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ORIGINAL ARTICLE

SIMULATION OF APPROPRIATE RHEOVASOGRAPHIC INDICATORS OF THE FEMUR IN VOLLEYBALL PLAYERS OF ECTOMORPHIC SOMATOTYPE DEPENDING ON ANTHROPOMETRIC FEATURES

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ABSTRACT
The aim of the study was to build regression models of rheovasographic parameters of the femur in volleyball players of ectomorphic somatotype depending on the features of anthropometric indicators.
Materials and methods: 113 volleyball players of a high level of sportsmanship of adolescence (from 16 to 20 years old) underwent somatotypological study according to the calculated modification of the Heath-Carter method. 26 volleyball players of ectomorphic somatotype were selected. They performed tetrapolar rheocardiography on a computer diagnostic complex according to the method of Ronkin and Ivanov to establish the indicators of peripheral hemodynamics and anthropometry according to the method of V.V. Bunak. The mathematical models were built in the package "STATISTICA 5.5" for Windows using direct stepwise regression analysis.
Results: Due to the use of multifactor regression analysis, we performed mathematical modeling of rheovasographic parameters of the femur in volleyball players of ectomorphic somatotype, which allows to determine the appropriate values of these indicators taking into account anthropometric and somatotypological features of each athlete. Linear regression equations for 16 indicators of peripheral hemodynamics were constructed from possible rheovasographic parameters of the femur. 4 models were built for time indicators (in which the indicators of the external structure of the body by 59.31 - 78.01% determine the value of the parameters of this group); for amplitude - 5 (coefficient of determination of features from 54.00 to 76.13%); for integral indicators of the rheovasogram of the femur - 7 (coefficient of determination 60.10 - 77.41%).
Conclusions: In volleyball players of ectomorphic somatotype up to 16 constructed regression models to determine the appropriate rheovasographic parameters of the femur included 94 dimensions of the external body structure, among them were often the thickness of fat folds, craniometric parameters, girth and anterior-posterior body dimensions, somatotype components.

KEY WORDS: volleyball, rheovasography of thigh, anthropometric parameters, ectomorphic somatotype, regression models

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INTRODUCTION
Modern scientific researches convincingly show that high sports results are based on the physiological mechanisms of central hemodynamics [1, 2], microcirculation and blood supply of muscles, which are provided by the peripheral link of the systemic circulation [3, 4, 5]. Numerous techniques are currently used to assess peripheral hemodynamics, but rheovasography remains being quite accurate, accessible and safe for the patient [6], makes it possible to assess the condition of the vascular wall, pulse blood flow, relative blood flow rate and balance between arterial and venous circulation. [7, 8]. Nevertheless, rheovasographic parameters are characterized by great variability, especially among a cohort of athletes whose body has long been systematically exposed to intense physical activity [9, 10]. Mathematical modeling of certain appropriate indicators of the body, in particular the cardiovascular system, can be considered as a new, modern way of individualization of instrumental and diagnostic examination [11, 12, 13, 14]. Consequently, the establishment of appropriate rheovasographic parameters of the thigh for highly qualified athletes in a particular sport is relevant and of great practical importance, because it can be used for diagnostic purposes in medical examinations due to the widespread cardiovascular pathology among a cohort of professional athletes [15].

THE AIM
The aim of the work was to build regression models of rheovasographic parameters of the femur in volleyball players of ectomorphic somatotype depending on the features of anthropometric indicators.

MATERIALS AND METHODS
On the basis of the research center in Vinnytsia Pirogov Memorial Medical University, a study of 113 high-level of adolescence volleyball players (from 16 to 20 years) was conducted. Sports experience in all cases was over 3 years.

Rheovasographic parameters of the femur were determined using tetrapolar rheocardiography on a computer diagnostic complex. The rheovasographic parameters were evaluated according to the method of Ronkin and Ivanov [16] In particular, temporal (s) (rheographic wave duration, ascending and descending rheogram time, fast and slow blood filling), amplitude (Ohm) (base impedance, systolic and diastolic wave amplitudes, incisors and fast blood filling) and integral (dichroic and diastolic indices) (%), average rates of slow and fast blood supply (Ohm / s), indicators of all arteries tone, arteries of large diameter, arteries of medium and small diameter, indicator of arteries tone correlation (%).

Anthropometry was performed by the method of V.V. Bunak [17]. Longitudinal, circumferential, anteroposterior and transverse dimensions of the body and the width of the distal pineal glands were determined in cm, the thickness of the skin and fat folds - in mm.

Somatotypological study was performed according to the calculated modification of the Heath-Carter method [18], the value of ectomorphic, mesomorphic and endomorphic components was determined in points. After somatotyping, it was found that 26 volleyball players belonged to the ectomorphic type of constitution, which is characterized by a large body length and the relative advantage of longitudinal body size over the transverse.

The mathematical models were built in the package "STATISTICA 5.5" for Windows using direct stepwise regression analysis. To achieve maximum comparison of the rheographic and anthropometric methods results in regression analysis, the following conditions were taken into account. Firstly, the final variant of the regression polynomial must have a coefficient of determination (R^2) at least 0.50. Secondly condition is the value of Fisher's criterion not less than 2.5. Thirdly - the number of free members included in the polynomial should be minimal. The fourth, the actual value of the Fisher criterion must be greater than its estimated value. The fifth, when independent variables have strong correlations (so-called multicollinearity), crest regression should be used to combat excess data [19].

RESULTS

In order to establish the constitutional parameters that affect the indicators of peripheral hemodynamics, by means of multifactor regression analysis usage, we conducted mathematical modeling in volleyball players of ectomorphic somatotype. The linear regression equations, developed by us, make it possible to determine the appropriate individual rheographic parameters of the femur in ectomorph volleyball players, taking into account the anthropometric and somatotypological features.

In particular, the duration of the rheographic wave in volleyball players of this somatotype by 61.82% (as evidenced by the coefficient of determination R^2) depended on the variability of 6 parameters of external body structure, most of which had high reliability, except for the thickness of skin and fat folds on the tibia and the greatest length of the head. Fisher's criterion of this model (F = 6.17) was greater than the calculated value of the F-criterion (Fcr. = 4.58). So, we could claim that the constructed regression polynomial is significant (p <0.01), which was also confirmed by the results of analysis of variance and crest regression. The model looked like:

REOGRAPHIC WAVE DURATION = 2,301 + 0,100 × thickness of fat fold on forearm - 0,061 × ectomorphic component of somatotype - 0,055 × - width of face - 0,022 × thickness of fat fold on the side + 0,017 × thickness of fat fold of the fibia - 0.035 the biggest length of the head.

The time of the ascending part of the femur rheovasogram in volleyball players with ectomorphic somatotype depended by 77.23% (according to the coefficient of determination) on the variability of 5 anthropological and 1 somatotypological parameters, all of which were reliable. In this regression model, Fisher's criterion was much larger than its calculated value (F = 9.61, Fcr = 6.17), which allows us to consider the constructed regression linear polynomial significant (p <0.01), which was confirmed by analysis of variance. The constructed model was the following:

TIME OF THE RISE PART = 0.415 - 0.005 × thickness of the fat fold on the abdomen - 0.019 × girth of the foot - 0.012 × thickness of the fat fold on the chest + 0.003 × girth of the femur + 0.011 × smallest width of the head - 0.010 × mesomorphic component of the somatotype.

We found out, that the time of the descending part of the rheovasogram of the thigh in the examined volleyball players by 59.31% depended on 6 indicators of external body structure, most of which (except for the thickness of the fat fold under the scapula and sagittal chest size) were reliable. The actual value of the Fisher test was 5.24, which was greater than the value of the critical F - 5.18, given that the regression polynomial had a high reliability (p <0.01), it can be maintained that it is significant, evidenced by the results of comb regression (l = 0,1) and analysis of variance (p <0,01). The linear regression equation is given below:

TIME OF DOWN PART = 0.857 + 0.111 × thickness of fat fold on the forearm - 0.066 × width of the face - 0.025 × thickness of fat fold on the side + 0.035 × thickness of fat fold under the scapula + 0.016 × sagittal size of the chest.

Half of the coefficients of the model of slow hip blood supply in volleyball players with ectomorphic somatotype had a fairly high reliability, except for the free member, the circumference of the forearm in the lower third and wrist, shoulder width. The coefficient of determination R^2 by 78.01% resolute this allowable dependent variable. Since F = 8.08 was greater than the calculated value (F is critical 7.16), this allowed us to consider the regression linear polynomial as highly significant (p <0.001), which was also confirmed by the results of analysis of variance and crest regression. The constructed model is:

SLOW BLOOD FILLING TIME = - 0.035 + 0.020 × smallest head width + 0.013 × outer conjugate - 0.013 × thickness of fat fold under the scapula - 0.011 × forearm girth in the lower third - 0.008 × wrist girth + 0.002 × the height of the trochanter point - 0.003 × the width of the shoulders.

The basic impedance value variability of the rheovasogram, of the femur in the examined volleyball players, depended on the total set of anthropometric and somatotypological parameters, included in the polynomial, by 60.61%. Most of the coefficients of the independent variables of this model, with the exception of the free member, neck circumference and width of the distal epiphysis of the forearm, were reliable. Fisher's criterion of this model (F = 6.17) is greater than the calculated value of

Fcr. = 4.37. Consequently, we could claim that the constructed regression polynomial is highly significant (p <0.01), which was also confirmed by the results of analysis of variance (p <0.01) and crest regression (l = 0.1). The linear regression equation was:

BASIC IMPEDANCE = 38,577 + 2,446 × thickness of the fat fold under the scapula - 2,027 × thickness of the fat fold on the front surface of the shoulder - 0,916 × sagittal size of the chest + 1,153 × shoulder girth in a tense state - 1,376 × neck girth + 4,762 × the width of the distal epiphysis of the forearm.

Analyzing the systolic wave amplitude variability, we found that 59.41% of the value of this indicator depends on the constitutional characteristics. Although Fisher's actual criterion was slightly larger than its calculated value and the regression polynomial was statistically significant (p <0.01), most of the coefficients of the independent variables of this model were not reliable, so recommend for practical use a regression polynomial to determine the appropriate values of the systolic wave amplitude of the hip rheogram in volleyball players of ectomorphic somatotype, we consider being not an appropriate, although the regression polynomial was the following:

SYSTOLIC WAVE AMPLITUDE = 0.027 - 0.001 × face width + 0.004 × mesomorphic component of somatotype - 0.001 × sagittal chest size - 0.001 × thickness of fat fold on the back surface of the shoulder + 0.0002 × height of the acetabulum.

Most of the coefficients of the independent variables of the femoral rheovasogram incisura amplitude model were reliable, except for the largest width and girth of the head. The coefficient of determination R^2 by 54.00% determined this variable. Fisher's test was 5.58, which was much larger than its calculated value (F critical 4.19), so the regression linear polynomial was statistically significant (p <0.01), which was confirmed by the results of analysis of variance (p <0.01) and crest regression. The model looked like:

AMPLITUDE OF THE INCISURE = 0.057 - 0.002 × face width + 0.003 × fat fold thickness on the front surface of the shoulder + 0.001 × maximum head width - 0.001 × head circumference.

We found that the amplitude of the diastolic wave of the rheovasogram of the femur in the examined volleyball players by 70.61% depended on 7 indicators of external body structure, most of which (except for the height of the finger point and sagittal arch of the head) were reliable. The actual value of Fisher's test was 7.16, which was greater than its estimated value of 5.48, given that the regression polynomial had a high reliability (p <0,01), it can be argued that it is significant, as evidenced by the results of comb regression (1= 0.1) and analysis of variance (p <0.01). The linear regression equation is given below:

DIASTOLIC WAVE AMPLITUDE = 0,080 - 0,001 × face width + 0,002 × thickness of fat composition on the anterior surface of the shoulder - 0,001 × ectomorphic component of somatotype - 0,002 × smallest head width - 0,001 × - maximum head length - 000 × × 0,0002 × the height of the finger point is 0.0003 × sagittal arch.

The variability of rapid blood supply amplitude of the rheovasogram of the femur in volleyball players of ectomorphic somatotype depended on the total complex of anthropometric and somatotypological parameters included in the polynomial by 76.13%. Most of the coefficients of the independent variables of this model, with the exception of the free member, the thickness of the fat fold on the back of the shoulder and the sagittal arch of the head, were reliable. Fisher's criterion of this model (F = 9.02) is greater than the calculated value of Fcr. = 6.17. Therefore, we could claim that the constructed regression polynomial is highly significant (p <0.001), which was also confirmed by the results of analysis of variance (p <0.001) and crest regression. The linear regression equation was like:

FAST BLOOD FILLING AMPLITUDE = 0.012 + 0.001 × maximum head width + 0.001 × mesomorphic component of somatotype - 0.001 × smallest head width + 0.001 × thickness of fat fold on the front surface of the shoulder - 0.0003 × thickness of the fat fold on the back of the shoulder - 0.0002 × sagittal arch.

Most of the coefficients of the independent variables of the diastolic index model of the femoral rheovasogram were significant, except for the free member and the transverse mean chest size. The coefficient of determination R2 by 60.10% determined this variable. Fisher's criterion was 5.41, which was much larger than its calculated value (F critical 5.18), so we consider the regression linear polynomial to be statistically significant (p <0.01), which was confirmed by the results of analysis of variance and crest regression. The model looked like:

DIASTOLIC INDEX = 69,34 + 2,086 × sagittal size of the chest - 7,356 × hand girth + 5,000 × thickness of the fat fold on the front surface of the shoulder + 2,314 × transverse middle chest size.

We found that the average rate of rapid blood supply to the femur rheovasogram in the examined volleyball players by 65.54% depended on 6 indicators of external body structure, most of which (except for sagittal chest size and thickness of skin and fat folds on the back of the shoulder) were reliable. The actual value of Fisher's test was 6.17, which was much higher than its estimated value of 5.38. Taking into account that the regression polynomial was reliable (p <0.01), we can say about its high significance, which is confirmed by the results of comb regression and analysis of variance. The linear regression equation is given below:

AVERAGE SPEED OF FAST BLOOD FILLING = - 0.441 + 0.037 × mesomorphic component of a somatotype + 0.017 × girth of foot + 0.018 × thickness of a fatty fold on a breast + 0 0.032 × width of the distal tibia epiphysis - 0.006 × sagittal size of the chest - 0.009 × thickness of the fat fold on the back of the shoulder.

Analyzing the variability of the average rate of slow blood supply, we found that 63.41% of the value of this rheovasographic indicator depends on the constitutional characteristics. Despite the fact that the actual value of Fisher's criterion (6.25) was greater than its calculated value (5.18), and the regression polynomial was statistically significant (p <0.01), 4 of the 6 coefficients of independent variables of this model were not reliable, so we do not consider it to be appropriate to recommend practical usage of a regression polynomial to determine the appropriate values of the amplitude of the systolic wave of the hip rheogram in volleyball players of ectomorphic somatotype, although the regression polynomial has the form:

AVERAGE SPEED OF SLOW BLOOD FILLING = 0,197 + 0,014 × mesomorphic component of somatotype - 0,009 ×

intertrochanteric distance - 0,009 × the smallest width of the head + 0,009 × girth of a tibia in the top third on 0.003 × the thickness of the fat fold on the tibia.

Most of the coefficients of independent variable models showing the tone of all femoral arteries in a volleyball player of ectomorphic somatotype were reliable, except for the free member and the thickness of skin and fat folds on the side and under the scapula. The coefficient of determination R^2 by 74.95% determined this variable. Fisher's test was 7.16, which was much larger than its calculated value (F critical 6.82), so we consider the regression linear polynomial to be statistically significant (p <0.001), which was confirmed by the results of comb regression and analysis of variance (p <0.001). The model looked like:

TONUS OF ALL ARTERIES = 35,76 - 2,347 × thickness of the fat fold on the forearm + 2,878 × smallest width of the head - 2,430 × mesomorphic component of the somatotype - 1,608 × girth of the foot - 0,521 × thickness of the fat fold on the femur + 0.514 × the thickness of the fat fold on the side - 0.878 × the thickness of the fat fold under scapular.

We found that the vast majority of the coefficients of the independent variables of large femoral arteries tone model were reliable, except for the girth of the femur. The coefficient of determination R^2 by 62.34% determined this variable. Fisher's test was 5.94, which was greater than its calculated value (F critical 5.18), so we consider the regression linear polynomial to be statistically significant (p <0.01), which was confirmed by the results of ridge regression and analysis of variance (p <0, 01). The linear regression equation was:

LARGE DIAMETER ARTERY TONUS INDICATOR= = 3,525 + 0,526 × intercostal distance - 0,206 × chest circumference on exhalation - 0,957 × thickness of fat fold on the forearm + 0,562 × intertrochanter distance - 0,235 × femur circumference.

We found that the rate of femur arteries tone of the medium and small diameter in the examined volleyball players by 77.41% depended on 7 anthropometric indicators, most of which, except for the free member, the height of the toe and foot circumference, were reliable. The actual value of Fisher's test was 7.85, which was greater than its estimated value of 7.16. Taking into account that the regression polynomial had a high reliability (p <0.001), it can be maintained that it is significant, which is confirmed by the results of comb regression (l = 0.1) and analysis of variance (p <0.001). The linear regression equation is given below:

INDICATOR OF ARTERIES TONUS OF MEDIUM AND SMALL DIAMETERS = 17,47 + 1,925 × the smallest width of the head - 0,706 × sagittal size of a chest + 0,182 × height of a finger point - 1,301 × thickness of a fatty fold of a foot under scapular× shoulder width.

We found that the value of the ratio of femoral arteries in volleyball players of ectomorphic somatotype by 69.11% depends on the constitutional characteristics, most of the coefficients of independent variables included in this model were reliable, except for hand circumference and maximum head width. But we found that the actual value of Fisher's criterion was much smaller than its calculated value (F critical 7,16). Therefore, despite the fact that the regression polynomial was statistically significant (p <0.01), which is confirmed by the results of analysis of variance (p <0.01), this regression polynomial requires additional verification. The linear regression equation has the form:

INDICATION OF THE ARTION TONES RATIO = 191.93 - 8.638 × - transverse lower chest size + 6.325 × transverse middle chest size - 5.801 × outer conjugate - 4.123 ×girth tibia in the lower third - 12.24 × width of the distal epiphysis of the tibia + 6,540 × hand circumference + 3,401 × maximum width of the head.

DISCUSSION

Scientists have proved that when increasing or decreasing individual anthropometric parameters, changes are detected in the morphological size of visceral organs []. Mathematical modeling of appropriate rheovasographic parameters individualizes the results of this instrumental diagnostic study and reveals the biological mechanisms of the course of peripheral hemodynamics. We have built 16 regression linear mathematical models in volleyball players of ectomorphic somatotype, which make it possible to determine the appropriate rheovasographic parameters of the femur, taking into account the individual constitutional features of the organism.

As a result of regression analysis, it was found that only 4 of the 6 time rheovasographic parameters of the femur in ectomorph volleyball players depended on the total impact of constitutional characteristics by more than 50%, R^2 =0,59 – 0,78. It should be noted that the variability of the time of the rise part of the rheovasogram (R^2 = 0.772) and the time of slow blood filling (R^2 = 0.781) depends to the greatest extent on the peculiarities of the body structure. The time of the rise part is the most constant indicator of a rheogram and does not depend on heart rate, and reflects the period of full opening of a vessel and gives accurate information on a condition of a vascular wall [80 вис., моя дис], therefore, the influence of constitutional characteristics on the value of this parameter, in particular the mesomorphic component of the somatotype and the value of subcutaneous fat deposition, is understandable. The value of the time of slow blood supply is mainly due to the tonic properties of the vascular wall of small and medium arteries [80 вис., моя дис], so found in our study, the dominant influence of constitutional features on the value of this rheovasographic index is natural.

It should be noted that for all 5 amplitude rheovasographic parameters of the thigh we built mathematical models in which the coefficient of determination ranged from 54.00 (for the amplitude of the incisure) to 76.13 (for the fast blood filling amplitude). According to scientific studies, the amplitude of the incisure characterizes the value of peripheral resistance in the smallest arteries and arterioles and depends on many factors [4, 5, 23, 24, 25], so the magnitude of the influence of constitutional factors on the variability of this indicator in our study is small. The fast blood filling amplitude depends on the degree of extensibility of vascular walls, their elasticity and tone [5], which is due to the constitutional features of the organism, in particular found in our study the predominant influence of mesomorphic component of somatotype and subcutaneous fat.

Of the 8 integral indicators of the rheovasogram of the thigh in volleyball players of ectomorphic somatotype, only the value of the dichroic index did not depend on the total influence of constitutional features, for the other 7 indicators of this group, which reflect the ratio of amplitude and time parameters 60.1 - 77.41% determine the value of the integral parameters of the rheovasogram of the femur. The highest coefficients of determination were found for the tone of the arteries of medium and small diameter and the tone of all arteries. Thus, volleyball players of ectomorphic somatotype included 94 sizes of external body structure in 16 constructed models. Indicators of fat fold thickness were included in 15 of the 16 built models (93.75%). They make up 28.72% of the other predictors included in the models, with the thickness of the fat fold under the shoulder blade and on the front surface of the shoulder being the most common predictors (5.31% of all parameters and 18.52% of all fat thickness indicators). Craniometric parameters were included in 12 of the 16 models (75.0%), accounting for 21.28% of other predictors, with the smallest head width being the most common predictor (7.45% of all parameters included in all models and 35.0 % of the craniometric dimensions). Comprehensive dimensions were included in 10 of the 16 models (62.5%). They make up 17.02% of other predictors included in the models, with foot circumference being the most common predictor (4.25% of all parameters and 25.0% of the range). Somatotype components were included in 8 of the 16 models (50.0%). They make up 8.51% of other predictors, with the mesomorphic component of the somatotype included in the 6 constructed models, accounting for 6.38% of all constitutional parameters and 75% of the somatotype components. The anterior-posterior dimensions were included in 50.0% of the built models. They make up 8.51% of the other constitutional indicators included in the models, with sagittal chest size being the most common predictor (6.38% of all parameters and 75.0% of anterior-posterior body size). In the study of O.P. Khapitska [26] noted that male volleyball players of mesomorphic somatotype among the predictors that determine the variability of peripheral hemodynamics are body size (30.9% of all predictors), craniometric (25%), transverse body diameters (19.1%), the thickness of fat folds (16.2%).

Therefore, we believe that the modeling of the cardiovascular system, which allows to establish the appropriate values of each parameter for a particular person, taking into account the external structure of his body - is the latest way to individualize the results of the survey and, from another point of view, reveals the biological mechanisms of physiological processes.

CONCLUSIONS

1. Volleyball players of ectomorphic somatotype have built 16 mathematical models, which make it possible to determine the appropriate rheovasographic parameters of the thigh, taking into account the individual constitutional features of the organism. 4 models were built for time indicators (accuracy of description of a sign within 59,31 - 78,01%); for amplitude - 5 (accuracy of the description of the sign 54.00 to 76.13%); for integral indicators of a rheovasogram of a hip - 7 (accuracy of the description of a sign 60,10 - 77,41%).
2. To the greatest extent the value of the parameters of thigh rheovasography is determined by the thickness of fat folds, craniometric parameters, body circumference (usually foot circumference), somatotype components (usually mesomorphic) and anteroposterior body size (usually sagittal chest size).

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