vital capacity rather than for forced vital capacity.

Per cent of predicted value = (observed value/predicted value) × 100.

The means and standard deviations were computed for the normalized data, and frequency histograms were constructed. If a random variable, x, has a normal distribution, with mean $\bar{x}$ and standard deviation σ, its probability density function is given by the following equation:

$$f(x) = \frac{1}{\sqrt{2\pi}\sigma} \cdot e^{-(x-\bar{x})^2/2\sigma^2}$$

This equation was used to generate normal density curves with the appropriate values for the means and standard deviations. The generated curves were superimposed on the fre-

TABLE 2

COEFFICIENTS OF CORRELATION AMONG PULMONARY FUNCTION MEASUREMENTS IN 3 GROUPS OF NORMAL SUBJECTS

Measurement	Group*	Age (*years*)	Height (*inches*)	Weight (*pounds*)	FVC (*ml*)	FEV_1 (*ml*)	MMF (*ml/sec*)	MEF (*ml/sec*)
Age, years	1	1.0	.01	0.25	−0.22	−0.33	−0.28	−0.01
	2	1.0	−0.20	0.08	−0.51	−0.60	−0.39	−0.25
	3	1.0	−0.17	—	−0.40	−0.50	−0.44	—
Height, inches	1		1.0	0.25	0.59	0.54	0.24	0.23
	2		1.0	0.48	0.52	0.47	0.21	0.19
	3		1.0	0.54	0.56	0.47	0.21	—
Weight, pounds	1			1.0	0.16	0.11	0.02	0.10
	2			1.0	0.24	0.19	0.03	0.11
	3			1.0	0.26	0.20	—	—
FVC,† ml	1				1.0	0.85	0.39	0.23
	2				1.0	0.88	0.38	0.28
	3				1.0	0.80	0.37	0.18
FEV_1, ml	1					1.0	0.62	0.37
	2					1.0	0.66	0.42
	3					1.0	0.68	0.17
MMF, ml/sec	1						1.0	0.43
	2						1.0	0.42
	3						1.0	0.15
MEF, ml/sec	1							1.0
	2							1.0
	3							1.0

* Group 1 = 134 females; group 2 = 604 males; group 3 = values reported by Kory and associates in the Veterans Administration Cooperative Study (3).

† The Veterans Administration data presented here are for vital capacity rather than for forced vital capacity.

quency histograms constructed from the observed data. The generated curve and the frequency histogram of FVC as per cent of predicted value for 604 male subjects are presented in figure 7. In all four instances (FVC, males; FEV_1, males; FVC, females; FEV_1, females), the theoretical curve showed a good fit with the observed distribution. It was concluded that the values for FVC and FEV_1 were normally distributed in this population of healthy subjects.

DISCUSSION

The method of on-line computerized spirometry described here has the advantage of presenting instantaneous data on an oscilloscope at the bedside or screening site while allowing simultaneous storage of data on tape and printout of formal reports. The spirometric measurements require less than 15 seconds, thus conserving physician and technician time. The programs, which were developed as part of the Intermountain Regional Medical Program Computer Monitoring Project, are available to other institutions with a MEDLAB type system.

The technique makes preoperative spirometric screening of surgical patients practical. Stein and associates (13) have shown the value of pulmonary function testing in identifying those subjects in whom postoperative pulmonary complications will develop. The technique also makes possible large epidemiologic studies in the field of pulmonary disease.

An examination of the standard deviations reported in table 1 shows that the measurements of MMF and MEF exhibited far more variability than did the measurements of FVC and FEV_1. The correlations of MMF and MEF with the

TABLE 3

REGRESSION EQUATIONS RELATING AGE, HEIGHT, AND WEIGHT TO PULMONARY FUNCTION MEASUREMENTS IN 3 GROUPS OF NORMAL SUBJECTS

		Equation II $\hat{Y} = A_1 \times$ (age in yrs) $+ A_2 \times$ (ht in inches) $+ C$					Equation III $\hat{Y} = A_1 \times$ (age in yrs) $+ A_2 \times$ (ht in inches) $+ A_3 \times$ (wt in lbs) $+ C$					
Measurement	Group*	A_1	A_2	C	r	Standard Error of Estimate (*ml*)	A_1	A_2	A_3	C	r	Standard Error of Estimate (*ml*)
FVC,† ml	1	−13	123	−4137	0.63	355	−14	118	1.8	−4075	0.63	354
	2	−28	124	−2967	0.66	461	−29	111	2.8	−2536	0.67	459
	3	−22	133	−3600	0.64	580						
FEV_1, ml	1	−14	92	−2571	0.64	281	−15	90	1.2	−2530	0.64	281
	2	−31	94	−1501	0.70	392	−32	84	2.2	−1158	0.70	390
	3	−28	94	−1590	0.63	520						
MMF, ml/sec	1	−21	71	−35	0.38	627	−22	68	1.2	7	0.38	629
	2	−36	57	2143	0.42	908	−36	59	−0.4	2087	0.42	909
MEF, ml/sec	1‡						1.3	130	−8.1	−1967	0.28	1132
	2	−43	120	723	0.29	1961	−46	85	7.7	1918	0.30	1952

* Group 1 = 134 females; group 2 = 604 males; group 3 = values reported by Kory and associates in the Veterans Administration Cooperative Study (3).

† The Veterans Administration data presented here are for vital capacity rather than for forced vital capacity.

‡ For MEF, the equation obtained for females at the second stage of regression was: $\hat{Y} = 129 \times$ (ht in inches) $- 8.0 \times$ (wt in lbs) $- 1922$; ($r = 0.28$; SEE = 1137).

anthropometric measurements were much lower than the corresponding values for FVC and FEV_1 (table 2). Finally, the regression equations developed for MMF and MEF showed low correlations between the observed and predicted values, as well as high values for the standard error of estimate (table 3). Similar observations apply to the data on males reported by Kory and co-workers (3). The marked variability of the measurements of MMF and MEF in normal subjects indicates that the use of these measurements in clinical situations has questionable validity.

Reliable equations were developed for predicting the measurements of both FVC and FEV_1 in normal subjects. The correlation between these two measurements was very high in the normal subjects ($r = 0.88$ for males; $r = 0.85$ for females). However, it should be observed that they do not measure the same parameter. The FVC is a volume measurement, whereas FEV_1 is essentially a rate measurement. In abnormal subjects, especially those with obstructive airway disease, the correlation might be much lower.

The mean values for the spirometric measurements on females were much lower than the corresponding values for males. In males, both FVC ($r = -0.51$) and FEV_1 ($r = -0.60$) showed a strong negative correlation with age. In the female group, however, these measurements were far less dependent on age (FVC: $r = -0.22$; FEV_1: $r = -0.33$). The single most important factor in predicting the performance of the females appeared to be height.

A comparison of the results obtained in this study of 604 males with those obtained in the Veterans Administration study of 468 males (3) reveals striking similarities. The Veterans Administration data are displayed in tables 1, 2, and 3. In both studies subjects in good health who were expected to exhibit normal pulmonary function were selected. The means and standard deviations for both the anthropometric and spirometric measurements are very similar for the two populations (table 1). It should be noted

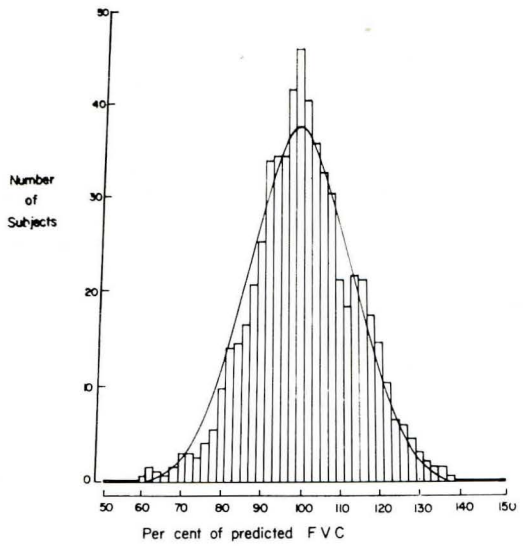

FIG. 7. Histogram of FVC as per cent of predicted value, and best fit normal density function for 604 male subjects. Mean FVC = 100%; SD = 13%.

that in the current investigation the subjects resided and were tested at 4,500 feet (Salt Lake City) or 6,400 feet (Kamas) above sea level.

Some differences in the spirometric testing procedures used in the two investigations should be made explicit. In the VA study, all tests were performed with the subject in the standing position. Both the vital capacity and the forced vital capacity were measured, but regression equations were not reported for the latter function. The vital capacity is defined as the maximal volume of gas exhaled without force or haste following maximal inhalation. The forced vital capacity differs in that the subject is instructed to exhale as rapidly as possible.

In the present investigation, the subjects were seated and the function studied was the forced vital capacity. With incapacitated patients, particularly those who are preoperative, the sitting position is frequently more comfortable than the standing position, and a forced exhalation gives a more reliable estimate of capacity than does an unforced exhalation. If spirometric measurements are to be used as an aid in the diagnosis of pulmonary malfunction, the testing procedure used to establish normal values for healthy subjects should be suitable for use with incapacitated patients. The computerized spirometric technique described here satisfies these requirements.

Although the two investigations used somewhat different procedures, the predication formulas derived for males were very similar:

$$\text{This study: FVC} = -28A + 124H - 2967 \quad (r = 0.66; \text{SEE} = 461).$$

$$\text{VA study: VC} = -22A + 133H - 3600 \quad (r = 0.64; \text{SEE} = 580).$$

$$\text{This study: } FEV_1 = -31A + 94H - 1501 \quad (r = 0.70; \text{SEE} = 392).$$

$$\text{VA study: } FEV_1 = -28A + 94H - 1590 \quad (r = 0.63; \text{SEE} = 520).$$

The spirometric measurements are given in milliliters, A = age in years, H = height in inches, r = correlation coefficient, and SEE = standard error of estimate in milliliters.

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RESUMEN

ESPIROMETRÍA POR COMPUTADOR EN 738 ADULTOS NORMALES

Se describe un método automatizado para practicar la espirometría por medio de computador. La diferencia promedio entre los valores manuales y los del computador al determinar la capacidad vital forzada (FVC) y el volumen espiratorio forzado en 1 segundo (FEV_1), fue menos de 13 por ciento de la diferencia promedio entre la determinación manual de espirogramas sucesivos en el mismo sujeto.

El método por computador mencionado se empleó para determinar la FVC, el FEV_1, el flujo espiratorio máximo (MEFR), y el flujo máximo en medio de la espiración (MMEF), en 604 hombres y 134 mujeres normales.Se constató además la edad, estatura, y peso de cada sujeto. Se informó el

promedio, desviación standard, y cocientes de correlación para cada variable. Se desarrollaron ecuaciones confiables para predecir la FVC y el FEV_1 para hombres y mujeres a base de su edad y estatura. El cociente de correlación entre los valores observados y los predichos fue de 0.63 o más. Las ecuaciones para el MEFR y el MMEF revelaron pobre correlación entre los valores observados y los predichos.

Los datos obtenidos para el FVC y el FEV_1 se expresaron en por ciento del valor predicho. Se computaron las desviaciones promedio y standard para estos valores normales y se trazaron histogramas de frecuencia. Se empleó la función de probabilidad de densidad para una distribución normal para desarrollar curvas normales de densidad con sus desviaciones promedio y standard apropiados. Estas curvas teóricas mostraron buena correlación con el histograma de frecuencia. Se concluye que el FVC y el FEV_1 presentaban una distribución normal en este grupo poblacional de sujetos normales.

RESUME

SPIROMÉTRIE ÉTUDIÉE SUR ORDINATEUR EN TEMPS RÉEL [ON-LINE COMPUTERIZED], CHEZ 738 ADULTES NORMAUX

On a décrit ici une méthode complètement automatisée de spirométrie sur ordinateur utilisé en temps réel. En ce qui concerne la capacité vitale forcée (FVC) et le volume expiratoire forcé en une seconde (FEV_1), la différence moyenne entre les mesures effectuées manuellement ou sur ordinateur, et concernant le même spirogramme, ont été inférieures à 13 pour cent de la différence moyenne relevée entre des mensurations manuelles de spirogrammes successifs obtenus chez le même sujet.

La méthode sur ordinateur décrite ici a été utilisée pour mesurer le FVC, le FEV_1, le taux de débit expiratoire maximal (MEFR), ainsi que le taux maximal à la moitié de l'expiration (MMF), chez 604 hommes normaux et chez 134 femmes normales. On a également enregistré l'âge, la taille, et le poids de chaque sujet. Les moyennes, les écarts-types, et les coefficients de corrélation, ont été fournis pour chacune des variables. Des équations fiables en ont été dérivées en vue de prédire le FVC et le FEV_1 des hommes et des femmes sous forme de fonctions de l'âge et de la taille. Les coefficients de corrélation entre les valeurs observées et les valeurs de prédiction se sont élevés à 0,63 ou davantage. Les équations développées pour le MEFR et pour le MMF ont montré des corrélations faibles entre les valeurs observées et les valeurs de prédiction.

Les valeurs observées pour la FVC et pour le FEV_1 ont été exprimées en tant que pourcentages de la valeur de prédiction. Les moyennes et les écarts-types ont été calculés pour les données normalisées, et des histogrammes de fréquence ont été tracés. La fonction probabilistique de densité [probability density function] pour une distribution normale, a été utilisée pour générer les courbes de densité normale avec les moyennes et les écarts-types appropriés. Ces courbes théoriques ont montré une bonne corrélation avec les histogrammes de fréquence. On en conclut que la FVC et le FEV_1 étaient distribués de façon normale dans cette population de sujets sains.

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