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TECHNOLOGY OF MODELLING THE MOTION KINEMATIC STRUCTURE DURING TECHNICAL PREPARATION OF SKILLED JAVELIN THROWERS

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Abstract

The Urgency of the Research Problem. The development and usage of models are connected with modelling – the process of designing, studying and using models for determination and specification of characteristics and optimization of the process of athletic preparation and participation in competitions. Therefore, elaboration of the technology for modelling the motion kinematic structure within the process of skilled javelin throwers' preparation is inactual scientific topic requiring detailed studying and substantiating. ***Objective and Methods of Study.*** To develop the technology of modelling the motion kinematic structure in the process of technical preparation of skilled javelin throwers. The following methods of study were used in attaining the objective: analysis of scientific and methodical literature and Internet information; video recording; video computer analysis; modelling; methods of mathematical statistics. ***Results.*** Average-group models of biomechanical structure of javelin thrower motor actions, regression models of javelin throwing techniques, prognostic model characteristics of javelin throwing techniques have been developed. And on this basis, the technology of modelling the motion kinematic structure in the process of technical preparation of skilled javelin throwers has been elaborated. ***Conclusions.*** The technology of modelling kinematic and dynamic motion structure in the process of technical preparation of skilled javelin throwers has been elaborated and substantiated. It is focused on the achievement of target sports results on the basis of the developed average-group, regression models and prognostic model characteristics being the foundation for selecting special preparation means maximally close to the competitive activity in form and structure, which contributes to the improvement of technical skills of athletes specialized in javelin throwing.

Key words: average-group models, regression models, prognostic model characteristics.

Олександр Клімашевський, Олена Козлова. Технологія моделювання кінематичної структури рухів у процесі технічної підготовки кваліфікованих метальників списа. ***Актуальність.*** Розробка й використання моделей пов'язані з моделюванням – процесом побудови, вивчення та використання моделей для визначення й уточнення характеристик та оптимізації процесу спортивної підготовки й участі в змаганнях. Тому розробка технології моделювання кінематичної структури рухів у процесі технічної підготовки кваліфікованих метальників списа є актуальним науковим напрямом, що потребує детального вивчення й обґрунтування. ***Мета та методи дослідження.*** Розробити технологію моделювання кінематичної структури рухів у процесі технічної підготовки кваліфікованих метальників списа. Для досягнення мети використовували такі ***методи дослідження:*** аналіз науково-методичної літератури та інформації світової мережі Інтернет; відеозйомка; відеокомп'ютерний аналіз; моделювання; методи математичної статистики. ***Результати роботи.*** Розроблено середньогрупові моделі біомеханічної структури рухових дій метальників списа, регресійні моделі техніки метання списа, прогностичні модельні характеристики техніки метання списа й на цій основі обґрунтовано технологію моделювання кінематичної структури рухів у процесі технічної підготовки кваліфікованих метальників списа. ***Висновки.*** Розроблено й обґрунтовано технологію моделювання кінематичної та динамічної структури рухів у процесі технічної підготовки кваліфікованих метальників списа. Технологія спрямована на досягнення заданих спортивних результатів на основі розроблених середньогрупових, регресійних моделей і прогностичних модельних характеристик, які є основою для вибору засобів спеціальної підготовки, максимально наближених за формою й структурою до змагальної діяльності, що сприяє вдосконаленню технічної майстерності спортсменів, котрі спеціалізуються в метанні списа.

Ключові слова: середньогрупові моделі, регресійні моделі, прогностичні модельні характеристики.

Александр Климашевский, Елена Козлова. Технология моделирования кинематической структуры движений в процессе технической подготовки квалифицированных метателей копья. ***Актуальность темы исследования***. Разработка и использование моделей связанны с моделированием – процессом построения, изучения и использования моделей для определения и уточнения характеристик и оптимизации процесса спортивной подготовки и участия в соревнованиях. Поэтому разработка технологии моделирования кинематической структуры движений в процессе технической подготовки квалифицированных метателей копья

является актуальным научным направлением и требует детального изучения и обоснования. ***Цель и методы исследования*** – разработать технологию моделирования кинематической структуры движений в процессе технической подготовки квалифицированных метателей копья. Для достижения цели использовали следующие ***методы исследования:*** анализ научно-методической литературы и информации мировой сети Интернет; видеосъемка; видеокомпьютерный анализ; моделирование; методы математической статистики. ***Результаты работы***. Разработаны среднегрупповые модели биомеханической структуры двигательных действий метателей копья, регрессионные модели техники метания копья, прогностические модельные характеристики техники метания копья, и на этой основе обоснована технология моделирования кинематической структуры движений в процессе технической подготовки квалифицированных метателей копья. ***Выводы***. Разработана и обоснована технология моделирования кинематической и динамической структуры движений в процессе технической подготовки квалифицированных метателей копья. Технология направлена на достижение заданных спортивных результатов на основе разработанных среднегрупповых, регрессионных моделей и прогностических модельных характеристик, которые являются основанием для выбора средств специальной подготовки, максимально приближенных по форме и структуре к соревновательной деятельности, что способствует совершенствованию технического мастерства спортсменов, специализирующихся в метании копья.

Ключевые слова: среднегрупповые модели, регрессионные модели, прогностические модельные характеристики.

Introduction. Effective management of the training process involves the usage of different models. The model is understood as the pattern (sample, standard) in the broader sense it is any pattern (imaginary or conditional) of a particular object, of the process or phenomenon [4]. The development and the usage of models are related to modeling - the process of constructing, studying and using the models to determine and specify the characteristics and to optimize the process of athletic performance and taking part in competitions [4]. The rates of growth of sportsmanship and sport results are mainly increasing, where the search of simulation techniques is conducted on an objective quantitative basis [6].

Javelin is a speed-force, acyclic exercise, the main purpose of which is to achieve maximum results within established rules. Specific technical requirements that were formed in the process of scientific research, determine performing certain motor actions in the javelin [1]. Nowadays, active work on biomechanical analysis of the javelin technique is performed by federations of countries in association with sports organizations [3, 7-9], but the sports experience shows that improving Ukrainian athletes' technical skills is based on the coach's knowledge, vision and the athlete's feeling about himself, which does not always coincide and complicates the process of sports training sessions. Therefore, in order to improve their work, the technology for modeling the kinematic structure of movements is required; it allows us to rely on quantitative criteria in the process of technical preparation of javelin throwers and represents a system of knowledge about methods (set and sequence of operations, their regimes), the assuring athletes' training session needs through the usage of the technical means. That determines the problem statement of the research.

It is fair to assume that the improvement of qualified athletes' technical skills can be successfully accomplished using widely the theoretical foundations and means of biomechanical modeling of motions taking into consideration the already developed models of different types (intergroup and regression) and predictive model characteristics of the javelin technique which makes it possible to aim at the achievement of the planned sports results.

The research was conducted in accordance with the Consolidated Plan for Research and Development in the field of Physical Culture and Sports for 2016-2020 of the Ministry of Education and Science of Ukraine on the topic "Theoretical and Methodological Basis for Increasing the Technical Skill of Qualified Athletes in Competitive Exercises (for example, track and field athletics, winter sports and cycling); and in accordance with the Consolidated Plan of Research in the Field of Physical Culture and Sports for 2016-2020 of the Ministry of Education and Science of Ukraine on the theme 2.26 «Improvement of the system of sports training and competitive action the number of skilled athletes in the modern conditions of intensification of competitive activities».

The strategic aim of the research is to develop a technology of modeling the kinematic structure of movements in the process of technical training session of qualified javelin throwers.

Data for study and research methods. The following methods of study were used in the obtaining of the objective: analysis of scientific and methodical literature and Internet information; video recording; video analysis; modelling; methods of mathematical statistics.

Study management. At the first stage of the study, the analysis of scientific and methodological literature, analysis and generalization of the experience of practical training in the technical training of athletes was carried out. We studied the kinematics and dynamics criteria of the javelin technique what influence high sport results achievement.

At the second stage, a search experiment was conducted. The kinematics (temporal, spatial and spatio-temporal) characteristics were investigated and the dynamic characteristics of the javelin technique were calculated to obtain complete information on the biomechanical structure of the javelin technique. During the process of the training exercises some videos were taken, using the SONY Digital 8 video camera, which was fixed and the optical axis of the lens remained perpendicular to the vector of the athlete's movement. It was done in order to obtain biomechanical characteristics. All metrological requirements were taken into consideration, that allows minimizing the systematic and chance mistakes which arise due to the specific properties of optics. We calculated the correct scaling of the shooting area to further determination of the real coordinates of points that are required; the correct orientation of the camera in space according to the motion plane. The cameras were cabled at the 20m distance from the subjects. The shooting frequency was 50 shots per second. The probability of error in the video shooting was 5%, so the level of significance is $\alpha = 0.05$.

60 attempts by 20 qualified athletes who are Candidate Masters of Sports title were analyzed. Each athlete has performed 15-20 attempts, but we selected three best attempts of each. The having results of the tests average were 64.2 m, S = 1.2 m, maximum was 66.4 m, and minimum - 59.8 m. Analyzed the results, we can draw the conclusion that the group is indiscrete, it is evidenced by the low value of the coefficient of variation (V = 1.8%), and close to each other average value, mod and median (x = 64,2; Mo = 64,2; Me = 63,8).

The spear flight range was used by us as a basic and systematic indicator that organizes other elements of javelin technology into a single system.

To reveal standard indicators of the javelin technique, we analyzed 20 attempts of 4 highly qualified athletes who have the sports rank of the international master of sport. We recorded all the athletes' attempts at the training sessions, but the five best attempts of each athlete were selected.

The results of javelin attempts made by athletes of high qualification averaged 73.8 m, S = 2.4 m, a maximum value is 76.8 m, and a minimum – 72.4 m. Having analyzed the obtained results, we can state that the group is indiscrete, the low value of the coefficient of variation indicates this (V = 3.2%), as well as close to one another average values of mod and median (x = 73.8; Mo = 73.4; Me = 73.6).

We have received an informed consent from all the participants to take part in the experiment.

The video-computer analysis of the biomechanical structure of motor actions was carried out using the software "BioVideo" developed by I.V. Khmelnitska [5] at the Department of Kinesiology of the National University of Physical Education and Sports of Ukraine, which allows to obtain the kinematic and energy characteristics of human motor actions using visible record. The developed technology of computer monitoring of human motility includes the application programme packages "BioVideo". The source data for the "BioVideo" program are files of shots of one-dimensional video-recording of human motion action in BMP, .DIB, .WMF, .EMF, .GIF, .JPG, .JPEG formats. The Windows XP operating system allows you to obtain these files directly from your local computer's memory device or hardware peripheral or by remote access, using a computer network or an Internet e-mail. "BioVideo" allows to receive biomechanical characteristics of individual biolink, and of the entire body of a person in each frame and in separate stages of motor action. Application software (ASW) "BioVideo" includes four sections:

- construction of models of the human musculoskeletal system (MS): (a 14-segment MS model was used, whose link coordinates according to the geometric characteristics and corresponds to the coordinates of position in the space of human body biolinks, and the starting point - to the coordinates of the centers of the major joints); the section allows to create the iterative models of the human MS;
- determination of the coordinates of points concerning the somatic reference system;
- computation of biomechanical characteristics of motor actions according to the coordinates of the human MS model; the software section capabilities allow to determine the localization of the centers of mass (CM) of biolinks and the general center of mass (GCM) of the human body;
- module of constructing of a biokinematic scheme (BKS) of a human body based on a videogram of motor action with the specification of trajectories of the centers of joints, biolink CM and GCM of the human body.

Statistical analysis. To study the significance of individual indicators of the javelin technique produced by athletes of different qualifications, we conducted a correlation analysis, based on which the close

relationship between the studied indicators was established and the most informative ones were found. Informativeness of indicators of technical readiness was determined by means of averaging of absolute values of coefficients of pair correlation in both groups of athletes. Seven most informative indicators of technical readiness, which had the greatest correlation with the flight range of the spear, were determined.

These indicators were used by us to construct a statistic meangroup model of the kinematic structure of the javelin technique. The built graphical meangroup models allow to identify the main directions of technical training improvement, to establish optimal levels of development of its various parts, as well as the connections and bonds between them among athletes of different qualifications.

The regression models of the javelin technique were developed, which include: dependent explanatory variable (Y) - spear flight distance, independent explanatory variables (xn): the speed, the length of the distance of final speed-up of the missile, the position of the body at the time of gab, the angle of the spear gab, the speed of the athlete's body GCM at the time of the tailend of the final run, the speed of the GCM of the athlete's body at the time of the previous tailend of the run, the duration of the phase reference of the first hurl step in the tailend, the force gradient in the phase reference of the first throw step in the run's tailend.

At the third stage of the research, the construction of the javelin modeling technology in the process of athletes' technical training on the basis of developed model types was developed.

Research results. As a result of the research, a javelin modeling technology was developed (Fig. 1), which allows:

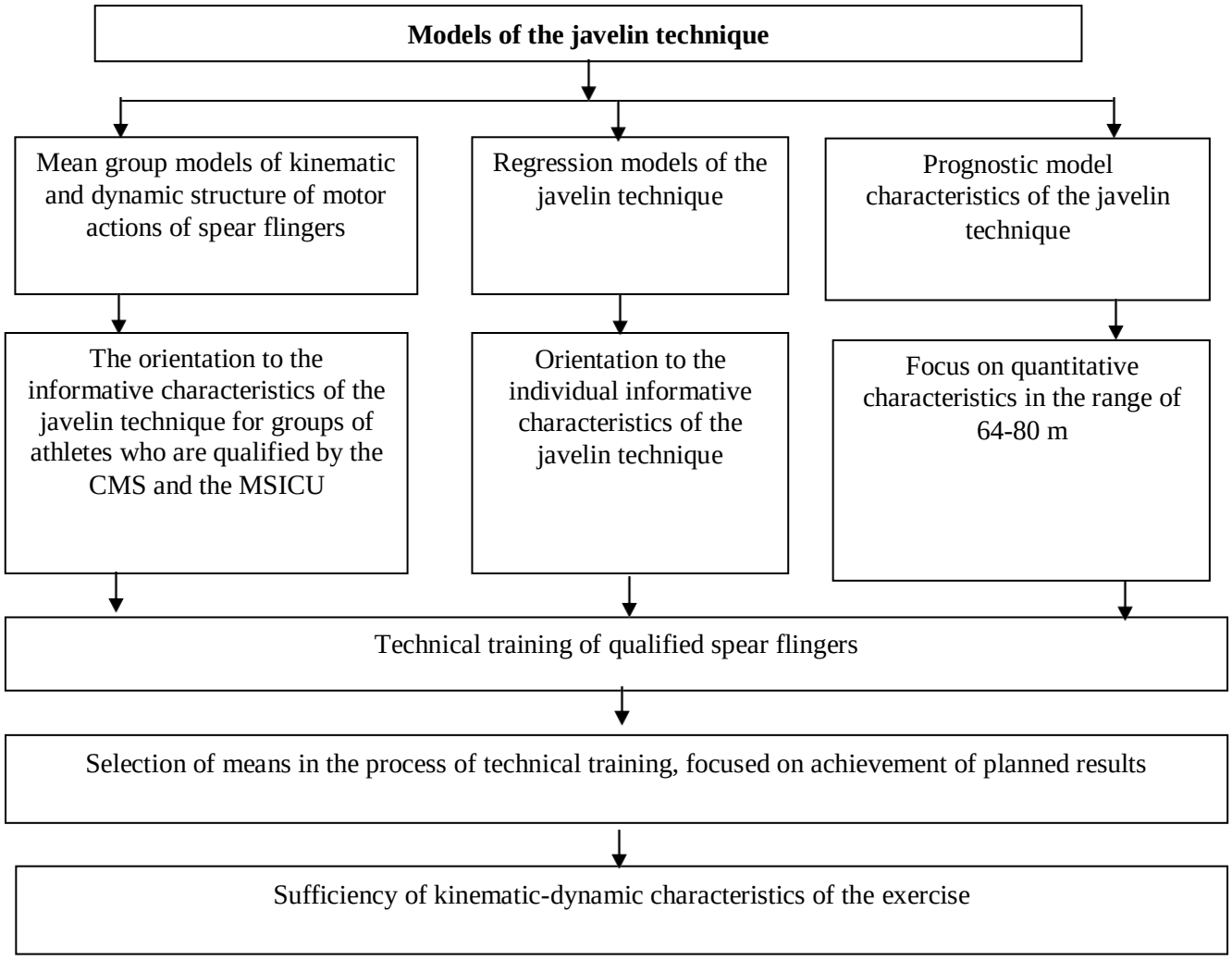

Fig. 1. *Javelin modeling technology in the process of athletes' technical training*

- to predict sport results required for success at various stages of preparation with regard to objective criteria of javelin throwing techniques, obtained in the course of the study; to create a database of competitive activity and special training of athletes;
- to analyze and simulate the characteristics of the technical training of javelin masters influencing the achievement of high sport results;
- to plan training programs based on identified patterns of rational building movements in the javelin, aimed at the achievement of high sport results, qualifications and level of special training;
- to individualize technical training of javelin thrower.

In each of these sections work should include the control of technical preparedness of sportsmen on the basis of the automated processing results.

Graphical mean group models of javelin throwing technique. Orientation to them allows to determine the main directions of the improvement of technical training, to establish the optimal levels of development of its different sides of the athletes, as well as links and correlations between the sportsmen of different qualifications. A model of this type is shown in figure 2.

The regression models of javelin throwing technique. In the course of the study we developed regression models of javelin, shown in table 1.

Developed regression models aimed at predicting a given flying range of the javelin and guide the coach and athlete on individual technical training. The use of these models by coach greatly facilitates the process of the current and operative control, and allows to assess differentially the technical preparedness of athletes specializing in throwing javelin.

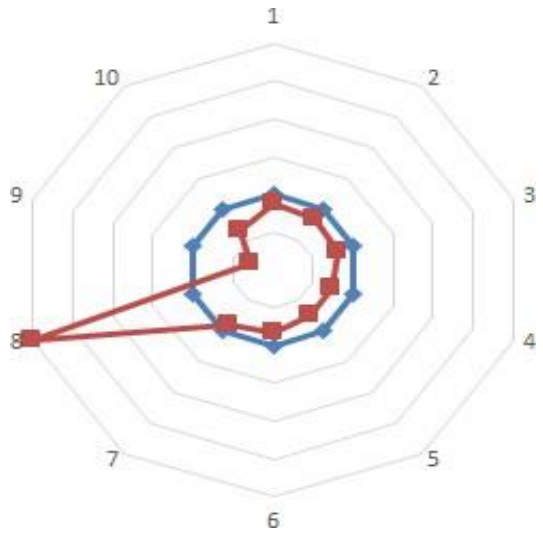

Fig. 2. *A model of the most important biomechanical characteristics of the technique of javelin throwing by athletes of different qualification*

highly qualified athletes
qualified athletes

1 – flying range of a javelin, m;
2 - launching speed of a javelin, m•s^{-1};
3 - the path length of the final acceleration of a javelin, m;
4 - the angle between the torso and the vertical at the launching moment, degrees;
5 - the angle of launching of a javelin, degrees;
6 - speed of general center of mass of the athlete's body at the end of the final part of the run , m•s^{-1};
7 - speed of general center of mass of the athlete's body at the time of the prior final part of the run, m•s^{-1};
8 - duration of the support phase of the first throwing step at the end of the run, s;
9 - gradient force in the support phase of the first throwing step at the end of the run N•s^{-1};
10 - angle of stability at the moment of javelin launching, degrees.

Table 1

Regression models of estimation of qualified javelin throwers' technique

№	Multiple regression equation	Coefficient of multiple regression	Measure of inaccuracy of a model
1	$Y= 1,96+1,141x_1+3,172x_2+0,029x_3+ 0,079x_4+0,0028x_5+ +0,2979x_6+7,23x_7+0,00016x_8$	0,846	1,52
2	$Y=4,12+1,023x_1+4,141x_2+0,298x_3+0,135x_4$	0,809	1, 07

Notes:

Y – flying range of a javelin, m;

x1 – launching speed of a javelin, m•s-1;

x2 – the path length of the final acceleration of a javelin, m;

x3 – the angle between the torso and vertical at the launching moment, degrees; x4 – the angle of launching of a javelin, degrees;

x5 – speed of general center of mass of the athlete's body at the end of the final part of the run, m•s-1;

x6 – speed of general center of mass of the athlete's body at the time of the prior final part of the run, m•s-1;

x7 – duration of the reference phase of the first kekovole step at the end of the run, with−1;

x8 – duration of the support phase of the first throwing step at the end of the run, s;

1 – an expanded regression equation;

2 – regression equation for operational control

Predictive model characteristics of javelin throwing technique. To facilitate practical activities of the trainers, evaluation tables are worked out, including a range of prognostic model characteristics of throwing technique of the javelin to reach the given sport results in the range of 64-80 m in 10 sm. Predictive model characteristics of the technique of javelin throwing for the achievement of given sports results are shown in table 2, where the selected data is provided through 50 sm.

Discussion. Biomechanical researches of the javelin were mainly aimed at studying the biomechanical characteristics of the delivery whip, including the initial speed of its departure, the departure angle, the angle of attack and the height of the release [1; 3]. We have expanded the concept of the technique of throwing the spear based on the identification of informative biomechanical characteristics that affect the performance of competitive activities namely - it is defined that the flying range of the missile depends on its flight speed, the length of the path of final acceleration; angle trunk-vertical at the time of departure; the angle of the lance's departure, the speed of the athlete's common center of mass at the end of the final part of the take-off; the speed of the athlete's common center of mass at the time of the previous final part of the take-off; duration of the supporting phase of the first throw step in the final part of the takeoff; the force gradient in the supporting phase of the first throw step in the final part of the running approach; Angle of stability at the time of projectile launch, which determines the dynamic equilibrium and is an important indicator for improving the technical skill of skilled javelin throwers [2]. These characteristics formed the basis for constructing various types of models, and they became the basis for the development of modeling technology in the process of technical training of qualified athletes.

Conclusions and prospects for further research.

1. Regression models of javelin throwing technique are developed.

In solving the problems of theory and training procedure regression biomechanical models of motor actions are a system-forming factor, which determines the structure and content of the process of improving the technical skill of qualified athletes. They allow to forecast individual variants of technology, focused on achieving the planned performance, significantly facilitate the process of carrying out step-by-step, current and operational control, allow to differentially assess the technical preparedness of qualified javelin throwers.

Table 2

Prognostic models of biomechanical characteristics of throwing spear technique to achieve the given sports results

Spear Range	Speed of departure of a spear	The path length of the final accelera- tion of the projectile	Corner torso vertical at the time of depar- ture	The angle of departure of the spear	The speed of the general body weight center of the athlete at the final end-time part of the running approach	The speed of the general body weight center body of the athlete at the time-end of the preceding running approach	The duration of the supporting phase of the first throw step in the final part of the running approach	The force gradient in the supporting phase of the first throw step in the final part of the running approach	Angle of stability at the time of projectile launch
64	22,7	1,513	25,813	26,813	7,429	6,844	0,060	25512,9	15,631
64,5	22,95	1,531	26,281	27,281	7,507	7,334	0,059	29063,2	16,057
65	23,2	1,550	26,750	27,750	7,585	7,823	0,058	32613,6	16,484
65,5	23,45	1,569	27,219	28,219	7,663	8,313	0,057	36163,9	16,912
66	23,7	1,588	27,688	28,688	7,741	8,803	0,056	39714,3	17,339
66,5	23,95	1,606	28,156	29,156	7,819	9,292	0,055	43264,6	17,767
67	24,2	1,625	28,625	29,625	7,898	9,782	0,054	46815,0	18,194
67,5	24,45	1,644	29,094	30,094	7,976	10,271	0,053	50365,3	18,622
68	24,7	1,663	29,563	30,563	8,054	10,761	0,052	53915,7	19,049
68,5	24,95	1,681	30,031	31,031	8,132	11,251	0,051	57466,0	19,477
69	25,2	1,700	30,500	31,500	8,210	11,740	0,049	61016,4	19,904
69,5	25,45	1,719	30,969	31,969	8,288	12,230	0,048	64566,7	20,332
70	25,7	1,738	31,438	32,438	8,366	12,719	0,047	68117,1	20,759
70,5	25,95	1,756	31,906	32,906	8,444	13,209	0,046	71667,4	21,187
71	26,2	1,775	32,375	33,375	8,523	13,699	0,045	75217,8	21,614
71,5	26,45	1,794	32,844	33,844	8,601	14,188	0,044	78768,1	22,042
72	26,7	1,812	33,313	34,313	8,679	14,678	0,043	82318,5	22,469
72,5	26,95	1,831	33,781	34,781	8,757	15,167	0,042	85868,8	22,897
73	27,2	1,850	34,250	35,250	8,835	15,657	0,041	89419,2	23,324

2. The prognostic model characteristics of the throwing technique of the spear were developed, orienting the athletes' output to the level of given sports results in the range of 64-80m and determine the main vector of the technical skills formation in the system of sports training, allow us to develop ways of practical tasks implementation of pedagogical management of the athlete's technical characteristics, to predict the growth of

sports results, to estimate individual achievement reserves of planned biomechanical indicators of qualified athletes' equipment.

3. The technology of modeling the kinematic and dynamic structure of movements in the process of technical training of qualified javelin throwers has been developed and justified. The technology is aimed at achieving the given sports results on the basis of developed intergroup, regression models and forecasting model characteristics, which are the basis for the selection of special training tools, as close as possible to the form and structure to a competitive intensity exercise that stimulates the perfection of technical skill.

Prospects for further research should be linked to the development of a methodology for the use of training aids in combination with the use of developed technology.

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