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Mathematical modelling of peripheral haemodynamics of the shin in volleyball players of mesomorphic somatotype

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Abstract. Statistical modelling of peripheral haemodynamics indicators, which is conducted based on determining anthropometric and somatotypic features of the organism, can be considered a new way of personalising instrumental diagnostic examination. Therefore, determining the suitable rheovasographic parameters of the shin in highly skilled volleyball players of a particular somatotype is relevant. The purpose of this study was to investigate the total influence of indicators of the external structure of the body on the value of indicators reflecting the specific features of blood circulation in the shin in volleyball players of mesomorphic somatotype. A comprehensive clinical and laboratory study of the state of health and physical development of 108 volleyball players aged 16-20 years was conducted. The method of tetrapolar rheography with the use of a diagnostic computer multifunctional apparatus was used to determine the rheovasographic parameters of the shin, amplitude, time, and indicators of the ratio of amplitude and time rheovasographic parameters were evaluated. An anthropometric study of total and partial body measurements was

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carried out. Somatotyping was performed using the Heath-Carter method. The study selected 28 volleyball players of mesomorphic somatotype. Statistical models were created using direct stepwise multivariate regression analysis. For all amplitude and time rheovasographic parameters of the hip in volleyball players of mesomorphic somatotype, statistical models with high accuracy of description of signs were built. The 10 models included 94 anthropometric dimensions. The key determinants of shin blood circulation parameters are body circumference (most often forearm, neck, and shin circumference), chest and pelvic diameters, thickness of skin and fat folds (most often on the shin, abdomen, flank), and width of the epiphyses of long tubular bones. It was found that the indicators of external body structure within 63.84-99.99% determine the value of indicators of regional blood circulation on the shin in volleyball players of mesomorphic somatotype. Statistical modelling makes it possible to determine the proper values of individual rheovasographic indicators on the shin depending on the anthropometric parameters of individuals of a certain gender, age, somatotype, which is especially significant for athletes of a certain sport, since their cardiovascular system indicators are greatly influenced by the specifics of sports activity

Keywords: stepwise regression; statistical modelling; rheovasography; anthropometric dimensions; mesomorphic somatotype; volleyball

INTRODUCTION

Technical and tactical efficiency in modern sport is determined by the functional state of the cardiovascular system of athletes, the indicators of which form the body's response to exogenous and endogenous influences [1, 2]. D. Berhtraum *et al*. [3] proved that changes in cardiovascular system indicators can signify the body's adaptive capacity, which was also noted in the studies of other scientists [4, 5]. O. Voloshyn *et al*. [6] emphasise that the ability of the human body to adapt will largely be determined by the functional state of its cardiovascular and respiratory systems, emphasising the significance of such studies in adolescence, when the importance of these systems increases for the harmony and sufficiency of physical development of the level of health of a young organism against the background of considerable changes in living conditions. The possibility of prompt diagnosis of changes in adaptive potential is an effective way to prevent overwork and overtraining in athletes. Scientists emphasise the significance of central haemodynamics indicators for sports performance and the specificity of these parameters in individuals engaged in various sports [5, 7, 8]. However, Y. Zhang *et al*. [7] note that the response of central haemodynamics to physical activity is transient, and therefore it is difficult to investigate it to obtain objective results. The importance of peripheral circulation indicators for sports performance was proved in the study by O. Usova *et al*. [9], noting that a decrease in the functional capabilities of the body will be accompanied by a decrease in blood filling of blood vessels, which is expressed in a change in the value of time and amplitude indicators of the rheogram. This is because the condition of the vessel walls, blood flow, and microhaemodynamics of skeletal muscles, especially in the lower extremities, can hinder the successful sports career of any athlete. During physical activity, the greatest changes in blood supply are inherent in skeletal muscle circulation, and therefore the condition of peripheral vessels is crucial in the development of adaptive responses to sports activities. S. Malyuga *et al*. [10] point out that it is necessary to consider the functional state of blood vessels, which can have a considerable impact on the processes of rapid recovery after static physical activity. However, along with sports activities, functional parameters of regional blood circulation can also be affected by the specific features of the athlete's external body structure. Therefore, it is crucial to determine the appropriate values of regional blood circulation parameters of the lower extremities, specifically, rheovasographic parameters of the shin, by statistical modelling. Athletes involved in sports, particularly volleyball, need special attention to the condition of the vessels of the lower limb. According to the findings of the study by O. Khapitska *et al*. [11], it is known that volleyball players can often show signs of venous stasis without substantial symptoms of organic vein pathology.

Thus, the literature analysis shows the significance of the morphological and functional state of the cardiovascular system, specifically peripheral haemodynamics, which may vary depending on the characteristics of sports activity and the constitutional characteristics of the athlete. Therefore, the study aimed at conducting statistical modelling of the rheovasographic parameters of the shin based on the determination of the constitutional characteristics of the organism is of great practical importance, as it will allow comparing the factual values of rheovasographic parameters with the respective values determined by concrete anthropometric features. The purpose of this study was to create statistical models for determining the suitable value of rheovasographic indicators of the shin in volleyball players of mesomorphic somatotype, considering anthropometric dimensions.

MATERIALS AND METHODS

During 2017-2023, a comprehensive clinical and laboratory study of the health and physical development of 108 female volleyball players aged 16-20 (youthful period of ontogeny) of high sports categories (from second adult to masters of sports) was conducted at the Research Centre of National Pirogov Memorial Medical University, Vinnytsia (Pirogov VNMMU). The female volleyball players played in the following teams: "Bilozhar – Medical University", "Dobrodii – Medical University – SHVSM", volleyball student teams of Vinnytsia higher education institutions, children's and youth sports schools of Vinnytsia and Kalynivka. Each female athlete who had at least 3 years of sports experience and the appropriate level and age (inclusion criteria) gave informed consent to take part in the study. All examinations were carried out no less than 12 hours after training. Admission to further studies was based on a preliminary electrocardiographic and echocardiographic examination. Exclusion criteria were hypertension, pathological hypotension, arrhythmias, mitral valve prolapse of II-III degree, pathological myocardial hypertrophy.

Rheovasographic parameters of the shin in volleyball players were determined by tetrapolar rheocardiography using a certified computer diagnostic multifunctional complex (developed by scientists of the Pirogov VNMMU) and the amplitude, time, and ratio indicators of amplitude and time rheovasographic parameters (integral) were evaluated. An anthropometric study of the total body and chest, pelvis, limbs, and head was performed according to the recommendations of R. Shaparenko [12], and a total of 50 external body dimensions were determined. Measurements were taken with certified equipment of the following sizes: Martin's anthropometer was used to determine longitudinal dimensions – body height and anthropometric points (cm); centimetre tape – girth dimensions (cm), large spreading caliper – transverse and sagittal body diameters (cm), sliding caliper – width of distal epiphyses of long tubular bones (cm), body fat caliper – thickness of skin and fat folds (mm), and medical scales – body weight (kg). The body surface area was calculated using the DuBois formula [12].

$$S = W^{0.425} \times H^{0.725} \times 0.007184, \quad (1)$$

where S is the body surface area (m^2); W is the body weight (kg); H is the height (cm).

The somatotypic study was conducted using the Heath-Carter calculation method [13], based on anthropometric measurements, and the size of the somatotype components (ectomorphic, mesomorphic, endomorphic) was determined in points (from 1 to 7). After somatotyping, it was found that 28 female volleyball players belonged to the mesomorphic type. The results were analysed using the licensed software Statistica 5.5.

To determine the variability of peripheral haemodynamics of the shin from the complex total effect of anthropometric and somatotypic parameters, a multivariate stepwise regression analysis was performed in compliance with the following conditions [14]. Firstly, the coefficient of determination R^2 of the regression polynomial should be equal to or greater than 0.60, which would indicate that a particular rheovasographic indicator depended on the total influence of constitutional factors by more than 60%, and this would be the basis for mathematical modelling. Secondly, the value of the Fisher's F-criterion must be at least 2; the calculated value of the Fisher's criterion must be less than its actual value. Thirdly, if the coefficient of determination approached 1,000 and the regression polynomial included many terms, a ridge regression was applied, with the correlation coefficient artificially lowered to allow for more stable beta coefficients.

The Bioethics Commission of the Pirogov VNMMU found that this study does not violate the basic bioethical standards established in the Declaration of Helsinki [15], as confirmed by the decision of the Bioethics Commission of the Pirogov VNMMU (Protocol No. 1 of 31 January 2018).

RESULTS

It was found that the value of the basic impedance (Ohm) in female volleyball players of the mesomorphic somatotype was 90.54% dependent on the complex influence of anthropometric dimensions and somatotype components. Most of the coefficients of this regression polynomial were statistically significant, except for the free term, the width of the distal epiphysis of the upper arm, and the sagittal arch of the head. The regression polynomial of the baseline impedance was significant ($p < 0.001$), and the analysis of variance confirmed this ($p < 0.001$). Since the Fisher's criterion of 14.89 is much higher than its calculated value ($F_{cr.} = 9.14$), it could be argued that the constructed mathematical model is significant:

BASIC IMPEDANCE = 66.12 + 9.323 × width of the distal femoral epiphysis - 7.576 × shin circumference + 0.996 × thickness of the skin and fat fold on the thigh + 1.100 × height of the finger point - 3.314 × width of the distal epiphysis of the shoulder - 3.091 × width of the shoulders + 3.978 × head circumference - 0.861 × thickness of the skin and fat fold on the abdomen - 1.546 × sagittal arch of the head.

The coefficient of determination R^2 of 96.91% substantiated the dependence of the systolic wave amplitude at the shin (Ohm) on the complex effect of somatometric parameters. All coefficients of this regression polynomial were statistically significant. Since the Fisher's criterion of 24.12 is significantly higher than its calculated value ($F_{cr.} = 13.10$), it could be argued that this regression polynomial is highly significant ($p < 0.001$). This is evidenced by the results of the analysis of variance ($p < 0.001$). The statistical equation of the model is presented as follows:

SYSTOLIC WAVE AMPLITUDE = - 0.261 + 0.006 × fold thickness on the back of the shoulder + 0.004 × neck circumference - 0.004 × shin circumference - 0.010 × fold thickness on the forearm + 0.005 × head circumference + 0.003 × thickness of the crease on the shin - 0.001 × thickness of the crease on the abdomen + 0.003 × inter-ridge distance - 0.005 × forearm circumference at the bottom - 0.001 × inter-axial distance + 0.002 × thigh circumference - 0.002 × upper leg circumference.

It was found that the value of the incisor amplitude (Ohm) was 83.34% dependent on the variability of the complex of anthropometric indicators. Most of the coefficients of this regression polynomial were significant, except for the free term. Since the Fisher's criterion of 9.38 is greater than its calculated value ($F_{cr.} = 8.15$), it could be argued that this regression polynomial is significant ($p < 0.001$). This is evidenced by the results of the analysis of variance ($p < 0.001$). The statistical equation of the model is presented as follows:

AMPLITUDE OF INCISURE = 0.015 + 0.004 × relaxed shoulder girth - 0.002 × waist circumference - 0.003 × hand girth + 0.002 × intercristal distance + 0.004 × width of the face + 0.002 × sagittal arch of the head - 0.006 × forearm circumference at the bottom - 0.001 × thickness of the fold at the lower angle of the scapula.

The coefficient of determination R^2 of 99.65% substantiated the variability of the diastolic wave amplitude at the shin (Ohm) from the complex effect of 15 anthropometric dimensions. Most of the independent variables of this polynomial had strong interrelationships with each other, and therefore the so-called multicollinearity arose, which required the additional use of the ridge regression method. In the new regression polynomial, the determination coefficient R^2 was already only 70.83% responsible for the variability of the diastolic wave amplitude. Most of the coefficients of the independent variables included in this regression equation were significant, except for the free term and the width of the lower tibial epiphysis. Since the actual value of Fisher's criterion of 8.74 was higher than the calculated value ($F_{cr.} = 5.18$), it could be argued that this regression polynomial is significant ($p < 0.001$). This is evidenced by the results of the analysis of variance ($p < 0.001$). The statistical equation of the model is presented as follows:

DIASTOLIC WAVE AMPLITUDE = 0.001 - 0.002 × thickness of the fold on the anterior surface of the shoulder + 0.006 × endomorphic component of the somatotype - 0.002 × lower arm circumference + 0.002 × relaxed arm circumference + 0.003 × width of the distal tibial epiphysis.

It was found that the value of the fast blood filling amplitude of the rheovasogram of the shin in mesomorphic volleyball players (Om) was 85.73% dependent on the total complex effect of indicators of the external structure of the body. Most of the coefficients of this regression polynomial were significant, except for the free term of this polynomial and the chest circumference at exhalation. Generally, this linear regression polynomial is significant ($p < 0.001$). Since the Fisher's criterion of 9.31 is higher than the value of its calculated value ($F_{cr.} = 9.14$), it could be argued that the constructed mathematical model is significant:

FAST BLOOD FILLING AMPLITUDE = 0.012 + 0.004 × relaxed shoulder circumference - 0.002 × smallest head width + 0.002 × transverse mid-thoracic diameter - 0.001 × neck circumference + 0.004 × width of the distal tibia epiphysis - 0.003 × shin circumference + 0.002 × sagittal mid-thoracic diameter + 0.001 × height of the finger point - 0.001 × chest circumference at exhalation.

It was found that all time parameters of the rheovasogram of the shin had a rather high dependence on the complex influence of anthropo-somatotypic characteristics of the organism of volleyball players of mesomorphic somatotype. Specifically, the variability of the rheographic wave duration on the tibia (c) depended by 96.11% on the total complex effect of anthropometric and somatotypic indicators. Most of the coefficients of this regression polynomial were statistically significant, with the exception of foot circumference. Generally, this regression linear polynomial was statistically significant ($p < 0.001$), as evidenced by the analysis of variance ($p < 0.001$). Since the Fisher's criterion of 32.46 was three times higher than its calculated value ($F_{cr.} = 10.13$), it was possible to assert the significance of the constructed mathematical model:

RHEOGRAPHIC WAVE DURATION = -0.771 + 0.072 × shin crease thickness + 0.049 × sagittal mid-thoracic diameter - 0.023 × lateral crease thickness + 0.044 × neck circumference - 0.034 × lower forearm circumference + 0.115 × width of the distal epiphysis of the upper arm - 0.012 × width of the shoulders - 0.021 × foot circumference + 0.030 × transverse mid-thoracic diameter - 0.011 × height of the acetabulum.

The coefficient of determination R^2 of 89.61% substantiated the variability of the time value (s) of rise part from the complex influence of somatometric indicators. All coefficients of this regression polynomial were statistically significant. Since the Fisher's criterion (16.09) was twice as high as its calculated value ($F_{cr.} = 8.15$), it could be argued that this regression polynomial was highly significant ($p < 0.001$), and the analysis of variance confirmed this ($p < 0.001$). The statistical equation of the model is presented as follows:

TIME OF THE RISE PART= -0.303 + 0.021 × hand circumference + 0.012 × hip circumference - 0.025 × lower forearm circumference - 0.021 × smallest head width + 0.018 × lower jaw width - 0.004 × waist circumference + 0.008 × relaxed shoulder circumference - 0.004 × external conjugate.

The variability of the time value (s) of the down part of the rheovasogram of the shin by 94.72% in mesomorphic female volleyball players is conditioned by the value of 10 anthropometric body sizes. Most of the coefficients of this regression polynomial were statistically significant, except for forearm circumference in the lower third and the width of the distal tibial epiphysis. Since the Fisher's criterion (23.29) was more than twice as high as its calculated value ($F_{cr.} = 10.13$), this regression linear polynomial was considered reliable ($p < 0.001$), and the analysis of variance confirmed this ($p < 0.001$). The statistical equation of the model is presented as follows:

TIME OF DOWN PART = -0.637 + 0.059 × thickness of the fold on the shin + 0.053 × sagittal mid-thoracic diameter - 0.019 × thickness of the fold on the side + 0.033 × neck circumference - 0.031 × inter-articular distance + 0.041 × width of the distal epiphysis of the upper arm - 0.027 × lower forearm girth + 0.025 × inter-articular distance - 0.039 × face width - 0.042 × width of the distal epiphysis of the shin.

The coefficient of determination R^2 of 95.91% determined the dependence of the time of rapid blood filling (s) on the complex effect of 10 indicators of the external structure of the body. Almost all of the coefficients of this regression polynomial were significant, with the exception of the largest head width. Since the Fisher's criterion (30.35) was three times higher than its calculated value ($F_{cr.}$ = 10.13), the polynomial for determining the time of rapid blood filling was considered highly significant ($p < 0.001$), and the analysis of variance confirmed this ($p < 0.001$). The statistical equation of the model is presented as follows:

RAPID BLOOD FILLING TIME = - 0.124 - 0.020 × smallest head width + 0.015 × transverse mid-thoracic diameter + 0.012 × sagittal mid-thoracic diameter - 0.003 × inspiratory chest circumference + 0.003 × relaxed shoulder circumference + 0.002 × finger point height - 0.004 × intercristal distance - 0.002 × thickness of the side crease + 0.001 × thickness of the abdominal crease + 0.004 × largest head width.

The variability of the value of the slow blood filling time (s) of the shin rheovasogram depended by 99.81% on the total effect of 13 indicators of the external structure of the body. To reduce the multicollinearity of the independent variables of this polynomial, a constant was added to the correlation matrix. However, after applying the method of ridge regression, it turned out that the Fisher's criterion was 5.79, which was lower than its calculated value ($F_{cr.}$ = 6.17), which contradicted the condition of the regression analysis, and therefore the mathematical modelling was carried out without ridge regression. All coefficients of the independent variables of the polynomial were significant. Generally, the regression linear polynomial was significant ($p < 0.001$). Since the Fisher's criterion of 36.78 was three times higher than its calculated value ($F_{cr.}$ = 13.10), the statistical model was statistically significant:

SLOW BLOOD FILLING TIME = - 0.071 + 0.007 × neck circumference - 0.004 × waist circumference - 0.002 × shoulder width + 0.006 × largest head width + 0.002 × thigh crease thickness + 0.004 × smallest head width - 0.018 × distal tibia width + 0.006 × transverse mid-thoracic diameter + 0.003 × chest crease thickness - 0.001 × forearm crease thickness + 0.005 × forearm girth at the bottom - 0.004 × width of the distal epiphysis of the upper arm + 0.001 × width of the lower jaw.

Since the integral rheovasographic parameters of the shin are derived from amplitude and time parameters, it was not advisable to perform statistical modelling to determine the appropriate values of each of them, but the analysis of the constitutional determination of their variability was performed. Specifically, the coefficient of determination R^2 of 88.71% determined the dependence of the dicrotic index on the complex effect of 10 indicators of the external structure of the body. The variability of the diastolic index depended on the complex effect of 22 anthropometric parameters by 99.99%, and after applying the method of ridge regression, the coefficient of determination R^2 decreased to 63.84%. The variability of the average slow blood filling rate of the shin rheovasogram by 71.23% depended on the complex effect of constitutional parameters. Indicators of the tone of all arteries of the shin rheovasogram and the tone of medium and small diameters in mesomorphic volleyball players depended on the complex influence of a considerable number of anthropo-somatotypic parameters by 100%; after applying the method of ridge regression, the coefficient of determination in the first case decreased to 66.23%, in the second – to 53.33%. Other integral rheovasographic parameters of the shin had low accuracy of feature description.

DISCUSSION

Under the influence of constant physical exertion in the athlete's body, the mechanism of adjusting various organs and systems to the demands of a particular sport is launched, which ensures rational or irrational adaptation to training and competitive activity [16]. Systematic volleyball training leads to substantial changes in the cardiovascular system in adolescent female athletes. Thus, Y. Yakusheva [17] found that stroke volume and stroke index, minute blood volume, blood volume velocity, left ventricular power were significantly higher in female volleyball players compared to the control group, while the total peripheral resistance in female volleyball players was several orders of magnitude lower. Furthermore, the author argues that volleyball players with different somatotypes have substantial differences in central haemodynamics. S.L. Popel *et al.* [18] also found changes in response to physical activity in the cardiohemodynamics of volleyball players, specifically, the values of stroke and minute blood volumes, and changes in red blood cells in the peripheral blood were recorded. The peripheral circulation of female athletes in this specialisation also underwent certain changes. I. Stepanenko *et al*. [19] note that female volleyball players, compared to girls who did not engage in sports, had substantial differences in the value of regional blood circulation indicators. Specifically, they registered higher values of amplitude and time indicators on the shin, namely, the amplitudes of fast blood filling, systolic and diastolic rheovasogram waves, rheographic wave duration, time of the rise and down parts of the rheogram, and slow blood filling of the shin rheovasogram.

For female volleyball players to achieve high sporting results, it is crucial to be able to predict possible deviations in regional blood circulation and to predict the appropriate rheovasographic parameters. One of the ways of such mathematical forecasting is statistical modelling of the proper values of peripheral haemodynamics indicators based on the influence of constitutionally determined anthropometric parameters. L.C. Summer *et al.* [20] note that changes in body weight composition during the competitive season in field hockey athletes are accompanied by changes in sports performance. N. Nalyvayko *et al*. [21] conducted a correlation analysis between haemodynamic bioimpedance indices and body composition in women with different types of haemodynamics. O. Vysochanskiy [22] found numerous correlations between anthropometric and somatotypic parameters and hip and tibia rheovasograms in practically healthy boys from Podillia. Therefore, the present study was based on statistical analysis to investigate the relationships and interdependencies between the rheovasographic parameters of the shin and indicators of the external structure of the body in volleyball players of mesomorphic somatotype. The authors of the present study built 10 statistical models for all amplitude and time parameters of the shin rheogram. Notably, the principal factors of variability of the baseline impedance in female mesomorphic volleyball players were mainly anthropometric dimensions of the lower limb and the shape of the head, which can be considered as a somatotypic attribute. The baseline bioelectrical impedance reflects the body's resistance to alternating current, which results from tissue resistance to current and the reactive resistance associated with the capacitive component of the tissue. O. Di Vincenzo *et al*. [23] conducted a retrospective analysis of the significance of determining the bioelectrical impedance in representatives of various sports and noted that changes in its value are directly related to sports performance. Furthermore, the variability of the bioelectrical impedance itself depends on age and gender. J.C. Koury *et al*. [24] found that the values of bioimpedance indices in male athletes of different sports were lower at a younger age, and there were direct correlations with body weight and body mass index. However, despite the interest of scientists in using such a non-invasive and affordable method in the practice of sports medicine, there is no unanimous understanding of the reasons that can lead to changes in performance. Therefore, the use of multivariate regression analysis to determine the causes of variability in the rheovasographic parameters of the shin may provide an answer to this question. Each built statistical model makes it possible to individually determine a separate indicator of peripheral haemodynamics for a female volleyball player of mesomorphic somatotype, considering their anthropo-somatotypic characteristics.

The 10 statistical models built in this study included 94 dimensions of the external structure of the body. Among them, body circumference was the most frequently represented, accounting for 35.11% of all predictors of the regression polynomial and being included in all the models built (100%). Forearm circumference was included in 7 models; neck circumference was included in 5 models; shin circumference was included in 4 out of 5 statistical models of rheovasogram amplitude indices.

Notably, a considerable influence on the value of rheovasographic parameters of the shin in volleyball players of mesomorphic somatotype of the chest and pelvis diameters was established – they accounted for 19.15% of all anthropometric sizes of regression polynomials and were included in 90% of the built models, only the value of the amplitude of incisure was not significantly influenced by body diameters. Of this group of anthropometric measurements, the most commonly included in the models were transverse mid-thoracic (40% of models), anterior-posterior mid-thoracic (40% of models), shoulder width (30% of models), and intercristal distance (30% of models).

Furthermore, the variability of these regional circulation parameters also depended on the width of the epiphyses of the long tubular bones, which accounted for 9.57% of all predictors and were represented in 6 models (60%). The thickness of the skin and fat folds accounted for 17.02% of all predictors of the regression polynomials and was included in 8 models (80%), most often skin and fat folds were present on the shin, abdomen, and flank area.

V. Khavtur *et al*. [25] performed statistical modelling of thigh rheovasographic parameters in female volleyball players of ectomorphic somatotype, for which 16 regression models were built, and they also modelled integral rheovasographic parameters. Notably, in female volleyball players of ectomorphic somatotype, who are distinguished by significant height, predominance of longitudinal body dimensions over transverse ones, low fat deposition, variability of regional blood circulation indicators on the thigh by fewer indicators of external body structure, because the 16 regression models included 94 anthropometric and somatotypic dimensions. To the greatest extent, the variability of rheovasographic parameters of the thigh in female ectomorphic volleyball players was conditioned by the thickness of fat folds, head size, girth and anterior-posterior body dimensions, and somatotype components.

Thus, modelling cardiovascular system parameters using statistical methods is a modern approach that allows individualising test results, considering the unique features of each person's body structure and revealing the biomechanics of physiological processes.

CONCLUSIONS

The obtained findings, which were based on the use of multivariate regression analysis, made it possible to fulfil the purpose of this study. This is because for all amplitude and time indicators of the rheovasogram of the shin in female volleyball players of mesomorphic constitutional type, statistical models with high accuracy of description of signs were built, which make it possible to determine the appropriate values of regional blood circulation indicators on the shin, considering the anthropo-somatotypic characteristics of each athlete.

A reliable predominant influence of indicators of the external structure of the body on the variability of rheovasographic parameters of the shin in volleyball players of mesomorphic somatotype was established, as evidenced by the high values of the coefficients of determination of regional blood circulation in the shin. For the amplitude indicators of the shin rheovasogram, the values of the determination coefficients were within the following limits: $R^2 = 0.833$-0.996; for time – $R^2 = 0.896$-0.998, for integral – $R^2 = 0.638$-0.999.

The 10 statistical models of the amplitude and time indices of the shin rheovasogram included 94 dimensions of the external body structure. According to the results of the stepwise regression analysis, the largest value of the parameters of shin rheovasography was determined by the body circumference, which accounted for 35.11% of all predictors (most often the circumference of the forearm, neck, and shin), and was included in 100% of the models; chest and pelvic diameters (19.15% of all anthropometric dimensions of regression polynomials and included in 90% of the models); thickness of skin and fat folds, which accounted for 17.02% of all predictors and included in 80% of the models (most often folds on the shin, abdomen, and flank); width of the epiphyses of long tubular bones (9.57% of all predictors and included in 60% of the models).

The obtained results make it possible to analyse and determine the appropriate parameters of peripheral haemodynamics in youth volleyball players of mesomorphic somatotype during screening studies of female athletes, considering their personal values of anthropometric dimensions. In the future, it is worth using the identified anthropometric parameters for screening athletes to determine their peripheral haemodynamics and improve the efficiency of the training process.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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Математичне моделювання показників периферичної гемодинаміки гомілки у волейболісток мезоморфного соматотипу

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Анотація. Статистичне моделювання показників периферичної гемодинаміки, яке проводиться на основі визначення антропометричних і соматотипологічних особливостей організму можна вважати новим способом персоналізації інструментального діагностичного обстеження, тому визначення належних реовазографічних параметрів гомілки у висококваліфікованих волейболісток окремого соматотипу є актуальним. Мета роботи полягала у дослідженні сумарного впливу показників зовнішньої будови тіла на величину показників, які відображають особовості кровообігу на гомілці, у волейболісток мезоморфного соматотипу. Проведено комплексне клініко-лабораторне дослідження стану здоров'я та фізичного розвитку 108 волейболісток віком 16-20 років. Для визначення реовазографічних показників гомілки використовували метод тетраполярної реографії із застосуванням діагностичного комп'ютерного багатофункціонального апарату, оцінювали амплітудні, часові та показники відношень амплітудних і часових реовазографічних параметрів. Здійснено антропометричне дослідження тотальних та парціальних розмірів тіла. Соматотипування проведено за методом Heath-Carter. Відібрано 28 волейболісток мезоморфного соматотипу. Створення статистичних моделей проведено з використанням прямого покрокового багатофакторного регресійного аналізу. Для всіх амплітудних і часових реовазографічних параметрів стегна у волейболісток мезоморфного соматотипу були побудовані статистичні моделі з високою точністю опису ознак. До 10 побудованих моделей увійшло 94 антропометричних розмірів. Найбільше визначають величину параметрів кровообігу гомілки обхватні розміри тіла (найчастіше обхват передпліччя, шиї та гомілки), діаметри грудної клітки та тазу, товщина шкірно-жирових складок (найчастіше на гомілці, животі, боку), ширина епіфізів довгих трубчастих кісток. Встановлено, що показники зовнішньої будови тіла у межах від 63,84 % до 99,99 % детермінують величину показників регіонального кровообігу на гомілці у волейболісток мезоморфного соматотипу. Статистичне моделювання надає можливість визначити належні значення окремих реовазографічних показників на гомілці залежно від антропометричних параметрів осіб певної статі, віку, соматотипу, що особливо важливо для спортсменів певного виду спорту, тому що їхні показники серцево-судинної системи зазнають колосального впливу специфіки спортивної діяльності

Ключові слова: покрокова регресія; статистичне моделювання; реовазографія; антропометричні розміри; мезоморфний соматотип; волейбол