Modeling of appropriate spirometric indicators in practically healthy young women from Podillia with ectomorphic somatotype

Sarafyniuk L. A., Kyrychenko Yu. V.
National Pirogov Memorial Medical University, Vinnytsya, Ukraine

Many researchers emphasize the practical importance of using mathematical modeling to determine the reference values of spiographic parameters, but unfortunately, there are no works that study the complex influence of anthropometric and somatotypological indicators on spirometric parameters in healthy young people. The purpose of the work was to build regression models to determine the proper indicators of external breathing in practically healthy young women (YW) ectomorphs and to establish the total influence of the constitutional characteristics of the body on spirometric parameters. We conducted a spiographic examination of 109 practically healthy YW (from 16 to 20 years inclusive) according to the American Pulmonology Association and the European Respiratory Society (2019) method on the Medgraphics Pulmonary Function System 1070 series. The anthropometric examination was carried out according to the method of Bunak V. V. as modified by Shaparenko P. P. (2000). The component composition of body weight was assessed according to Matiegka method (1921), muscle mass according to the method of the American Institute of Nutrition (1991). Somatotypological research was carried out according to the Heath-Carter (1990) method. After somatotyping, it was found that 31 YW had an ectomorphic type of constitution. For them, we conducted a direct step-by-step regression analysis in the “STATISTICA 5.5” package. On the basis of multivariate regression analysis, the total influence of anthropometric, somatotypological and dynamometric indicators on the variability of spirometric parameters of the body was determined. Mathematical modeling was carried out to determine the appropriate individual spiographic indicators in practically healthy YW of the Podillia ectomorphic somatotype. 11 reliable regression linear models were built with the accuracy of the description of the feature in the range of 57.63-94.44 %. To the greatest extent, the value of the spirometric parameters was determined by the girth of the body (most often the girth of the hand), the diameters of the pelvis (most often the external conjugate and intercristal distance), the width of the distal epiphyses (most often the shins), the skinfold thickness (most often under the shoulder blade).

Keywords: spiography, young women, youth, ectomorphic somatotype, regression models.

Introduction
At present, the conditionality of the macro- and microstructure of individual organs of various systems of the human body does not cause objections [8, 19]. In addition, modern studies have proven the existence of a mutually determined relationship between the features of the external structure of the body and functional parameters [3]. But it should be noted that the majority of such studies focus on the cardiovascular system [10, 11, 13, 18, 20, 23]. Although recently, scientists emphasize the need to study the interrelationships and interdependencies between indicators of respiratory organs and body structure parameters [1, 9, 15]. The relevance and practical importance of studying this issue is determined by the prevalence and progression of respiratory diseases among different population cohorts [6, 16, 17, 25] and the need for an individual approach to determining normative indicators [1, 14].

The practical importance of using mathematical modeling to determine the reference values of spiographic parameters is emphasized by many researchers who draw attention to the need to take into account the factor of sex and age [4, 7, 15]. Unfortunately, there are no works that
study the complex influence of all anthropometric and somatotypological indicators on spirometric parameters in healthy young people.

It is interesting that a certain number of studies related to the relationship between the indicators of pulmonary ventilation and the characteristics of fat deposition, such as fat and lean body mass, sagittal diameter of the abdomen, and the total amount of water in the body [4, 15, 24]. It has been proven that obesity, even in the absence of disease, is the cause of a decrease in external respiration, which is considered a predictor of mortality and a risk factor for diseases [7]. From our point of view, it is interesting to determine the dependence of spirometric indicators on the total influence of parameters of the external structure of the body in young women of the ectomorphic somatotype, which are characterized by minimal development of subcutaneous adipose tissue.

The purpose of the study was to build regression models to determine the proper parameters of external breathing in practically healthy young women ectomorphs and to establish the total influence of the constitutional characteristics of the body on spirometric parameters.

Materials and methods

On the basis of the research center of the National Pirogov Memorial Medical University, Vinnytsya, as a result of a comprehensive survey of the urban population, 109 practically healthy young women (from 16 to 20 years inclusive) were selected, who in the third generation lived in the territory of the Podillia region of Ukraine. Their state of health was assessed on the basis of a preliminary comprehensive clinical and laboratory examination.

Committee on Bioethics of National Pirogov Memorial Medical University, Vinnytsya (protocol № 6 From 8.06.2020) found that the studies do not contradict the basic ethical standards of the Declaration of Helsinki, the Council of Europe Convention on Human Rights and Biomedicine (1977), the relevant WHO regulations and laws of Ukraine.

A spirometric examination was conducted according to the methodology of the American Pulmonology Association and the European Respiratory Society [5] on the MedGraphics Pulmonary Function System 1070 series. Anthropometric examination was performed according to Bunak's V. V. method, modified by Shaparenko P. P. [21]. This study included the assessment of total body dimensions: length (cm), mass (kg), body surface area (m²) and partial: longitudinal, girth, transverse and sagittal body dimensions and the width of the distal epiphyses - determined in cm, the skinfold thickness measured in mm. The assessment of the component composition of body weight was carried out according to the Matiegka method [12], the amount of muscle, fat and bone mass of the body was determined in kg. In addition, body muscle mass (kg) was determined according to the method of the American Institute of Nutrition [22]. The strength of the hand flexor muscles was determined using a hand dynamometer (kg).

The somatotypological study was carried out according to the Heath-Carter method [2], the value of mesomorphic, endomorphic and ectomorphic components was estimated in points. After somatotyping, it was found that 31 girls had an ectomorphic type of constitution. For them, we conducted a direct step-by-step regression analysis in the "STATISTICA 5.5" package.

Results

On the basis of multivariate regression analysis, we performed mathematical modeling of spirometric parameters in practically healthy YW ectomorphic somatotype of the Podillia region of Ukraine, depending on the characteristics of indicators of external body structure. Constructed linear regression models provide an opportunity to determine appropriate individual spirometric indicators on the basis of anthropometric and somatotypological characteristics of each person of young female age.

In particular, we found that the volumetric exhalation rate, respectively, at 50% of the forced vital capacity of the lungs (FIF 50%) was 81.00% dependent on the combined effect of 9 anthropometric and 1 dynametric indicators. Most of the coefficients of the independent variables included in this regression polynomial had high reliability, with the exception of the free member and the skinfold thickness on the chest and under the shoulder blade. Fisher's criterion of this mathematical model (F=8.50) was greater than its calculated value (Fₐ=10.20). Accordingly, we could claim that the constructed regression polynomial is highly significant (p<0.001), which was also confirmed by the results of variance analysis. The built model had the form of the following linear equation:

\[
\text{FIF 50} = 3.388 + 3.916 \times \text{width of the distal epiphysis of the shoulder on the left} - 0.066 \times \text{circumference of the right hand} + 0.655 \times \text{circumference of the forearm in the upper third} + 0.203 \times \text{transverse middle chest size} - 0.200 \times \text{skinfold thickness on the shin} + 0.197 \times \text{skinfold thickness on the chest} + 0.093 \times \text{shoulder width} + 0.113 \times \text{skinfold thickness under the shoulder blade}.
\]

We found that the variability of the forced vital capacity of the lungs (FVC) in YW ectomorphic somatotype was 95.55% dependent on 13 anthropometric parameters, which were correlated with each other. To reduce multicollinearity, we used the ridge regression method, where a constant (lambda) equal to 0.1 was added to the correlation matrix. Ridge regression in this case reduced the coefficient of determination \(R²=72.42\) and the number of independent variables of the regression polynomial, the vast majority of whose coefficients were reliable, with the exception of the inter-ridge pelvic distance. Fisher's criterion of this model (F=13.11) more than doubled its calculated value (Fₐ=5.25). Accordingly, we could claim that the constructed regression polynomial is highly significant.
Modeling of appropriate spirometric indicators in practically healthy young women from Podillia with ectomorphic...

In YW ectomorphs, almost all coefficients of the model of forced inspiratory flow, which is 50% expiratory from forced vital capacity (FEF50FIF), had high reliability, with the exception of shoulder width. The coefficient of determination R² by 78.24% determined adm issibly this dependent variable. The regression linear polynomial was reliable (p<0.001), which was also confirmed by the results of variance analysis. Based on the fact that Fisher's criterion of this model (F=8.81) was greater than its calculated value (F₀ = 6.24). Accordingly, we could claim that the constructed regression polynomial is highly significant (p<0.001), which was also confirmed by the results of variance analysis. The model had the form of the following linear equation:

FEF50FIF (l/s) = -17.77 + 2.959 x width of the distal epiphysis of the left shoulder + 0.589 x sagittal size of the chest + 0.742 x foot circumference - 0.480 x muscle body mass - 0.134 x shoulder width - 0.277 x skinfold thickness under the scapula + 0.108 x height of the acetalabular point + 0.687 x external conjugate + 1.636 x width of the distal epiphysis of the forearm on the right.

The variability of maximum voluntary lung ventilation (MVV) depended on 77.44% of the total complex of 10 parameters of the external structure of the body and 1 dynamometric index. Most of the coefficients of the independent variables that were included in the polynomial had high reliability, except for the free member, the intertrochanteric distance of the pelvis, and the chest circumference at expiration. Fisher's criterion of this model (F=5.92) was smaller than its calculated value (F₀ = 11.19). The constructed regression polynomial was reliable (p<0.001), which was also confirmed by the results of variance analysis. The model had the form of the following linear equation:

MVV (l) = 212.5 + 4.805 x sagittal size of the chest - 36.06 x width of the distal epiphysis of the tibia on the right + 1.351 x dynamometry of the left hand + 4.700 x skinfold thickness under the scapula - 1.636 x height of the acetabular point - 7.663 x girth of the hand + 16.25 x bone body weight + 8.454 x neck circumference - 2.669 x hip circumference + 6.166 x intertrochanteric distance - 1.045 x chest circumference on exhalation.

Expiratory volume rate, respectively, at 25% of the forced vital capacity of the lungs (FEF 25%) in YW ectomorphs depended by 57.63% on the influence of only 4 anthropometric indicators that were included in the linear polynomial. All coefficients of independent variables and the free term of this model were reliable. Fisher's test (F=8.81) was greater than its calculated value (F₀ = 6.24). The constructed regression polynomial was reliable (p<0.001). The model had the form of the following linear equation:

FEF 25% (l/s) = -20.06 + 0.934 x forearm girth in the upper third - 0.522 x external conjugate + 0.815 x intercostal distance - 0.137 x body weight.

The value of the vital capacity of the lungs (SVC) is determined by 79.73% of the complex influence of anthropometric and somatotypological indicators, which were included in the regression polynomial. Most of the coefficients of the independent variables of this model had high reliability, with the exception of the free member and skinfold thickness under the scapula. Fisher's criterion of this model (F=12.90) was greater than its calculated value (F₀ = 7.23). The constructed regression polynomial was reliable (p<0.001), which was also confirmed by the results of variance analysis and comb regression. The model had the form of the following linear equation:

SVC (l) = 0.026 + 0.073 x thigh girth - 0.249 x...
mesomorphic component + 0.039 x muscle body mass according to the American Institute of Nutrition + 0.080 x interspinous distance - 0.294 x width of the distal epiphysis of the ipur on the left + 0.368 x skinfold thickness on the abdomen - 0.042 x skinfold thickness under the scapula.

Inhalation capacity (IC) in YW ectomorphs by 91.84 % is due to the complex influence of constitutional indicators that were included in the polynomial. All coefficients of independent variables of this model were reliable. Fishers criterion of this model (F=19.73) was greater than its calculated value (F_{cal}=11.19). The constructed regression polynomial was highly significant (p<0.001), which was also confirmed by the results of variance analysis. The model had the form of the following linear equation:

\[
\text{IC (l)} = -1.817 - 0.020 x \text{dynamometry of the right hand} + 0.155 x \text{intercristal distance} + 0.060 x \text{skinfold thickness on the chest} - 0.204 x \text{hand circumference} + 0.280 x \text{forearm circumference in the lower third} - 0.175 x \text{foot circumference} + 0.094 x \text{shin circumference in upper third} - 0.100 x \text{thickness of the fat fold under the scapula} + 0.021 x \text{height of the acetalabular point} - 0.114 x \text{ectomorphic component} - 0.036 x \text{sagittal chest size}.
\]

Most of the coefficients of the expiratory residual volume (ERV) model had high reliability, except for free member, sagittal chest size, and body length. The coefficient of determination \( R^2 \) determined this dependent variable by 79.61 %. Based on the fact that F=10.73, which is greater than the calculated value (F_{cal}=8.22), it was possible to claim that the regression linear polynomial is highly significant (p<0.001), as evidenced by the results of the variance analysis. The model looked like this:

\[
\text{ERV (l)} = -2.259 + 0.197 x \text{foot circumference} + 0.097 x \text{intercristal distance} - 0.386 x \text{width of distal femoral epiphysis on the right} - 0.122 x \text{transverse mid-chest size} + 0.150 x \text{hand circumference} - 0.213 x \text{forearm circumference in the lower third} + 0.047 x \text{sagittal chest size cells} + 0.014 x \text{body length}.
\]

The maximum peak expiratory flow (FEF MAX) in YW ectomorph somatotype depended on 94.44 % of the total complex 1 dynamometric and 13 indicators of external body structure. Most of the coefficients of the independent variables of this regression polynomial had high reliability, with the exception of the free member, neck circumference and the thickness of the fold under the shoulder blade. Fishers criterion of this model (F=19.28) is greater than its calculated value (F_{cal}=14.16). Accordingly, we had grounds to claim that the constructed regression polynomial is highly significant (p<0.001), which was also confirmed by the results of variance analysis. The model had the form of the following linear equation:

\[
\text{FEF MAX (l/s)} = -4.910 + 0.665 x \text{interspinous distance} - 1.049 x \text{external conjugate} + 0.519 x \text{body length} - 0.274 x \text{height of the pubic point} + 0.690 x \text{shin circumference in the lower third} + 1.346 x \text{forearm circumference in the upper third} - 0.558 x \text{hand circumference} - 0.369 x \text{height of the suprasternal point} - 0.284 x \text{skinfold thickness on the shin} + 0.631 x \text{skinfold thickness on the chest} - 0.100 x \text{dynamometry of the left hand} - 3.455 x \text{width of the distal epiphysis of the right forearm} - 0.411 x \text{neck circumference} - 0.146 x \text{skinfold thickness under the shoulder blade}.
\]

**Discussion**

The use of regression analysis makes it possible to create mathematical equations for determining the appropriate parameters of various organs and systems [3, 11, 18], in particular for spirometric forecasting, where predictors are anthropometric and somatotypological variables [4, 7]. Despite the fact that there are separate works in which mathematical modeling of external breathing indicators is performed [1, 8, 15], this does not negate the expediency of such studies, especially for certain ethno-territorial population groups of a certain age, sex, health status, constitutional type, because it will make it possible to establish reference values of spirometric parameters. The main predictors of lung function are most often height while sitting, body length and weight, component composition of body weight [9]. Unfortunately, there are no works that study the complex influence of all anthropometric and somatotypological indicators on spirometric parameters in practically healthy YW of a particular somatotype. We conducted such a study for the first time, where the combined influence of 55 constitutional parameters and 3 dynamometry indicators on the functional state of the lungs was studied. Therefore, let's dwell in more detail on the predictors of indicators of external breathing in female representatives of the ectomorphic constitutional type.

Thus, we have built mathematical models with the accuracy of the sign description in the range of 57.63 - 94.44 % for only 11 spirometric indicators, out of 16 possible parameters of external breathing that we determined. These mathematical models, or polynomials, included 99 constitutional indicators. Among them, girth sizes of the body were most often presented, included in 11 out of 11 models (100 %). They accounted for 29.29 % of the other predictors included in the models, while hand girth was the most frequent predictor (5.05 % of all parameters and 17.24 % of girth sizes). The dimensions of the pelvis were included in 10 out of 11 models (90.9 %). They accounted for 14.14 % of the other predictors included in the models, among them external conjugate and intercristal distance were most frequently represented.

Indicators of the width of the distal epiphyses of the long tubular bones of the limbs were included in 7 out of 11 models (63.63 %), accounted for 13.13 % of other variable polynomials, while the width of the epiphysis of the shin was the predictor most often (4.04 % of all parameters and 30.76 % of other indicators of this groups). The skinfold thickness was also included in 63.63 % of the models and accounted for 15.15 % of the other predictors that were included in the regression polynomials, while the fold under the scapula was the most common (6.06 % of all
parameters and 40.0 % of the indicators that indicate subcutaneous fat.

5 models (45.45 %) included the heights of the acetabulum, pubic and suprasternal points, they accounted for 6.06 % of the other predictors included in the regression polynomials. It is noteworthy that in YW ectomorphs, the main difference of which is a large longitudinal elongation of the body, body length (18.18 %) was found in only 2 models, which, according to the results of research by individual authors, was the main predictor of respiratory volumes [1, 15, 24].

In 45.45 % of the models of spirometric parameters, the sagittal size of the chest, body weight components (muscle, bone, fat mass), and dynamometry indicators were presented. All of them accounted for 5.05 % of the other predictors included in the models.

The transverse dimensions of the body were included in 4 out of 11 models (36.36 %). They accounted for 5.05 % of other variable polynomials, with transverse mean chest size being the predictor most often (3.00 % of all parameters and 60.00 % of transverse dimensions).

The obtained results provide an opportunity in further studies to conduct an analysis and determine the appropriate individual spiographic parameters in YW ectomorphic somatotype.

Conclusions

1. 11 mathematical models were built to determine the appropriate spirometric parameters with the accuracy of character description in the range of 57.63 - 94.44 % for practically healthy YW ectomorphic somatotype of the Podillia region of Ukraine.

2. To the greatest extent, the value of spirometric parameters in YW ectomorphs was determined by girth sizes (29.29 % of other predictors included in the models), skinfold thickness (15.15 %), pelvis sizes (14.14 %), width of distal epiphyses (13.13 %).

References

МОДЕЛИВАННЯ НАЛЕЖНИХ СПІРОМЕТРИЧНИХ ПОКАЗНИКІВ У ПРАКТИЧНО ЗДОРОВИХ ДІВЧАТ ПОДІЛЛЯ ЕКТОМОРФНОГО СОМАТОТИПУ

Сарафюк Л. А., Кириченко Ю. В.

На практичному значенні використання математичного моделювання для визначення референтних значень спірографічних параметрів наголошують багато дослідників, але робіт, в яких би вивчався комплексний вплив антропометричних та соматотипологічних показників на спірометричні параметри у здорових осіб юнацького віку, нажаль, немає.

Метою роботи було побудувати регресійні моделі для визначення належних показників зовнішнього дихання у практично здорових дівчат ектотоморфів та встановити сумарний вплив конституціональних характеристик організму на спірографічні параметри.


Ключові слова: спірографія, дівчата, юнацький вік, ектотоморфний соматотип, регресійні моделі.