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Spirometry in selected clinical situations

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ABSTRACT

Spirometry is the most frequently performed functional test of the respiratory system. In pulmonological practice it is a basic tool used to diagnose ventilation disorders and to monitor treatment. The results obtained during the test are compared to predicted values, that is, assumed parameter values, computed on the basis of anthropometrical data such as: age, gender and height, with the use of complex equations. The use of additional variables including, e.g. an ethnic group or a race as well as corrective factors, enables a more exact determination of their values. Spirometry can be conducted in a sitting or standing position; however, for the subject safety reasons it is usually performed in a sitting position. It allows to eliminate the risk of fall as a result of syncope or impaired balance. Spirometry in a standing position should be considered in measurably obese patients or in patients with a wide abdominal circumference caused by other reasons. Patients with normal body weight obtain equivalent or slightly higher spirometric values in a standing position. In the selected clinical situations some problems with the measurement of the actual hight of patients in a standard way (measurement without shoes, feet together, upright position, eyes straight ahead) and with correct calculation of predicted values occur. They are, among others, silhouette-disturbing disorders or diseases causing changes in body proportions, from the less often occurring, like Marfan syndrome or achondroplasia, to more frequent posture defects and mobility impairments. These diseases influence the change of the predictive functional parameter values which are used to compare with the obtained results. The aim of the study is to demonstrate the methods of height and predicted values determination on the basis of measurements of ranges between different body points with the use of simple and complex equations in a group of patients in whom the application of standard measurement methods is impossible.

Keywords: spirometry.

Introduction

Spirometry is the most frequently performed functional test of the respiratory system. In pulmonological practice it is a basic tool used to diagnose ventilation disorders and to monitor treatment. The results obtained during the test are compared to predicted values, that is, assumed parameter values, computed on the basis of anthropometrical data such as: age, gender and height, with the use of complex equations. The use of additional variables including, e.g. an ethnic group or a race as well as corrective factors, enables a more exact determination of their values [1]. Spirometry can be conducted in a sitting or standing position; however, for the subject safety reasons it is usually performed in a sitting position [2]. It allows to eliminate the risk of fall as a result of syncope or impaired balance. Spirometry in a standing position should be considered in measurably obese patients or in patients with a wide abdominal circumference caused by other reasons. Patients with normal

body weight obtain equivalent or slightly higher spirometric values in a standing position [3].

In the selected clinical situations some problems with the measurement of the actual hight of patients in a standard way (measurement without shoes, feet together, upright position, eyes straight ahead) and with correct calculation of predicted values occur. They are, among others, silhouette-disturbing disorders or diseases causing changes in body proportions, from the less often occurring, like Marfan syndrome or achondroplasia, to more frequent posture defects and mobility impairments [4]. These diseases influence the change of the predictive functional parameter values which are used to compare with the obtained results.

Aim

The aim of the study is to demonstrate the methods of height and predicted values determination on the basis of measurements of ranges between different body points with the use of simple and complex equations in a group of patients in whom the application of standard measurement methods is impossible.

Height determination on the basis of rigid body proportions

A simple method of patient's height determination allowing to minimize errors in the determination of predicted spirometric values, is to determine averaged, rigid body proportions in healthy subjects in a particular population [5]. Knowing the proportions, predicted height of a person can be estimated with the help of selected body parts' measurements [6]. It is a simple and fast method used in practice, however burdened with a margin of error due to non-consideration of other factors, such as age or an ethnic group [7]. In the group of patients with achondroplasia or Marfan syndrome the margin of error may be even bigger due to impaired body proportions [8]. This method may be successfully used in screening examination of patients with skeletal malformations, mobility problems or faulty postures. There are numerous formulas for the prediction of height with the use of proportional equations, the most frequent employ: arm span measurement (height in a standing position = arm span/1.06), measurement of height in a sitting position (height in a standing position = height in a sitting position/0.52), measurement of feet-navel range (height in a standing position = feet-navel range x 1.618). The arm span is measured between the tips of middle fingers, the height of a sitting position is determined from the top of the head to the base on which the patient is sitting, the feet-navel range is measured in a standing position [9].

Height determination based on regression equations

The inadequacy of the method of height determination on the basis of rigid body proportions caused the search for better solutions in the form of regression equations based on anthropometric parameters and different variables, which enable more exact estimation of patients' height.

Based on a group of 5415 healthy adults and 13,821 healthy children Cameron developed the regression equation which allows to compute the predicted height of patients with mobility and psychophysical impairments. During the development of the equations he considered parameters like: age, gender, ethnic group, absolute height, height in a sitting position, height from the ground to knees, range from the buttock to knees. The most credible regression equation estimating proper height of women, men and children whose measurement was impossible with a standard method included the knee height. The expansion of the margin of error in the calculated height was connected with posture impairment intensification [10].

Based on arm span measurements, Miller developed similar regression equations, which predicted the height of patients with chest deformations equally well [11].

Arm span as an independent predictor of lung function parameters

Golshan created equations of pulmonary system function parameters based directly on arm span measurements in a group of 1865 healthy, non-smoking subjects [12]. He performed height

measurements in a standing position, arm span measurements and pulmonary function tests. Then, he compared the obtained results of spirometry with the predicted values computed with the use of different methods. He demonstrated that the predicted values computed with the use of a prediction equation, based on the arm span, are the most exact ones when it comes to the prediction of values obtained during spirometry of healthy subjects. Slightly bigger discrepancies between the estimated and the obtained results were observed in the case of the predicted values computed with the use of the height of subjects. However, the predicted values determined for height, which were computed with a regression equation based on the arm span, did not correspond to the spirometric results [13].

The determination of the values of the pulmonary functional parameters with the use of prediction equations, based on the arm span, is equally reliable as the use of equations based on height measurements in a standing position. It is an effective method in patients in whom standard measurement methods are not possible [14].

Chest deformations and lack of limbs

Inborn and acquired skeletal abnormalities such as profound kyphosis (syringomyelia, muscular atrophy) or kyphoscoliosis disable standard height measurements. In these cases, an estimation of height is possible with the use of the above-mentioned equations: patient's height = arm span/1.06, patient's height = range from the top of the head do the base which the patient is sitting on/0.52 or patient's height = feet-navel range x 1.618 [15].

The application of the above-mentioned equations causes some uncertainty when it comes to the accuracy of the calculated predicted values of the functional parameters and the measured to predicted value ratio. It especially concerns extreme cases such as: significant chest deformations or problems with proper arm spreading. A possible outcome of the determination of predicted values in this way is a misdiagnosis or a false exclusion of ventilation disorders [16]. A more precise method of height estimation is the use of developed by Parker regression equations including the measurement of the arm span, race, age and patient's gender. A standard estimation error in height measurement is within 3.0 to 3.7 cm [17]. The application of similar equations using knee height in a patient's height estimation is also possible. Such equations were developed in 1994 by Chumlea [18].

Regression equations and the above-mentioned formulas may be used in a height estimation in patients with no lower limbs (congenital abnormalities, post-amputation condition). In exceptional situations when a patient is also deprived of one upper limb, the measurement is taken from the middle of a body to the tip of a middle finger with a wide-open arm and the obtained value is multiplied x2 and is used in the chosen formula [2].

Marfan syndrome

Marfan syndrome is a genetic disorder of connective tissues caused by a mutation in the FBN1 gene, resulting in abnormalities in the creation of elastic fibres, elastin and the ground substance of connective tissues. This disease is inherited in an autosomal dominant fashion and its *de novo* mutation frequency is estimated at about 25%. In a general population the frequency of the disorder occurrence is estimated at 10–20:100 000. The clinical picture includes: tallness (average final height for men: 191 cm, for women: 175 cm), body proportion abnormalities — including limb prolongation, degenerative spine arthritis, chest deformations, eyesight, nervous system and cardiovascular defects [19].

One of the first reports regarding the necessity to use in Marfan syndrome patients separate predicted values to evaluate spirometic results, is a study by Streeten [20]. The author of the publication analysed the results of 79 patients with diagnosed Marfan syndrome. He demonstrated that patients without significant chest deformations had lower values of forced vital capacity (FVC) than the predicted values determined on the basis of a standard height measurement (83 percentile). However, when prediction equations were used in prediction value calculations with the use of sitting position height, the obtained values were higher (FVC: 105 percentiles, FEV1: 92 percentiles). In the case of significant chest

deformations, lower FVC and forced expiratory volume in 1-st second (*FEV1*) were demonstrated regardless of the predicted value determination method [10].

Giske performed spirometry tests in a group of 17 Marfan syndrome patients at the age of 18–30. He demonstrated normal or slightly lowered FVC and FEV1/FVC values. Nevertheless, the results of functional tests were based on predicted values calculated with a standard height measurement method [21].

Achondroplasia

Achondroplasia is a genetically conditioned disorder with an autosomal dominant inheritance pattern, caused by a mutation of a gene responsible for a receptor synthesis for the fibroblast growth factor. The origin of the disorder is abnormal endochondral ossification leading to osteochondral dysplasia with long bones and spine growth impairments, which result in dwarfism. Clinical picture includes, among others, short stature (average height: 125 cm) and limb size reduction with a normal length of torso (ratio of height in a sitting position is 0.66 with the norm of 0.52–0.53 for healthy population) [22].

Dennis conducted spirometry tests in 102 subjects at the age of 7–60 who suffered from achondroplasia. Then, on the basis of the obtained results, he developed prediction equations which may be used to calculate proper predicted values for this group of patients. They included sitting position height and age and referred to FEV1 and FVC (**Table 1**) [23].

The author additionally compared the obtained spirometric results with the predicted values obtained with the use of other methods, e.g.: he used the predicted values for height, calculated with a regression equation including sitting position height. The obtained in the regression equation values did not correspond to the predicted values calculated with the prediction equations [24].

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Conflict of interest statement
The authors declare no conflict of interest.

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Table 1. Examples of prediction equations for the predicted FVC values. Source: own elaboration based on D.C. Stokes, R.E. Pyeritz, R.A. Wise, D.L. Fairclough, E.A. Murphy, Spirometry and Chest Wall Dimensions in Achondroplasia, Chest 1988;93;364–369

Men under the age of 25	FVC(L) = -3.56+0.162*height in a sitting position (in)+0.067*age (in years)
Men over the age of 25	FVC(L) = -0.73+0.162*height in a sitting position (in)+0.047*age (in years)
Women under the age of 20	FVC(L) = -3.56+0.150*height in a sitting position (in)+0.067*age (in years)
Women over the age of 20	FVC(L) = -1.92+0.150*height in a sitting position (in)+0.016*age (in years)

in – inch.

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