Analysis of strength indicators of the muscles of the lower extremities: an instrumental method

UDC 796.051.2

Postgraduate **Mintszyunke Shan**[1]
M.S. Kozhedub[1]
Dr. Hab., Professor **E.P. Vrublevskiy**[1, 2]
[1]Skorina Gomel State University, Gomel, Belarus
[2]Smolensk State University of Sports, Smolensk

Corresponding author: vru-evg@yandex.ru

Received by the editorial office on 17.08.2024

Abstract

Objective of the study was to adapt an instrumental method for assessing the strength of the leg extensor muscles and test its effectiveness in various sports.

Methods and structure of the study. To assess the strength and speed-strength capabilities of the leg extensor muscles in female athletes, the computer tensodynamography method was used, consisting in recording and analyzing the «strengthtime » curve. Based on the obtained tensodynamometric curves, the maximum isometric muscle strength (F_{max}) demonstrated in the described movement, the time (t_{max}) during which the maximum effort was achieved were determined. The following were calculated: the differential index (gradient) of strength (I), characterizing the rate of its increase to the maximum ($I = F_{max} / tmax$), the force achieved in 0,1 s, as well as strength indicators relative to the body weight of the athletes. The experiment involved female athletes aged 15-17 (n = 36), specializing in short and middle distance running, as well as in ice hockey.

Results and conclusions. An instrumental method for assessing the strength characteristics of the leg extensor muscles has been improved and tested. Its use for pedagogical control over the dynamics of athletes' condition in sports practice conditions has shown a positive effect. The dynamometric characteristics of the leg extensor muscles in the isometric mode obtained using the instrumental method have authenticity criteria and are recommended as tests for assessing the level of special strength training of female athletes of different specializations. Multiple regression equations have been developed for predicting the probable sports result and establishing the proper values in control exercises that determine the planned sports result, which can be used in practice for individual correction of the training process of female athletes.

The dynamometric measurements of the leg extensor muscles, obtained using the new method in an isometric mode, have been validated as reliable indicators. They are recommended as tests for assessing the level of athletes' special strength training across various disciplines. To predict athletic performance and set appropriate benchmarks for control exercises that contribute to achieving the desired athletic result, multiple regression equations have been created. These equations can be used in practice to tailor the training process for individual athletes.

Keywords: *method, strength abilities, female athletes, extensor muscles, regression equations, tests.*

Introduction. The implementation of the idea of managing the training process requires diverse and comprehensive information about the athlete's condition [1, 5, 6]. Such information also includes a quantitative characteristic of the individual's ability to demonstrate muscular effort in a limited time. It is impossible to determine certain strength manifestations and the process of their changes over time using pedagogical tests. The most effective and rational way to assess the nature of the development of muscular effort in athletes of various specializations and qualifications, as well as to track the dynamics of the development of strength indicators is to use the computer tensodynamometry method, which allows not only to obtain detailed and accurate dynamometric indicators of the subjects, but also to quickly process and analyze the results.

Objective of the study was to modify an instrumental approach for assessing the power of the leg extensor muscles and assess its efficacy in different athletic disciplines.

Methods and structure of the study. For instrumental control of the strength and speed-strength capabilities of various muscle groups of female athletes, the method of computer tensodynamography was used, consisting in recording and analyzing the curve of muscle strength development over time. This instrumental technique allows us to assess the level of special strength training of female athletes based on a set of specific data characterizing the individual's ability to demonstrate «explosive» efforts that are inaccessible to direct measurement using traditional means. The approach to measuring the speed of voluntary tension of the leg extensor muscles proposed by Yu.V. Verkhoshansky [1] and improved by us on the basis of a modern electronic base was taken as a basis.

The measuring complex includes two main units: mechanical and electronic. The design of the first provides the subjects with a comfortable standard sitting position for maximum effort and its stable reproduction during repeated testing, and the small dimensions, weight of the structure and its disassemblability make it possible to transport it to training camps, which significantly expands the potential of research. An industrial sensor of the DACELL LOAD CELL company (Korea) was used as a force recorder. The electronic unit is represented by a computer, in which the developed program ensures coupling with the sensor, allows monitoring the modulation of the muscle strength manifestation curve and the rate of its change on the monitor, makes it possible to carry out express processing and save the obtained data in the form of tables.

Tensodynamograms of the strength manifestation of the leg extensor muscles in the knee and hip joints were recorded and processed. In the isometric mode, the setting was given to show the absolute arbitrary force (Po) without taking into account time, in the explosive isometric mode – to quickly achieve maximum force in the shortest period of time. According to the obtained tensodynamometric curves, the maximum isometric muscle force (Fmax) manifested in the described movement, the time (tmax) during which this maximum was reached were determined, the differential indicator (gradient) of force (I) was calculated, characterizing the rate of increase in force to the maximum (I = Fmax / tmax), the force achieved in 0,1 s, as well as strength indicators relative to the body weight of the athletes. The latter characteristics are very informative, since a high level of absolute strength does not guarantee the proper percentage of its use during muscle contraction under time pressure, and the manifestation of strength characteristics largely depends on the individual's weight. To measure the strength characteristics of the lower limb muscles, the angle in the knee joint (110o) was set using a goniometer-protractor when changing the distance of the platform for the foot and was chosen as meeting the criteria of reliability and reproducibility for such studies [1, 6]. All recorded characteristics were determined for the right and left legs, and the arithmetic mean value of the characteristics of both legs was taken into account during further processing.

Results of the study and discussion. Table 1 shows the dynamometric characteristics of the leg extensor muscles in the isometric mode in female athletes of different specializations. It is evident that short-distance runners have higher indicators for all analyzed characteristics, especially the gradient of strength relative to body weight. Hockey players are ahead of middle-distance runners in absolute indicators, but are inferior to them in the magnitude of strength characteristics relative to body weight, while having the highest range of variation of characteristics.

It should be emphasized that physical training occupies an important place in modern hockey. It is noted that a hockey player must have high absolute and explosive strength, speed, in order to be able to effectively carry out a short shift, while implementing complex coordination techniques [2, 5]. The outstanding Soviet coach A.V. Tarasov describes the hockey player's model as follows: «A high-class hockey player is a physically versatile athlete who has pronounced speed, strength qualities, explosive reaction speed» [7, p. 3].

It is significant that the strength gradient in female athletes has a relatively low variability: the variation coefficient does not exceed 5%. This is due to the fact that the realization of strength potential occurs in two ways: by increasing strength indicators and reducing the time to achieve it. Analysis of individual values has shown that among representatives of different specializations there are athletes with high muscle strength values and athletes capable of extremely rapid development of effort, for whom the time to achieve maximum effort does not exceed 0,15 s. Since studies show [cit. according to 6] that the strength gradient correlates with the composition of muscle fibers, it can be assumed that the speed of voluntary tension of the leg extensor muscles indirectly characterizes the ratio between the fast and slow motor units of the muscles performing this movement. The characteristics

Table 1. Strength characteristics of the lower limb muscles in female athletes of different specializations $\bar{X} \pm \sigma$)

Power characteristics	Short distance runners (n=13)	Middle distance runners (n=11)	Hockey players (n=12)
Absolute muscle strength, kg	143,7±5,1	129,8±4,3	136,8±7,5
Absolute muscle strength relative to body weight, conventional units	2,48±0,25	2,36±0,22	2,25±0,64
Manifestation of force in 0,1 s, kg	69,8±3,1	54,3±2,5	59,2±4,8
Manifestation of force in 0,1 s relative to body weight, conventional units	1,21±0,12	0,99±0,11	0,97±0,16
Maximum muscle strength in explosive effort, kg	126,3±6,2	112,1±3,5	116,8±6,1
Time to reach maximum force, s	0,29±0,03	0,38±0,01	0,36±0,05
Force gradient, kgf/s	434,5±13,2	292,1±11,5	324,4±15,1
Force gradient relative to body weight, conventional units	7,48±1,1	5,36±1,0	5,31±1,3

assessing the strength capabilities of the muscles of the lower extremities were tested for informativeness (validity), reliability and consistency. To determine the informativeness, statistical analysis was used, which revealed a significant correlation between the test indicators and the athletic performance of female runners and the time it took to skate forward for a distance of 17,7 to 27,5 m for female hockey players [4]. To determine reliability, the double testing method (test-retest) was used, and to check consistency, the correlation coefficient was calculated between the results obtained in different studies when testing the same subjects. The degree of connection (rtt) between the test results in all cases exceeded 0,95, indicating excellent reliability and consistency (objectivity) of the data [3]. Thus, the dynamometric characteristics of the leg extensor muscles in isometric mode obtained using the instrumental method meet metrological requirements and are recommended as tests for assessing the level of special strength training of female athletes of different specializations. Using short-distance runners as an example, multiple regression analysis was used to identify the functional dependence of sports results on individual indicators of special training, which takes into account the mutual compensation of various factors that determine sports achievements. The regression equations Y = Bo + B1X1 + B2X2 + B3X3 + B4X4 +... + BnXn can be used to predict the probable sports result (Y) and establish the required values in control exercises (X), which determine the planned sports result [3]. The results of the regression analysis are presented in Tables 2 and 3 in the form of regression coefficients calculated on a natural scale, which makes it possible to express the assessed characteristic in units of its measurement.

The multiple determination coefficients (D) given in the tables show the percentage of variation in the sports result due to the combined effect of the independent variables (arguments) included in the equation. It should be noted that the multiple correlation

Table 2. Coefficients of the regression equation of the type $Y=B_o+B_1X_1+B_2X_2+B_3X_3$ *for calculating the result in 100 m running (Y) based on the strength gradient indicator (*X_1*), the result of the standing long jump (*X_2*) and the shot throw (4 kg) from bottom to front (*X_3*) (for female athletes of the 2nd sports category)*

B_o	B_1	B_2	B_3	R	S	D
16,304	-0,004	-0,106	-0,095	0,924	0,23	85,4

Table 3. Coefficients of the regression equation of the type $Y=B_o+B_1X_1+B_2X_2+B_3X_3+B_4X_4$ *for calculating the result in 100 m running (Y) based on the time of running 60m from a low start (*X_1*), the result of the triple jump from a place (*X_2*), the force gradient indicator (*X_3*) and the manifestation of force in 0,1 s (*X_4*) (for athletes of the 1st sports category)*

B_o	B_1	B_2	B_3	B_4	R	S	D
5,311	1,610	-0,310	-0,004	-0,016	0,936	0,18	87,6

coefficients (R) are quite high (0,924-0,936), characterizing the closeness of the relationship between the dependent variables and the set of analyzed fitness indicators. The use of the developed equations in practical activities makes it possible to significantly individualize the training of female athletes and thereby increase their effectiveness.

C**onclusions.** An instrumental method for assessing the strength characteristics of the leg extensor muscles has been improved and tested. It can be used for pedagogical control of the dynamics of athletes' fitness throughout the training macrocycle in order to identify its trends depending on the content of training effects and their predominant focus. The use of this method for monitoring the relationship between the specified training load on various structural units of the annual cycle and the dynamics of the state of special strength fitness of female athletes has shown good results in the conditions of sports practice [8], which is of fundamental importance for the implementation of the idea of managing the training process.

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