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DETERMINATION OF APPROPRIATE SPIROMETRIC INDICES IN JUVENILE GIRLS OF THE MESOMORPHIC SOMATOTYPE BASED ON MATHEMATICAL MODELING

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Using multivariate regression analysis, which made it possible to determine the total influence of external structure indicators on the variability of spirographic body parameters, we performed mathematical modelling in girls of the mesomorphic somatotype to determine appropriate individual spirographic indices. For 12 spirometric parameters, linear regression models were built with the accuracy of character description within 55.30–96.64 %. To the greatest extent, the value of spirometric parameters was determined by the body's girth, the pelvis's diameters and the transverse mid-thoracic width of the distal epiphysis.

Key words: spirography, anthropometry, somatotyping, juvenile ontogenesis, regression models.

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ВСТАНОВЛЕННЯ НАЛЕЖНИХ СПІРОМЕТРИЧНИХ ПОКАЗНИКІВ У ДІВЧАТ ЮНАЦЬКОГО ВІКУ МЕЗОМОРФНОГО СОМАТОТИПУ ЗА РАХУНОК МАТЕМАТИЧНОГО МОДЕЛЮВАННЯ

Використавши багатофакторний регресійний аналіз, який дав можливість визначити сумарний вплив показників зовнішньої будови на варіабельність спірографічних параметрів тіла, ми провели математичне моделювання для визначення належних індивідуальних спірографічних показників у практично здорових дівчат юнацького віку мезоморфного соматотипу. Для 12 спірометричних параметрів побудовано регресійні лінійні моделі з точністю опису ознаки у межах 55,30-96,64 %. У найбільшій мірі величина спірометричних параметрів детермінувалася обхватними розмірами тіла, діаметри таза і поперечним середньогрудним, шириною дистальних епіфізів.

Ключові слова: спірографія, антропометрія, соматотипування, юнацький період онтогенезу, регресійні моделі.

The study is a fragment of the research project "Somato-viscometric features of the human body in different periods of ontogenesis", state register No. 0121U113772.

Scientific studies have established a mutually determined relationship between the morpho-functional parameters of various organs and systems and the features of the external structure of the body [5]. It should be noted that a historical excursion into the study of this issue makes it possible to reveal the constitutional features of the morphological and functional indices of the cardiovascular system in various ways [2, 3, 13, 14]. At the same time, the correlations of respiratory indicators with parameters of body structure are not numerical and refer only to individual spirometric characteristics [11]. Evaluating the relationship between pulmonary function and some anthropometric parameters and body mass composition indices in healthy young women with different body mass indices, scientists found direct relationships between body weight, fat-free and fat mass, the total amount of water in the body, forced vital capacity and the volume of forced exhalation in the first second [12]. The influence of body fat mass on the indices of pulmonary ventilation in children and adolescents [6] and adults [15] was proven. It was noted that excessive obesity, even in the absence of disease, is the cause of a decrease in the indices of external respiration, which is considered a predictor of mortality and a risk factor for diseases [8].

Scientists insist on the need for an individual approach to the evaluation of spirometry indicators and recommend that local reference tables be used to determine the appropriate spirometric values, taking into account the gender difference [9, 10]. Fat-free mass, fat mass, body length, and sagittal abdominal diameter are essential determinants of lung volume and key variables in predictive regression equations for assessing lung function [12]. Therefore, the study of the dominant influence of indicators of the external structure on the variability of spirographic parameters of the body has undeniable theoretical and practical significance.

The purpose of the study was to establish the influence of the constitutional characteristics of the body on external breathing indicators and to build regression models to determine the appropriate indices of spirography in apparently healthy girls-mesomorphs of the youthful period of ontogenesis.

Material and methods. We performed a spirographic examination of 109 apparently healthy girls of the adolescent period of ontogenesis (from 16 to 20 years inclusive) according to the American Association of Pulmonologists and the European Respiratory Society [7] on the Medgraphics Pulmonary Function System 1070 series device. Their health status was assessed on the basis of a preliminary comprehensive clinical and laboratory examination. Girls who were found to have abnormalities in their health did not participate in the further study. The anthropometric examination was performed according to the method of V.V. Bunak modified by P.P. Shaparenko [4]. This study included the assessment of total body dimensions: length (cm), mass (kg), body surface area (m^2) and partial: longitudinal, circumferential, transverse and sagittal body sizes and the width of the distal epiphysis were determined in cm, the thickness of the skin-fatty folds was measured in mm. The evaluation of the component composition of body weight was carried out according to the method of J. Matiegka [1]. The amount of muscle, fat and bone mass of the body was determined in kg. Somatotypological research was carried out according to the Heath-Carter (1990) method. The value of mesomorphic, endomorphic and ectomorphic components was estimated in points. After somatotyping, it was found that 32 girls had a mesomorphic type of constitution, for which we performed a direct step-by-step regression analysis in the "STATISTICA 5.5" package.

Results of the study and their discussion. Using multivariate regression analysis, which made it possible to determine the total influence of external structure indices on the variability of spirographic body parameters, we performed mathematical modeling in girls of the mesomorphic somatotype. Constructed linear regression models provide an opportunity to determine appropriate individual spirographic indices based on anthropometric and somatotypological characteristics of each person of the young age of the female gender. In particular, we found that the variability of the expiratory volumetric rate at 50 % of the forced vital capacity of the lungs (FIF 50 %) was 96.64 % dependent on the combined effect of 1 physiometric and 12 anthropometric indices. Most of the coefficients of independent variables included in this regression polynomial had high statistical significance, except the constant term and the thickness of skin-fat folds on the anterior surface of the shoulder and abdomen. Fisher's criterion of this mathematical model (F=34.11) was significantly greater than its calculated value ($F_{cr.}$=14.17). 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 ($p<0.001$). The constructed model had the form of the following linear equation:

FIF 50 % (L/sec) = 1.018-1.714 ×the width of the distal epiphysis of the tibia is 0.301×the girth of the tibia in the lower third+0.190×interaxial distance–0.083×height of the shoulder point+0.336×forearm girth in the upper third+0.168×external conjugate+0.212×girth of the brush–0.154×the intercristal distance+0.423×the thickness of the crease on the forearm+0.186×transverse average chest size–0.132×thickness of the fold on the front surface of the shoulder–0.040×thickness of the fold on the abdomen.

Forced vital capacity of the lungs (FVC) in girls of the mesomorphic somatotype had a dependence on the total complex of anthropometric indicators included in the polynomial by 78.02 %. All coefficients of independent variables in this model were reliable. Fisher's criterion of this model (F=10.20) was more significant than the calculated value ($F_{cr.}$=8.23). Accordingly, we can state that the constructed regression polynomial is highly significant ($p<0.001$). The model had the form of the following linear equation:

FVC (L) = 7.144+6.967×body surface area–0.463×transverse mid-thoracic size–0.357×intertrochanteric distance+0.103×shoulder width+0.418×forearm girth in the lower third+0.068×hip girth–0.238×shoulder circumference at rest–0.480×width of the distal epiphysis of the forearm.

Forced expiratory volume in the first second **(**FEV1) was 87.40 % dependent on the combined effect of anthropometric and somatotypological indices, which were included in the regression polynomial. The vast majority of the constitutional indices' coefficients act as independent variables of exceptable, except the constant term, the endomorphic component of the somatotype, and hip girth. Fisher's criterion of this model (F=12.56) was greater than its calculated value ($F_{cr.}$=11.20). We could claim that the constructed regression polynomial is highly significant (p<0.001), which was also confirmed by the results of the variance analysis. The model had the form of the following linear equation:

FEV1 (L) = –1.096–0.618×transverse mid-thoracic size+0.093×shoulder width+0.397×forearm girth in the lower third–0.130×abdominal fat fold thickness+0.239×foot girth+0.212×body fat mass+0.586×width of the distal epiphysis of the tibia+3.244×body surface area–0.221×intertrochanteric distance–0.381×endomorphic component+0.035×hip girth.

The variability of maximum voluntary ventilation (MVV) in girls of the mesomorphic somatotype depended on 61.94 % of the total set of anthropometric parameters. Most of the coefficients of independent variables included in the polynomial had high reliability, except for the constant term, interaxial distance of the pelvis, hip circumference. Fisher's criterion of this model (F=5.57) was slightly lower than its calculated value ($F_{cr.}$=7.24). The model had the following view:

MVV (L) = 2.927+8.153×shoulder width–12.51×transverse mid-thoracic size+14.71×width of the distal epiphysis of the tibia+13.98×thickness of the fat fold on the anterior surface of the shoulder–14.76×thickness of the fat fold on the forearm+5.597×interaxial distance–2.379×hip girth.

Tiffeneau index, reflecting the ratio of the one-second volume of forced exhalation to the forced vital capacity in girls of the mesomorphic somatotype, had a dependence of 55.30 % on the total set of anthropometric indicators that were included in the regression polynomial. Half of the coefficients of independent variables in this model and the constant term were unreliable. Only the coefficients of transverse mid-thoracic size, abdominal fat fold thickness, and forearm girth in the lower third were statistically significant. Fischer's criterion of this model (F=6.25) is greater than the calculated value of the F-criterion ($F_{cr.}$=5.16). Accordingly, we could claim that the constructed regression polynomial is significant (p<0.01), which was also confirmed by the results of the variance analysis. The model had the form of the following linear equation:

Tiffeneau index (%) =52.15–3.553×transverse mid-thoracic size–1.157×abdominal fold thickness+3.724×forearm girth in the lower third+2.024×forearm girth in the upper third+3.833×width of the distal epiphysis of the tibia+1.489×thickness of the forearm fold.

Volumetric exhalation rate, respectively, at 25 % of the forced vital capacity of the lungs (FEF 25 %) in girls of the mesomorphic somatotype depended by 73.63 % on the combined effect of anthropometric and somatotypological indices included in the linear polynomial, respectively. Most of the coefficients of the independent variables of this model had high reliability, except for the constant term and body surface area. Fischer's criterion of this model (F=8.23) is greater than the calculated value of the F-criterion ($F_{cr.}$=7.99). The model had the form of the following linear equation:

FEF 25 % (L/sec) = 4.330–0.192×muscle body mass–0.859×transverse mid-thoracic size+0.274×hip girth–0.600×intertrochanteric distance+3.701×body surface area+0.428×intercristal distance–1.258×width of the distal epiphysis of the shoulder+0.134×height of the acetabular point.

Variability of the expiratory volumetric rate at 50 % of the forced vital capacity of the lungs (FEF 50 %) in girls of the mesomorphic somatotype was 84.04 %, dependent on the total set of constitutional indicators included in the polynomial. The vast majority of the coefficients of the independent variables of this model had high reliability, except for the constant term and hand girth. Fisher's criterion of this model (F=9.52) was greater than its calculated value ($F_{cr.}$=11.20). The constructed regression polynomial was very significant (p<0.001).

FEF 50 % (L/sec) **=**4.037+0.243×hip girth–1.052×transverse mid-thoracic size+0.665×forearm girth in the lower third+0.239×pubic point height–1.550×width of the distal epiphysis of the shoulder–0.092×muscle mass–0.713×intertrochanteric distance–0.159×thickness of the fat fold on the abdomen+1.765×width of the distal epiphysis of the forearm+0.791×mesomorphic component–0.162×brush girth.

The value of the expiratory volume rate corresponding to 75 % of the forced vital capacity of the lungs (FEF 75 %) is due to 68.30 % of the complex influence of the anthropometric indices that were included in the polynomial. Most of the coefficients of the independent variables of this model had high reliability, except for the constant term and shoulder width. Fisher's criterion of this model (F=8.97) was greater than its calculated value ($F_{cr.}$=6.25). The model had the form of the following linear equation:

FEF 75 % (L/sec) = –0.811–0.153×thickness of the fat fold on the abdomen+0.283×thickness of the fat fold on the forearm–0.455×transverse mid-thoracic size+0.436×forearm girth in the lower third+0.074×pubic point height+0.053×shoulder width.

Variability of inspiratory capacity (IC) in girls of mesomorphic somatotype by 72.23 % is due to the complex influence of constitutional indicators that were included in the polynomial. Most of the coefficients of the independent variables of this model had high reliability, except for the constant term, width of the distal epiphysis of the forearm, and muscle mass. Fisher's criterion of this model (F=8.23) was greater than its calculated value ($F_{cr.}$=7.48). The constructed regression polynomial was very significant ($p<0.001$), which was also confirmed by the results of the variance analysis. The model had the form of the following linear equation:

IC (L) = –0.805+0.126×chest girth at rest+0.041×supraspinatus point height–0.174×transverse mid-thoracic size+0.169×forearm girth in the lower third–0.099×chest girth on exhalation–0.088×interaxial distance–0.208×width of the distal epiphysis of the forearm + 0.021×muscle mass of the body.

The maximum peak expiratory flow (FEF_{MAX}) depended on 74.44 % of the total set of indicators of the external structure of the body. Most of the coefficients of the independent variables of this regression polynomial had high reliability, except the width of the tibia's distal epiphysis, the pelvis's intercristal distance, and the sagittal size of the chest. Fisher's criterion of this model (F=9.22) is greater than the calculated value of the F-criterion ($F_{cr.}$=7.10). Accordingly, we had grounds to claim that the constructed regression polynomial is highly significant ($p<0.001$). The model had the following view:

FEF_{MAX} (L/sec) = –25.19–0.683×transverse mid-thoracic size+0.197×tibia girth in the upper third–0.148×muscle mass of the body+1.170×external conjugate+0.442×shoulder circumference in the tense state+0.604×width of the distal epiphysis of the lower leg+0.350×intercristal distance+0.242×sagittal chest size.

The variability of the expiratory volume rate, respectively, from 75 % to 85 % of exhalation from the forced vital capacity of the lungs (FEF 75–85) in girls of the mesomorphic somatotype depended by 64.11 % on the total set of indicators of the external structure of the body included in the polynomial. Most of the coefficients of the independent variables of this model had high reliability, except for the constant term and hip girth. Fisher's criterion of this model (F=7.24) is greater than the calculated value of the F-criterion ($F_{cr.}$=6.12). The model had the form of the following linear equation:

FEF 75–85 % (L/sec) = –2.981–0.100×abdominal fat fold thickness+0.225×forearm fat fold thickness+0.254×forearm girth in the lower third+0.456×ectomorphic component–0.222×transverse mid-thoracic size+0.133×sagittal chest size+0.035×hip girth.

The value of the forced inspiratory vital capacity (FIVC) by 77.00 % is due to the influence of 8 constitutional parameters, most of which were statistically significant, except for the constant term and hip girth. Fisher's criterion of this model (F=9.64) is greater than its calculated value ($F_{cr.}$=8.23). 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:

FIVC (L) = –4.374+0.084×waist girth–0.419×forearm girth in the lower third+0.159×pubic point height–0.095×muscle mass–0.217×tibia girth in the lower third–0.535×bone body weight+0.101×tibia girth in the upper third+0.036×hip girth.

The practical importance of using mathematical modeling to determine the reference values of spirographic parameters is emphasized by many researchers who draw attention to the need to take into account the factor of gender and age [6, 8, 12]. Mwangi F.M. [11] claims that modern equations for spirometric prediction use anthropometric variables and are marked with sufficient accuracy. This does not negate the need for additional studies of individuals of certain ethnic groups to improve the prediction of the occurrence of respiratory diseases and to establish reference values for these indicators. Most epidemiological studies consider age, sex and standing or sitting height, fat and lean body mass as the main predictors of lung function [15]. But unfortunately, there are no works that would study the complex influence of all anthropometric and somatotypological indicators on spirometric parameters in healthy adolescents. For the first time, we performed such a study, which studied the total effect of 53 indices of the external structure of the body on the functional state of the lungs. Therefore, we will focus in more detail on the predictors of external respiration indices.

We have constructed mathematical models for only 12 spirometric indices, out of the 16 possible parameters of external respiration that we have determined. These spirometric models, or polynomials, included 100 indices of external body structure. Among them, body girths were the most frequently represented, included in 12 out of 12 models (100 %) and accounted for 29.0 % of other predictors. Forearm girth in the lower third was most often represented in the models (8 % of all parameters and 27.6 % of girths). Shoulder width and transverse mid-thoracic size were included in 11 of the 12 models (91.6 %). They account for 15 % of other polynomial variables, with mid-thoracic size being the most frequent predictor (11 % of all parameters and 73.3 % of transverse chest sizes). Pelvic size was included in 8 out of 12 models (66.7 %) and accounted for 12 % of other predictors. Indices of the width of the distal epiphysis of long tubular bones were included in 9 out of 12 models (75 %), accounting for 10 % of the other predictors included in the models. At the same time, the width of the distal epiphysis of the tibia acts as a predictor most often (5 % of all parameters and 50 % among other indices of the width of the distal epiphysis).

Many studies have emphasized the importance of fat deposition indices on the lungs' functional state. But we found that in practically healthy adolescent girls with a mesomorphic body type. This is accompanied by excellent skeletal muscle development and moderate fat deposition. The thickness of skin-fat folds was included only in 7 out of 12 models (58.3 %). It should be noted that only 3 of the 7 indices of this group of anthropometric dimensions were included in the models (folds on the abdomen, forearm and front surface of the shoulder). They account for 13 % of other polynomial variables, with abdominal fat fold thickness being the most predictive (6 % of all parameters and 46.2 % of fat fold thickness indices). Indices of the component composition of body weight were included in 50 % of models and 7 % of other variables of polynomials. In comparison, muscle mass acts as a predictor most often (5 % of all parameters and 71.4 % of indices of the component composition of body weight). Somatotype components were included in 3 out of 12 models (25.0 %). They make up 3 % of other predictors included in regression polynomials.

The obtained results permit further studies to analyse and determine the appropriate individual spirographic parameters in mesomorphic somatotype adolescent girls.

Conclusions

1. 12 mathematical models were constructed in adolescent girls of mesomorphic somatotype to determine the appropriate spirometric parameters with an accuracy of describing the trait in the range of 55.30–96.64 %.

2. To the greatest extent, the value of spirometric parameters are determined by the girth dimensions (most often the dimensions of the forearm in the lower third), the transverse mid-thoracic size, the pelvic diameters, and the width of the distal epiphysis (most often the tibia).

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