

ORIGINAL RESEARCH PAPER

INTEGRATIVE APPROACH TO THE STUDY AND EVALUATION OF TECHNICAL PREPAREDNESS IN SPORTS BIOMECHANICS

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Abstract

The conception of “sports technique” or “sports technical mastery” is one of the most difficult to define distinctively. This is because it reflects various sides of athlete’s technical preparedness. In biomechanics “sports technique” is considered in two aspects. First of all, it is technique of sports exercise through which there’s carried out sports struggle and, namely, means of performing sports movement, quantity of such technical elements and their variety. In order to describe and evaluate this side of sports technique there have been introduced indicators like volume, versatility and rationality of sports technique. The second aspect of sports technical mastery is considered to be the technical preparedness of an athlete, who is applying this or another option to perform exercise. The efficiency and the degree of acquiring of sports technique is related to the indicators determining this side of technical preparedness. In practice the quality of sports technique and its acquiring degree quite often is evaluated by the demonstrated sports performance. Such evaluation is not correct as the sports performance is determined not only by technical mastery, but also by a lot of many other important factors, like fitness, motor skills, external conditions, differences in age, body constitution and sex, chosen tactics and etc. Namely thus the scientists strive to work out more objective methods of research and evaluation of athlete’s technical mastery, as well as maximally grant it quantitative assessment. The aim of the article is to describe the main research methods used in sports biomechanics and to justify the logic of integrative approach to the study and evaluation of sports technique.

Key words: *sports technique, technique’s realization effectiveness, biomechanisms, integrative approach.*

Research methods of the sports movement execution techniques in sports biomechanics

In sports biomechanics the study of the technique of physical exercises and athlete's technical preparedness in majority of cases is carried out by the method of biomechanical analysis of kinematical, dynamical and energetically characteristics of movement by means of application of various research methods - optical-electronic, mechanical-electrical, and electrophysiological, etc. (Bartlett, 2001; Donskoy, 1981; Gratton, Jones, 2004; Lanka, 2003; Safrit, Wood, 1989). However, there also exist other methods, like, logical-static, mechanical-mathematical, as well as – systemic methods (Donskoy, 1981; Gaverdovsky, 2007; Shalmanov, 2002). Each of the listed methods has its advantages and shortages, the knowledge of which is needed not only to successfully solve the research tasks, but also for search of new approach to solve the problems of athletes technical mastery. The development and experimental verification of the efficiency of such approach is considered to be one of the most actual methodological tasks of sports biomechanics.

When studying the technique of sports exercises and evaluating the technical mastery of athletes, researchers faced the problem of selection of namely those indicators that are predominantly informative to evaluate the level of athletes technical mastery. Most often the solution comes to the following: basing on the kinematical, dynamical, electrophysiological and other characteristics of the movement and motor apparatus of man's body, there are chosen various indicators and according to the degree of their correlation with sports result or based on application of some other static procedure, there's determined the most significant of them. The core question of applying such an approach is working out the logic of search and choice of the indicators for a subsequent analysis.

The simplest way of solving the problem is a choice of maximum greater number of indices and selection of only those that highly correlates with sports result. There can be mentioned quite a big amount of studies where authors have exposed for statistical processing tens and even hundreds of biomechanical indicators. Yet, a comparatively low efficiency of such approach is evident and the most important is that the existence of a high correlation with the result doesn't say that this indicator characterizes technique of performing an exercise. In any measurable indicator there's reflected technique, physical capabilities, as well as other factors that define sports performance. Thus, the researchers studied more effective methods to solve problems. One of such methods was worked out to evaluate the level of athletes technical mastery (Donskoy, Zatsiorsky, 1979; Lanka,

Shalmanov, 2004; Lanka, Konrads, & Shalmanov, 2005; Shalmanov, Shalmanov, 1990). It originated on the basis of the idea of making use of athlete's own motor potential in competitive exercise. The most correct quantitative means of realization of this idea is the method of regression remnants.

The main idea of this method reduces to athlete being offered two exercises. The result in the 1st exercise has to significantly depend on the development of some athlete motor ability (for instance, speed, force, power or endurance), and its execution technique has to be maximum simple. In the same way also the motor potential of athlete is evaluated in the exercise. The result in the 2nd exercise has to be determined by athlete's technical preparedness, as well as the already mentioned motor ability. In case the correlation between the results of exercises are high enough, the regression equation is calculated, in which the argument is to be considered the result of the task, evaluating athlete's potential, and the function is – the result in the exercise the technique of which is need to evaluate. On regression equation it's possible to define theoretical result of athlete that he has to show based on his motor abilities. The difference between the theoretical result and the actually demonstrated, named the regression remnants, is used to evaluate the realization efficiency of technique.

For instance, the speed in running hurdles depends on as minimum two factors: maximal velocity in the smooth running and technique of overcoming hurdles. Let's offer a hurdler to perform two exercises. In 1st exercise it's needed to run maximum fast distance of 30 m from stroke and based on the results of this test to evaluate athletes speed capacities. In 2nd exercise it's needed to do the same, yet with hurdles. Afterwards a correlation and regression line between the results of both tests is calculated. The regression line shows the average results a athlete shall show at the given result during smooth running. In case the time in hurdles run is less the time forecasted by regression equation, then one can assume that it's connected with the technique of hurdling. And, wise versa, in case the time in hurdling is more than the time forecasted by regression equation, the athlete's technical mastery is worse. So, the quantitative indicator of the effectiveness of realization of hurdler's speed qualities is the difference between the result in hurdle run and the result computed according to the regression equation and the actual achieved sport result, and not the sport result itself.

Hereinafter the researchers widened the scope of application of the method of regression remnants (Lanka, 1998; Lanka & Shalmanov, 2004; Shalmanov, 2002). Originally the idea of usage of athlete motor potential

was accompanied by an idea of evaluation of the level of usage of any integral action components or of its motor apparatus properties in a competition exercise (for instance, some parts of motor action, swing movements of body segments, biomechanical properties of muscles, etc). For instance, a comparison of the results of track-and-field athletics throws from stand position and from run up allows to evaluate the level of realization of the last (Lanka & Shalmanov, 1982; Lanka, 2007), but the comparison of the results of a standing vertical jump with a upward swing by the arms and without a swing, allows to evaluate the technique of performing arms swing and their contribution to the height of the jump (Shalmanov & Shalmanov, 1990).

Advantage of the method of regression remnants is in the fact that the criterion of the measure of athlete's technical mastery is not the sports results that depends on a great number of factors, but the athlete's ability to realize his motor capabilities. It is assumed that this depends on the level of athlete's technical mastery (Lanka, Konrads & Shalmanov, 2006). Besides, this method allows selectively or complex (in case of usage of a multiple regression analysis) evaluate the realization efficiency of the technique of the athlete. However, the described method has got a significant disadvantage. By means of this method there can be made only a conclusion that the technique of the given athlete is higher or lower the average level, but one can't say – why? An answer to this question might be found by means of other biomechanical research methods and in particular with mechanical-mathematic and systemic methods.

The usage of methods of mechanical-mathematic modeling in biomechanical research can be divided into two stages. The tasks of the first foresee the usage of the existing, as well as the working out of the new mechanical-mathematic models and the control of their efficiency to solve some definite circle of tasks (Bartlett, 1999; Khokhlov, 2000). The primary goal of this stage is to obtain quantitative information about the external picture of movements (angular and linear kinematic features of movements), as well as to study man's movements on the level of dynamics, t.i., define strengths and moments of strengths in joints, the work, power and mechanical energy of the whole body and separate segments of body, mechanical characteristics of muscular contraction and much more. When solving these tasks the researchers faced many difficulties like the precision of measuring device and its capabilities; problems with preliminary processing of input data; construction of the model, as well as the corresponding software; experimental examination of its efficiency and much more (Zatsiorsky & Prilutsky, 1989).

The tasks of the second stage foresee the usage of the mechanical-mathematic apparatus to study biomechanical problems, including sports biomechanics. For instance, to evaluate the efficiency of performing different variations of technique, to define different indicators of mechanical efficiency of some motor activity, to estimate load values in joints in order to find out the mechanical causes of injuries, to exercise sourcing of mistakes in exercise performance technique and much more. In this way one can use the mechanical-mathematic approach as one of the methods to solve the tasks of sports biomechanics. The solution is carried out on the bases of many principles and laws of mechanics that are put into the grounds of any method. As an example may be used the work of V. Nazarov (Lanka & Shalmanov, 2004) on the application of methods of mechanics of the controlled body in order to study and construct sports movements. The research of G. Popov and others (Lanka, 2004) on application of methods of wave mechanics to study the technique of track-and-field athletics throws, the works of J. Dapena (2000), M.R. Yeadon (2000), J. Gaverdovsky (2007) and others on usage of laws of conservation of impulse and the moment of impulse in order to study athletes movements in a support-free position and etc.

The initial use of the methods of mechanics reduced to the measurement and calculation of kinematic and dynamic characteristics of the movements of individual points, links or whole-body using various experimental techniques (goniometry, speedometer, accelerometry, opto-electronic systems, various options dynamometry, etc.). The quantitative data on human movement that was obtained using these methods mainly related to its interaction with the external environment.

The desire to penetrate into the internal dynamics, and through it reach the solution to the problem of the control of movements of such a complex system, that is a human, required the development of various models of the human body, from the model of a material point to multi-link models. The development of more advanced models, their mathematical and software basis, has led to the fact that there began to be included into their composition not only the hard links, but also the muscle-tendon structures as the main and most interesting in terms of the control of movements. Therefore to learn to measure or calculate the mechanical properties of muscles in the human body (muscle contraction forces, force arms, types of muscle contraction, etc.) is crucial (Khokhlov, 2000; Zatsiorsky, Aruin & Seluyanov, 1981; Zatsiorsky, 1998). To implement these models there is also needed information about the mass-geometrical characteristics of the human body (masses and moments of inertia of the segments of the human body, the position of segments centers of mass, etc.) (Zatsiorsky, 2002).

The use of mechanical-mathematical methods in conjunction with recording electrical activity of muscles makes it possible to obtain a large number of kinematic, dynamic and electrophysiological parameters in the movements of athletes. However, their application, on the one hand, is very time-consuming and requires skilled professionals and on the other hand, it allows to evaluate the technical skills of athletes, so to speak, in its purest form. A special place in biomechanics is taken by the methods based on the idea of block structure of human motor actions (Berkenblit, Gelfand & Feldman, 1990) and on the principles of consistency and hierarchical, multilevel construction of motor control system (Abernethy, Hanrahan & Kippers, 2005; Bernstein, 1947; Zatsiorsky, 1998). Although the authors of these works have different concepts of blocks, they all share the idea that these units exist, they are quite a lot, and they interact with each other and operate parallel or sequentially. From the standpoint of cybernetics, the organization of motor acts allows us to solve the problem of minimizing the number of control parameters and makes easier for the central nervous system to control the movements of man. The ideas of systemic approach based on the principles of integrity and systemic structure of complex objects and phenomena are widespread and used in human sciences (Donskoy, 1981; Gavardovsky, 2007). In relation to the motor actions of man it can be said that the properties of the system are not the result of the mechanical properties summing its constituent elements, but it is determined by the property of the structure as a whole, by specific backbone bonds of the object (Donskoy, 1981). Based on this, in order to understand the essence of the structure of motor actions, including sports movements, it is needed to develop a method for separating and studying both the system elements (blocks), and the relations between them, i.e. its structure. Hence the emphasis in a systemic approach is put on identifying and studying the elements of the manifold connections, both inside the system and its interaction with the external environment (Donskoy, 1981).

One of the options for a systemic approach is the method of biomechanical substantiation of the structure of motor actions of man. The method is based on the concept of biomechanisms proposed in the work (Seluyanov, Shalmanov, 1995). The introduction of this concept was preceded by works associated with the study of basic kinematical mechanisms that lies in the basis of different jumping exercises (Lanka, Konrad, & Shalmanov, 2006; Seluyanov & Shalmanov, 1983), hits and throwing actions (Lanka & Shalmanov, 1982; Lanka, 2000; Lanka, 2004; Lanka, 2005) and the movements associated with preserving the body stability in an exercise in balance (Lukunina & Shalmanov, 2000).

Biomechanism is a model of a part or all the locomotor system of man that enables achieving the objectives of the movement at the expense of converting one form of energy into another or the transfer of energy between the body segments (Shalmanov, 2002). As an integrated subsystem biomechanism consists of a set of elements that belong to it. Each element has certain properties that can be manifested differently in the movements of man. Muscles, bones and joints - are structural elements, of which the brain creates more or less complex subsystems – biomechanisms by means of which there can be reached the goal of the movement target set before.

It is important to emphasize that biomechanism combines a certain structure (subsystem), which consists of a set of body segments, as well as the interaction of these segments, which allows the use of the properties of elements in the system.

When developing our version of the method of biomechanical substantiation of the structure of human motor actions, we proceeded from the following assumptions.

1. Since the human body is a complex multisegment system, then, to control the movement, the brain, integrates the relevant units in the subsystems (biomechanisms), which can act independently of each other, yet their operation is aimed at achieving a common goal of action.

2. Each of the biomechanisms can be formed both from different and from the same parts of the body; has got a fundamental difference in their functioning, though it may be implemented differently depending on the motor tasks to perform.

3. The implementation of each biomechanism is caused by the structure of the human musculoskeletal system and the biomechanical properties of muscles involved in the performance of motor actions.

4. Relatively independent biomechanism depend on each other during the execution of motor actions, ie realization of one of them can positively or negatively influence the realization of others.

Thus, when using this method of study of various motor actions it is necessary to, first of all, on the basis of meaningful analysis, allocate the biomechanism, then, based on experimental data examine patterns of realization and, finally, using the knowledge of the peculiarities of structure and functions of the human musculoskeletal system, explain how they function.

The method of biomechanical substantiation of the structure of the motor action includes a phased implementation of the following tasks:

- Stage 1. Logical-meaningful analysis of the studied motor actions with a description of the kinematics and dynamics of movements of the body parts and of the whole body.

Stage 2. An explanation of the physical mechanism of motion.

Stage 3. Establishing the structure of motor actions, based on the selection of biomechanisms of their organization and functioning.

In the first stage the main task of the researcher is to analyze the external picture of the motion and the forces acting on the body. In this analysis it is necessary to identify the source and nature of acting forces and their role in achieving the goal of action.

The main objective of the second phase of biomechanical studies of the motor task is to reveal the physical mechanism of motion. By the mechanism of movement one understands the process of changing movements that result of applied forces, including muscular strength, based on the laws of mechanics. In essence, the question is to according the fact of change of the movement establish the causes of these changes and find the relevant forces and the law of their application.

The third stage involves establishing ways to organize all the action, at the same time basing on the following key provisions:

1. Numerous joint movements are combined into blocks, which are regarded as biomechanism.

2. Each of biomechanisms has their own organization and function, aimed at achieving the ultimate goal of action.

3. Management of the blocks is based on the multi-level motor control system, taking into account the characteristics of the structure and properties of the human musculoskeletal system.

Thus, the establishment of the structure of the motor task is reduced to determining biomechanisms, methods of their realization and mutual relationship in the whole operation, as well as a contribution to the final result.

Successful application of the method involves the examination of selected biomechanisms in the exercises, that have a common goal (for example, to achieve the greatest height or distance in jumping), but are performed with different motor tasks (for example, jump up with or without upward swing by the arms, drop jumps, long jump from run up, etc.). The main purpose of this methodological procedure is that the variation of the motor task alters the significance of any biomechanism or eliminates the possibility of its use at all, that allows a deeper study of the patterns generated by other biomechanisms and methods for their realization. In addition, a methodological procedure in some cases makes it possible to indirectly evaluate the quantitative contribution of a biomechanism to complete the action.

The method of biomechanical substantiation of the structure of motor actions allows penetrating deeper into the essence of the organization

of the set of joint movements during the integral motor acts. However, using only this method to study the techniques of sports exercise and assess the level of technical skill of athletes can not completely solve the problem. So, it is necessary to use an integrative approach, that could combine the advantages of these methods of research and to establish the sequence of their application.

Integrative approach to study and assessment of athletes' technical mastery.

The main idea of the integrative approach is to combine the positive features of the method of biomechanical substantiation of the structure of motor actions, the logical-statistical method for assessing the realization effectiveness of athletes' motor potential and the method of mechanical and mathematical modeling to improve the study of technical preparedness of athletes. Let's consider the application of an integrative approach on a simple concrete example while study and evaluate a jump up from stand position. This exercise is used in training process, testing athletes' motor skills preparedness and most often is considered a subject of research in sports biomechanics.

The main purpose of a jump is to achieve maximum lift height of body's center of mass (COM) when it loses contact with the ground. The upward force exerted by the ground on the athlete changes the vertical velocity of the COM from a value zero to a large upward vertical velocity. The vertical velocity of the athlete at the end of the takeoff phase determines how high the COM will go after the athlete leaves the ground, and is therefore of great importance for the result in the jump. To maximize the vertical velocity of the takeoff phase, the product of the vertical force exerted by the athlete on the ground and the time during which this force is exerted should be as large as possible. This can be achieved by making a large vertical force while the COM travels through a long vertical range of motion during takeoff phase. Thus, the impulse of a body created by the time of the takeoff is determined by the impulse of the vertical component of the force of ground reaction, created by the athlete. This is the essence of the physical mechanism of the body of athlete.

The impulse of the vertical component of the force of ground reaction and the nature of its change depend on the speed and power capabilities of the athlete and the nature of the interaction of a body parts during a jump. Using the method of biomechanical substantiation of the structure of motor actions to study technique of jump showed that they are based on three main biomechanisms: biomechanism of leg extension, trunk extension biomechanism (torso and head) and biomechanism of the arms upward swing. The main regularities of the implementation of these biomechanisms have been identified the experimental study of

biomechanisms revealed common patterns of their implementation, regardless of athlete's preparedness.

The implementation of biomechanisms of leg and trunk extension leads to the following basic facts:

1) legs extends sequentially, first hip joint, then knee and ankle joints at the end; The factor of subsequence is due to differences in muscle force capabilities, servicing these joints, ie from strong to weak.

2) during their extension in the adjacent leg joints (hip and knee, knee and ankle) there is a multidirectional movement. During transition from flexion to extension there takes place multidirectional changes in the angles of hip and knee joints. During active extension of the hip joint in the knee joint there takes place a flexion. Such a movement allows a possibility for two-joint muscles for a long time contract in excentric and isometric mode, and thus creates a greater force to the bone. In addition, the two-joint thigh muscles transfer part of power from the extensor muscles of the hip joints in the knee joints (Shalmanov, Shalmanov, 1990; Zatsiorsky, Aruin & Seluyanov, 1981; Zatsiorsky, 2002). Similar laws apply to motion in the knee and ankle joints.

3) While squatting an optimal flexion of a leg at the knee joints makes about 85°. Reducing or increasing the depth of squatting reduces the height of the jump.

4) Because the torso and head have a large mass (about 50% of body weight), the active extension during the take-off from the ground gives rise to a large inertial forces that increase pressure on the ground and creating significant resistance to the muscles extending legs (Lanka, Konrad & Shalmanov, 2005; Lanka, Konrad & Shalmanov, 2006).

The effectiveness of the realization of the leg and trunk extension biomechanisms is enhanced by the implementation of prior squatting. The contra movement allows storing energy of elastic deformation in the muscles of the lower limbs, the use of which increases the impulse of the vertical component of the force of ground reaction.

The implementation of biomechanism of upward swing by the arms is as follows:

1. An accelerated upward arms swing leads to inertia forces in the centers of mass of segments that increase or decrease pressure on the ground. In addition, these forces create additional resistance to the extensor muscles of the lower limbs at the end of amortization phase and at the beginning of the takeoff that allows us to develop a large force of muscle pull.

2. Velocity of the jumpers COM at the time of separation from the ground depends on the position and acceleration of the arms, so active and

timely properly execution of arms swing increases the height of the jump.

Logical manifestation of the considered biomechanisms was identified in the study of jumping exercises, when the criterion of the effectiveness of their performance was the height of the jump (Shalmanov, Shalmanov, 1990). However, as noted above, the result is not a sufficiently reliable criterion for the characterization of the technique of performing the exercise. So, before you learn biomechanism you need some way to assess the level of technical skill of athletes. For example, how an athlete is using the swing actions with body parts to increase the height of the jump. Such an assessment can be made using the method of regression remnants, comparing the results of the jumps with and without upward swing.

The subjects performed standing vertical jumps without and with an arms swing movements on a force platform (AMTI). According to the vertical component of force of support reaction there was calculated the height of jump, and other kinematic and dynamic indicators. In the experiment, there participated 68 subjects, specializing in different sports. The average age was $23,3 \pm 4,6$, the mean body weight $68,9 \pm 12,6$ kg, average body length $1,70 \pm 0,06$ m. The average result in a jump without arms swing was $0,28 \pm 0,058$ m, and in a jump with swing $0,33 \pm 0,077$ m ($p < 0,001$). Thus, the use of arms swing in an average increases jump height by 0.05 m. Figure 1 shows the correlation and regression equation between the results of two kinds of jumps.

The way how effectively the athlete uses the upward swing by the arms in a standing vertical jump, can be determined by the regression equation and the effectiveness of the biomechanism can be evaluated. For example, if the athlete showed in a jump without arms swing the result of 0.3 m, then theoretically (calculated from the regression equation) when jumping with a swing he needs to show the result of 0.35 m. In fact, athletes can show both the same, as well as a higher or lower result. If the result is higher than the calculated one, it can be assumed that the technique of execution swinging movements is above average, and if the result is less than estimated, then the technique is worse average. As can be seen from Figure 1, there are athletes whose hands "interfere" because their jump height with hands swing is lower, than the height of the jump without hands swing.

Thus, a quantitative measure of swinging technique is the difference between the actually reached result in jumping with arms swing and the result calculated by the regression equation. It is important to emphasize that such an assessment can be made throughout the range of demonstrated results.

And the indicator is not the result in a jump with arms swing, but the extent of the use of this biomechanism.

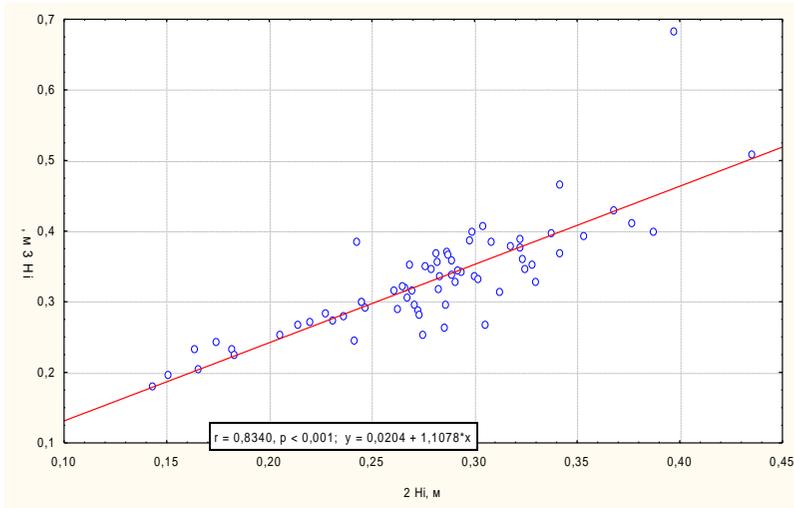


Figure 1. The correlation between the results in standing vertical jump without and with upward arms swing

Based on the regression equation there can be constructed a table on which it is easy to estimate the implementation efficiency of the swinging body parts in the jump (Table 1).

Table 1

The rating scale of the efficiency of the arms swing movement technique in a standing vertical jump

X	«VERY BAD»	«BAD»	«AVERAGE»	«GOOD»	«EXCELLENT»
0,20	<0,13	0,13-0,20	0,20-0,28	0,28-0,36	>0,36
0,22	<0,15	0,15-0,23	0,23-0,30	0,30-0,38	>0,38
0,24	<0,17	0,17-0,25	0,25-0,32	0,32-0,40	>0,40
0,26	<0,19	0,19-0,27	0,27-0,35	0,35-0,42	>0,42
0,28	<0,22	0,22-0,29	0,29-0,37	0,37-0,45	>0,45
0,30	<0,24	0,24-0,31	0,31-0,39	0,39-0,47	>0,47
0,32	<0,26	0,26-0,34	0,34-0,41	0,41-0,49	>0,49
0,34	<0,28	0,28-0,36	0,36-0,44	0,44-0,51	>0,51
0,36	<0,30	0,30-0,38	0,38-0,46	0,46-0,53	>0,53
0,38	<0,33	0,33-0,40	0,40-0,48	0,48-0,56	>0,56
0,40	<0,35	0,35-0,43	0,43-0,50	0,50-0,58	>0,58
0,42	<0,37	0,37-0,45	0,45-0,52	0,52-0,60	>0,60
0,44	<0,39	0,39-0,47	0,47-0,55	0,55-0,62	>0,62

In this table, each result in a jump without arms swing (X) correspond to the five intervals results in a jump with swing, that are characterized by qualitative assessment of the appropriate technique, "Very bad", "Bad", "Average", "Good" and "Excellent". The width of the intervals are calculated on the basis of the average standard deviation of the results of jumps with arms swing referring to the regression line, and the number of intervals is chosen by the researcher.

The table can be used as follows. If the athlete performed a jump without a hands swing at 0.4 m (X), and jump with hands swing at 0.56 m, his technique can be considered as "Good."

As noted above, these methods can only state the fact that the technique of the athlete is better or worse than average. Hence, to answer the question of why this is happening there are applied mechanical-mathematical methods of research.

The analysis of upward swing by the arms technique in the jump from a stand was carried out by using force plate AMTI and opto-electronic systems «Qualify» with software «QTM» and «Visual 3D» (C-Motion). To register the movements of man's body parts, passive markers are attached to those body parts that are of interest for analysis. In this study, there were marked anatomical references recommended by the manufacturer (C-Motion). Thus, 38 reflective markers were sealed on the man's body (Fig. 2).



Figure 2. The subject with the fixed passive markers

In the program «Visual 3D» (C-Motion) it is possible to construct a skeletal model of the man making use by means of the «QTM» of the coordinates of the passive markers, (Fig. 3). To do this, the program uses built-in regression equations.

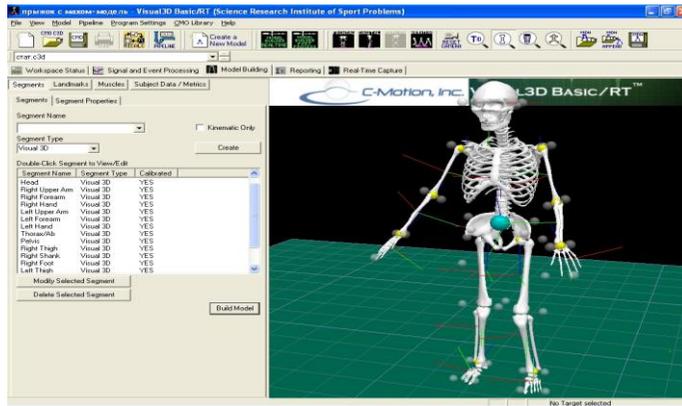


Figure 3. The program interface «Visual 3D» (C-Motion), part of building a model of skeleton

The data on the kinematics and dynamics of parts of a body in the performance of motor tasks are obtained in the result of integration of the static file into the Visual 3D, with the help of which there has been constructed skeletal model of the test, and the dynamic data file on the same subject performing motor tasks. In the result, the program carries out visualization of the performance of motor tasks of the skeletal model, as well as a graphical representation of changes in characteristics as trajectory of body's COM, trajectories, velocities and accelerations of body segments centers of mass, as well as the dynamogram of ground reaction force (excluding the weight of the body). The example of analysis of motor tasks using Visual 3D is shown in Figure 4.

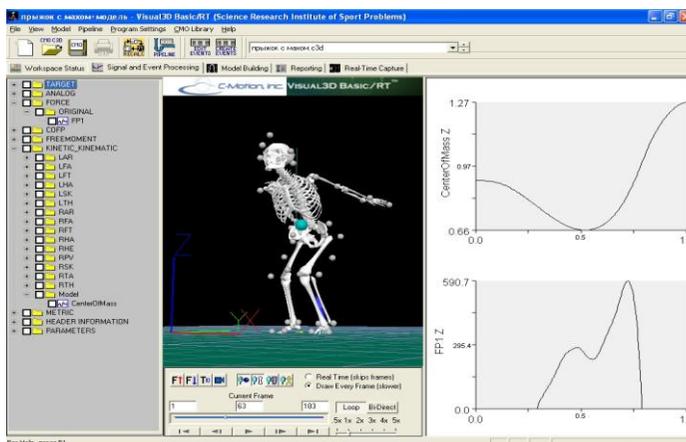


Figure 4. The program interface «Visual 3D» (C-Motion), the part of analysis of motor task

To study the differences in the technique of execution of arms swing there were selected four athletes with different levels of technical skill. The level of technical skill was determined by the data in Table 1. Information on the subjects is presented in Table 2.

Table 2

Characteristics of subjects with different levels of arms swing technique efficiency in a standing vertical jump

№	Subject	Weight (kg)	Height (m)	Age (years)	Rating of technique
1	P. V.	63,7	1,77	22	Bad
2	A.A.	45,2	1,63	18	Bad
3	I. D.	75,7	1,78	24	Good
4	T. M.	56,0	1,70	19	Good

A comparative analysis showed that the total impuls of inertia force in the centers of mass of arms parts in athletes with a good technique creates a greater contribution to the impulse of a takeoff force than in athletes with a poor technique (Fig. 5).

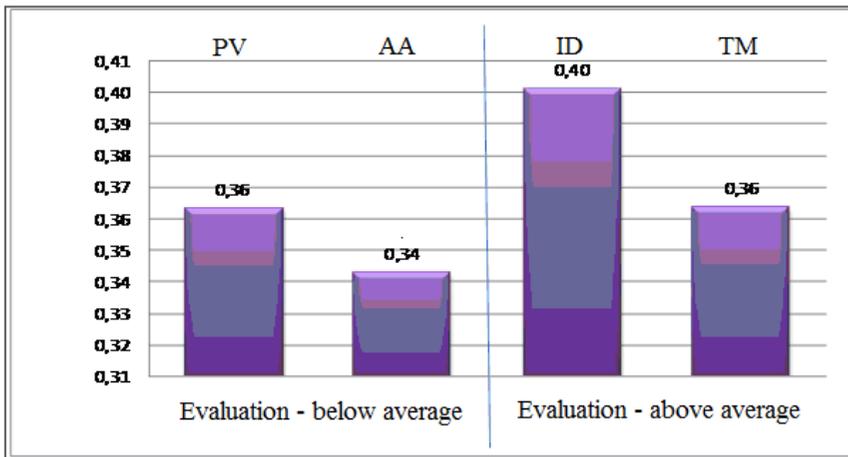


Figure 5. The contribution of arms swing in subjects with various efficiency of technique

In addition, the use of arms swing for athletes with a high estimate of realization effectiveness leads to a significant increase in the contribution of the impulse of the inertial force arising at the center gravity of the trunk.

The torso and head has a large mass, so at an accelerated movement, it improves the result of jump. (Fig. 5) And in spite how strange it is, but effectively performed arms swing promote a more efficient movement of the upper body and the realization of biomechanisms of legs and trunk extension.

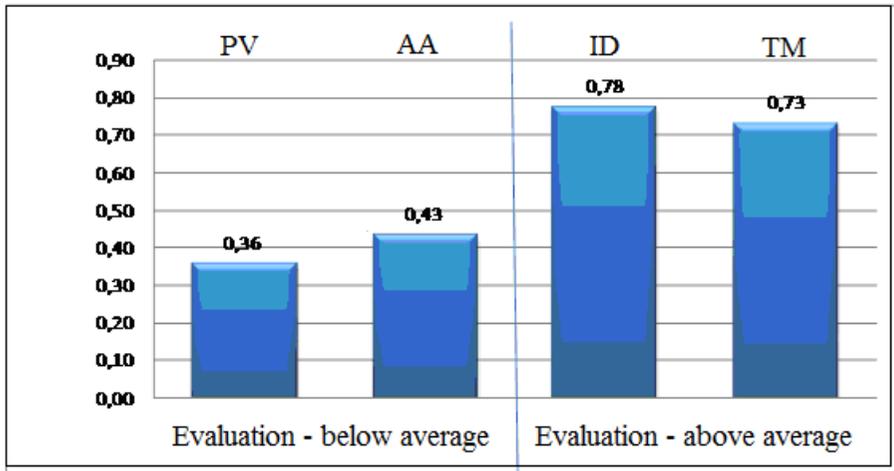


Figure 5. The contribution of trunk swing in subjects with different technique effectiveness

Conclusion

As the main purpose of this article was to outline the logic of the integrative approach to the analysis and assessment of technical skills of athletes, we will not discuss in detail the results obtained using the mechanical-mathematical methods. It was important to show the possibility of a consistent application of existing methods of investigation, to discover their strengths and weaknesses.

Thus, on an example of learning and assessment of techniques of performance of a jump up from a stand shows the need for an integrative approach. The main essence of this approach is to successively apply the method of biomechanical substantiation of the structure of motor actions, logical-statistical method of regression remnants and mechanical and mathematical modeling to improve learning and assessment of technical skill of athletes.

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Submitted: May 5, 2012

Accepted: June 14, 2012

The pioneer studies on the biomechanics of martial arts were published in the nineteen sixties and seventies. After these articles were published, several other biomechanical studies have been conducted about martial arts and other related punching sports using a variety of different measures and methods, especially in the last decade. In general, these studies were concerned with the enhancement [Show full abstract] of performance and extending the understanding of injury risk. This paper presents a comprehensive review on this subject. It is divided in two major topics: the first topic..