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Original Article

Practical use of biomechanical principles of movement organization in the analysis of human motor action

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Abstract:
The aim of work is generalization of theoretical data on the biomechanical principles of the organization of movements in sports and their practical use in conducting qualitative biomechanical analysis. The material and methods are theoretical analysis and generalization of data from special scientific and methodological literature and information from the Internet, optic-electronic system of registration and analysis of movements "Qualisys", pedagogical experiment, quantitative and qualitative biomechanical analysis, methods of mathematical statistics. The study involved 6 persons aged from 15 to 17, who are qualified athletes, having degree of Candidate in Masters of Sports of Ukraine and I degree according to the Unified sport qualification of Ukraine.
In result of the study characteristic of biomechanical principles of the organization of movements are carried out and their importance is shown in practical experiment at the analysis of technique of a jump upwards on the spot. In conclusion, information obtained from the analysis of exercise techniques using biomechanical principles can give key ideas for solving specific problems arising in the process of technical improvement.
Key words: movement, biomechanical principles, analysis, sports technique

Introduction

The modern concept of the study of human movements during physical training and sports is based primarily on such methodical techniques as system biomechanical analysis and system synthesis of actions using quantitative characteristics, in particular modeling (Gamaliy, 2006; Gamaliy, 2013; Donskoy, 1968), including the concepts of "kinematic mechanism", "Bio-mechanism" (Seluyanov, 1996; Shalmanov, 2004; Lanka, 2010), which, in our opinion, can be supplemented methodologically by using biomechanical principles of the organization of movements. The aim of given research is to Generalize the theoretical data on the biomechanical principles of the organization of movements in sports and use them practically during conducting of qualitative biomechanical analysis.

Material and methods

During the research were used: theoretical analysis and generalization of data from special scientific and methodological literature and information from the Internet, optic-electronic system of registration and analysis of movements "Qualisys", pedagogical experiment, quantitative and qualitative biomechanical analysis, methods of mathematical statistics. The research was carried out at the Department of Biomechanics and Sports Metrology of National University of Physical Education and Sports of Ukraine, the Laboratory of Biomechanical Technologies in Physical Education and Olympic Sports of the National University of Physical Education and Sports of Ukraine The study involved 6 persons aged from 15 to 17, who are qualified athletes, having degree of Candidate in Masters of Sports of Ukraine and I degree according to the Unified sport qualification of Ukraine.

Results

The conception of "biomechanical principles" was introduced into the scientific glossary by the German biomechanics expert G. Hochmuth in the 60s of the last century (Hortmund, 1968). The principles he developed were based on the theoretical and mechanical foundations of movement and focused on the rational organization of forces in the performance of physical exercises, as a fundamental component of the production of motion, without taking into account the biomechanical particularity of implementing multi-purpose movements in sports. These principles included: the principle of the initial force (impulse generation), the principle of the temporal coordination of individual impulses, the principle of the optimal acceleration path, the principle of the optimal trend in the acceleration curve, the counteraction principle, the principle of impulse retention. Later, in his works (Hortmund, 1968; Hortmund, 1981; Hortmund, 1984) and the works of other scientists (Bahamonde R. and Knudson D., 2000; Bober T., Morecky A., Fidelus K. and Witt A., 1980; Harnes E., 1974), the doctrine of biomechanical principles was extended and adapted practically to the whole spectrum of physical and physiological components associated with the development and improvement of sports movements.

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According to R. Bartlett, 1997, the development and implementation of various movements in sports should be based on the biomechanical principles of the organization of movements that represent "general conditions for organizing the coordination structure of movements whych are based on the laws of physics and biology and determine their effectiveness". More simply, biomechanical principles are any scientifically grounded generalized position relating to the organization of movements, which in the learning process can not be ignored without possibl damage of its result.

They can be divied on:

- general, implementation of which is important for a certain group of movements;
- private, which are important in the performance of a certain motor task.

General and private biomechanical principles are associated with the coordination particularities of the interrelation of the body parts, joints and muscle groups in the implementation of the motor task, which ensures its effective implementation. As noted (Bartlett R., 1999), the model of any movement that is proposed for studying by the student can be considered correct only if it is performed according to the biomechanical principles of organizing the coordination structure of movements.

Basically, in the each biomechanical principle lies the certain fundamental scientifically substantiated knowledge from the field of the relevant sciences on which the principle and the mechanisms for its implementation themselves are based. In the absence of the above principles and mechanics, a sports exercise and the associated motor task are in principle unenforceable.

As Yurii Gaverdovskii notes, it is, first of all, physical mechanisms that have to work under certain conditions, giving a specific mechanical effect in the form of spatial motion, force interaction, stabilization of position, etc. Each of such physical mechanisms can be realized only in the presence of the sum of certain factors, the main of whom are the active actions carried out by the athlete himself. These actions, ultimately, are brought to the mechanical effects of muscle traction and represent the physiological mechanism of this motor action.

Both of these mechanisms (or a group of private mechanisms) operate in indissoluble connection with each other and stipulate the principle possibility and technique of performing of this exercise, which, in point of fact, is the main subject of work in teaching the exercise and improving it. The implementation of a holistic exercise is principally possible only when and if this aggregate biomechanical mechanism of the exercise works correctly.

During constructing motions with preassigned characteristics and determined conditions for their implementation, more rational can be the approach based on the theoretical basis of biomechanical principles. Each of them, defining the general scientific concept of the production and organization of human movements with the desired motor effect, can be realized by using several different bio-mechanisms. This greatly expands the theoretical and practical views on the variability of the solution of identical motor tasks in different groups of movements, taking into account the individual motor capabilities of the athlete and the conditions of the competition. There are the main purposes, for the achievement of which the biomechanical principles can be used (Hochmuth G., 1984):

• maximization of the final speed (support interactions, repulsion from the rigid and resilient support, throwing);

• providing of maximum power (maximum effort at the beginning of the movement for overcoming inertia and gravity forces (weightlifting, freestyle wrestling, judo);

• maximization of force (achievement of maximum force at the beginning of the movement to overcome inertia and gravity – weightlifting, wrestling, judo);

• minimizing of time (overcoming a short distance, suddenly for a rival – boxing, fencing);

• optimization of time variations of moments of inertia (free-flight rotation);

• optimization of the posture during or at the end of the phase of flight (the phase of flight and landing during jumping – gymnastics, jumping from a springboard);

• optimal supply of energy and its transformation (rotations around fixed and free axes);

• maximum efficiency of propulsive power in fast-flow interactions (time of repulsion from water during cyclic movements, front and rear support with a subsequent phase of flight or sliding in cyclic movements, pedaling on a bicycle).

As an example of the practical significance of the biomechanical principles of the organization of movements in the analysis of human motor activities, we have conducted an experiment which included a jump upwards from the spot with various methods of it performance: a normal jump with individual preparatory actions and a swing of arms, a jump similar to normal jump, but with a 1, 5 – 2 second pause after squat, jump without arm swing, jump with a slow squat, jump with the maximum deep squat.

This variation in the performance of the jump made it possible to change the way for accelerating the center of mass of the athlete's body and determine its influence on the height of the jump. The results of the experiment are shown in Fig. 1.

Using the data obtained in a result of the experiment, within the framework of the traditional biomechanical analysis, the following conclusions can be made:

• the highest jump height is achieved during the normal version of the jump;

• the absence of preparatory actions and arm swings reduces the height of the jump;

• despite the elongation of the acceleration path for the body's centre of mass from the second to the fifth variant, the jump result have not increased.

And as a general conclusion: the maximum acceleration path does not guarantee the maximum jump height!

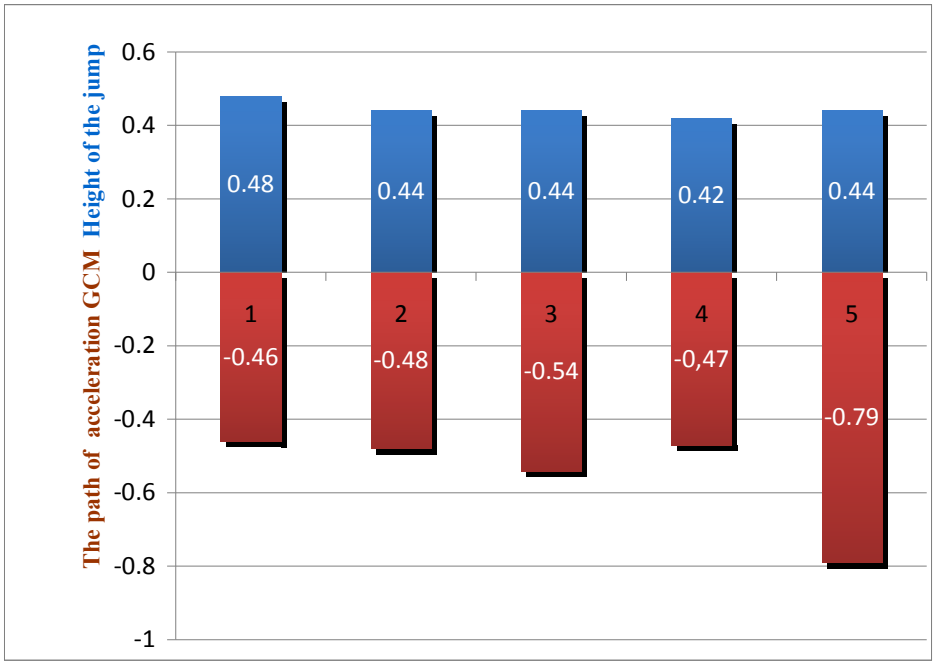

Fig. 1. The height of the jump and the way of acceleration of the center of the mass of the athlete's body at various method of performing a jump upwards on the spot:

1 – normal jump with individual preparatory actions and a swing of arms; 2 – the jump similar to the normal jump, but with a 1, 5-2 second pause after squat; 3 – jump without arm swing; 4 – jump with a slow squat; 5 – jump with the maximum deep squat.

Discussion

Not only the final result of the performed physical exercise, which is expressed by certain mechanical characteristics (jump height, repulsive force, speed, etc.) is important for coach, but also the factors making it possible to achieve these characteristics. These factors include both mechanical (providing the structural unity of individual movements and, first of all, coordinating them in time), and physiological (allowing to optimize the participation of the musculoskeletal system, as the main component of the movement, in solving the motor problem) mechanisms for organizing movements.

Conclusions based on biomechanical principles of the organization of movements. In the second variant of the jump (with a pause), offence of two principles are noted: the optimal acceleration path is exceeded and, secondly, the pulse generation (initial force) is not effective, since there is no effect of recurrent movement, based on the mechanism of using the resilient strain energy of the muscle-tendon structures.

The principle of the optimal path of acceleration. The optimal length of the acceleration path is determined by the moment of realization of the maximum acceleration, which depends on the speed and strength capabilities of the athlete, the angular positions of body parts and the time conditions of a particular sport motions. Principle of initial strength. In reversible movements with an instantaneous change in the direction of motion, by deceleration the movement of the body toward the support and at the beginning of the movement of the body from the support, with a 1,5-2,0 second pause, the additional positive start of the force for acceleration is significantly reduced. This decrease is due to the inefficient use of resilient deformation forces of the muscular-tendon structures, which adversely affects the rapidity of the rising of force, and consequently its power, which under favorable conditions can be much higher. In the third variant of the jump (without a hand swing) two principles are not followed: the optimal acceleration path has been exceeded, the temporal coordination of individual pulses is violated. The impulse of movement of hands is blocked. The jump is realized exclusively due to the work of the extensor muscles of the legs and trunk. A jump of this kind eloquently testifies to the role of swinging movements in the organization of inertial forces and their contribution to the overall result of the action.

In the fourth variant of the jump (slow squat), the optimal acceleration path is exceeded, pulse generation is not performed effectively, the principle of temporal matching of impulses is violated.

The principle of time matching of partial impulses is in the connection of two or more force actions, for example, extension in the joints of the low limbs against gravity and inertia of the swinging links, due to which the acceleration of the center of gravity of the body increases, thereby increasing the kinetic energy of the entire

movement. With the optimal alignment of individual impulses involved in the implementation of motor action, the athlete usually has a feeling of ease of its execution, and this despite the fact that the result of the action can even be personal best for this athlete. In the fifth variant of the jump (deep squat), the optimal acceleration path was exceeded, pulse generation was not performed efficiently, spatial coordination of individual pulses was violated. The principle of spatial coordination of individual impulses. Due to the excessively sharp angle in the ankle, knee and hip joints, the load of the moments of gravity is so high that they connect accordingly the moments of muscle strength which can not be used for effective acceleration. This principle forms the basis of the biomechanical justification of the optimality of the poses executed by the athlete in performing of physical exercises. Its value is particularly important in modeling of various starting positions, from which the athlete must extract the maximum strength or speed.

Conclusions

Analysis of movements using biomechanical principles of their construction provides, first of all, an understanding that the final result of the action is determined by the systemic unity of the goals achieved at each stage of the motor act. It is important for coach to teach the ability of a holistic perception of the action from the position of cause-effect relations between the particular phases of the motor action.

In each phase of the physical exercise, there are key components of the movement, the realization of which is theoretically explained from the standpoint of specific biomechanical principles of motion construction, with the help of which the coach has the ability to analyze the movement.

Particular importance in the process of technical improvement acquires that, what the coach decides to do with the knowledge gained from such analysis. The modern coaching approach to the formation and improvement of the motor skill is entirely based on the individual motor priorities of the athletes. The coach should encourage the aspirations of his student to make his own decision in the organization of movements as far as possible in case it does not contradict the common sense of implementation of biomechanical principles and does not threaten his safety at any stage of training. The coach should not overload the athlete with excessive technical information, but give him the opportunity to form a movement by himself within the limits of the requirements. Information derived from the analysis of the movement can provide key ideas for solving specific problems that arise in the process of technical improvement, and it is important to help the athlete on the way to achieving the highest level of sports and technical skills. A significant contribution from the coach in achieving this goal can be specific knowledge and understanding of the specific application of biomechanical principles of the organization of movements in sports activities.

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