Biomechanics of sports and technical skill, taking into account causal relationships and the effectiveness of technical actions

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Abstract. The article deals with the formation of technical skill with a close relationship of all aspects of an athlete's training, which is a complex dynamic system of conjugated interaction of structures and functions, due to the specifics of the high jump. The main objective of the study was to determine the true cause of the shortcomings in the athlete's movement technique, taking into account the complex causal relationships of factors that determine the high efficiency and stability of technical actions. The study revealed a system of relationships between these factors in high jumps; which is of fundamental importance for building and improving technical skills.

1 Introduction

Among the factors that determine the growth of sports results in high jumps, the most important factor is, along with physical training, technical skills. Only with the help of a high level of technical skill does an athlete get the opportunity to fully "open up" and use their functional capabilities (motor potential). At the same time, the leading role of technology itself is increasing due to the specialization of physical training. Technique serves as a structural-dynamic basis in the selection of means and modes of application of special exercises; only in this case it is possible to properly organize and apply the conjugate improvement of the technical and physical training of athletes of the highest qualifications, and even more so, the development and use of training devices for this.

However, despite the great importance that the formation of technical skills has for achieving high sports results, there are major shortcomings in the practice of training athletes in this regard.

This is explained by the fact that the greatest difficulties for athletes and sports teachers preparing the reserves of big sport arise precisely in matters of technical training. This is due to many reasons, which ultimately come down to the lack of awareness of many coaches in the field of rational technique and technical skill in the high jump, the most effective methods of teaching and improving technical skill. This is further complicated by the fact that the coach does not have objective information about the athlete's motor characteristics for effective control and correction. As a rule, the coach's instructions do not

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contain exact data that speaks about the level of the athlete's preparedness, the method of monitoring changes in the characteristics of various aspects of preparedness is not sufficiently objective. Therefore, already in the youth teams there are athletes who have achieved fairly high results thanks to their talent, but at the same time have serious shortcomings in the technique of movements. Further progress of such athletes is unthinkable without serious retraining. This process is very painful for the teacher and especially for the athlete.

In order to increase the efficiency of the process of forming technical mastery without radical retraining, it is necessary that the teacher knows well the patterns of constructing a rational jump technique and uses them creatively in the process of improving each athlete individually.

There are many examples among top coaches showing how this creative approach to training leads to new qualitative leaps in the preparation of highly qualified athletes. These are new technical options, new techniques, new approaches to the formation of motor qualities and, in general, the personality of an athlete.

This article discusses the techniques in the technical training of highly qualified athletes. Improvement in technical skill is essentially almost limitless. In this regard, it is necessary to consider not only the concept of sports equipment, but, most importantly, technical skill. The concept of technical excellence reflects all the factors that meet the requirements of reliability and, in essence, it contains programmatic requirements for the organization of the process of improvement itself.

2 Materials and methods

The study was conducted on the basis of the track and field arena of the Don State Technical University (Rostov-on-Don) in the period 2019-2020. In total, 15 people took part in the study, members of the national high jump team of the Rostov region, of which the bulk (10 people) with the first sports category, three candidates for the master of sports of Russia (CMS) and one master of sports (MS).

Concerning the practical issues of technical mastery, it should be emphasized that technical mastery, no matter how high a level would be achieved, should not be considered as a kind of "ceiling". In practice, technical skill should be steadily improved, and in accordance with the pace of development of world sports, the individual capabilities of a particular athlete and the requirements of predictive models of the jumper of the future. The latter is set as the goal of sports improvement, calculated on the planned terms of training.

Here again there are colossal difficulties in the pedagogical activity of the trainer. It turns out that it is possible to give the technique of movements in a particular sport, to be able to teach the technique, but not to have the skill to sharply see and recognize mistakes. Naturally, this does not concern those errors that lie on the surface of movements (even an inexperienced viewer can notice them), but deep-seated errors-causes hidden from the eyes of the observer, without the elimination of which the path to perfection will be closed.

The fact is that in complex sports exercises, including high jumps, there are chains of causal relationships between the elements of movements. Through these connections, movement control is carried out (they must be improved first of all). As a rule, these communication elements are located in the initial phases of the movement link (leading elements of coordination), at the junctions between different structural elements of an integral motor act. In jumps, for example, between a run-up and a push.

To understand the patterns of technical mastery improvement and the formation of the ability to control one’s movements, it is important to see significant differences between movements and motor actions, to understand well that the technique of movements itself is

not an end in itself in training, but only an effective means by which a motor task is solved and are most fully used. athlete's motor skills.

The point is; that movements and motor actions belong to different categories: the first - movement, belongs to the biomechanical category, the second - the action to the psychological and carries a semantic content; causing a purposeful manifestation of the athlete's activity.

An example is simply raising your hands up. In the first case, it is a simple mechanical upward movement (with different speeds, accelerations, etc.), in the second case, this movement of the hand serves as a means to solve a specific problem - for example, to get the desired, high-placed object. In this case, the movement of the hand, direction, trajectory, speed, etc. will be consistent with the meaning of the task and the external conditions in which it is performed. Naturally, the upward movement of the hand in the second case can be significantly changed.

A similar thing happens in sports exercises, although both the technique of movements and the tasks of action are determined in advance.

Therefore, for the desired organization and construction of the most rational movements, it is not indifferent what the athlete's attention will be drawn to: the meaning of the action - the final result, or the technique of the movement itself, and how interaction between them will be established at various stages of improving technical skills.

In a complex sports motor act, each phase has its own semantic tasks, which, being in subordinate relationships, constitute its semantic structure, determined by the purpose of the exercise.

In accordance with the semantic structure of the motor action in each specific form and the external conditions in which the motor act is performed, the improvement of the technique of movements should take place. At the same time, the perfection of the technique itself should be assessed by how effectively motor tasks are solved, both in phases and in the entire system of movements in the case.

The main thing depends on how the structure of the movement, the speed of their implementation and the rhythm correspond to the semantic structure of the action, external conditions and biomechanical expediency - the degree of realization of the athlete's motor capabilities.

In this article, we do not accidentally draw the attention of specialists to these issues. The fact is that the most common mistake made by sports teachers when teaching and improving technique is “replacing an action with movement” into an unjustified one; excessive switching of the athlete's attention from the result of the action (from the task) to self-movement. This happens when the semantic content of the studied technical element is overlooked in the educational task of improving the technique of movements. This is especially true for teachers when using simulation exercises.

However, to determine the true cause of the shortcomings in the technique of movements of a particular athlete, it is necessary to take into account much more complex causal relationships of factors that determine the high efficiency and stability of technical actions.

3 Results

One of the objectives of the study was to determine the true cause of the shortcomings in the technique of movements of a particular athlete, taking into account the complex causal relationships of factors that determine the high efficiency and stability of technical actions.

The study revealed a system of relationships between these factors in high jumps; which is of fundamental importance for building and improving technical skills, the data are presented in Table 1.

From the above table it can be seen that the reserves for improving technical skills can be found in each of the six components indicated, as well as in a combination of vertically constituent factors, and horizontally.

Table 1. The system of links between factors that determine the effectiveness of improving technical skills in high jumps.

Semantic structure (semantic tasks)	**Technical tasks of building movements**	**Technical solutions for building movements**
Preparing to perform an action (jump)	Setting the psyche for the upcoming action Setting the sports-motor apparatus for action	Psychological mechanisms of movement control. Running up to the starting mark is elastic on the forefoot
Overclocking	Entering the run-up Gain optimal speed Give the body an optimal working posture in the run-up Enter the run with "active coasting"	Slight inclination of the shoulders forward. Legs forward from the hip, the pelvis is tucked under itself, a calm start with a gradual increase in the pace and length of the run-up steps.
Preparing for a toss	Preliminary preparation Entering the take-off preparation phase Finishing the preparation	Lowering on the push leg at the transition to the penultimate step Extending the fly leg forward Rolling onto the fly leg "keep the shoulders, move the pelvis" Descend from the fly leg in a position of readiness for repulsion
Body toss up	Transition to take-off Entering take-off Finishing take-off with a vertical toss	Taking out the push leg with a running step to the place of repulsion with a circular abduction of the arms Together with the setting of the push leg, sending the pelvis with the fly leg and at the same time the arms Pushing out, toss the arms-shoulders and the fly leg up
Moving the body over the bar	Entering the bar Transitioning through the bar Leaving the bar	Slight abduction of the near shoulder with the sending of the far arm and shoulder through the bar while raising the free leg under the bar; transition with a dive and pulling up the push leg with the knee up and down; completion of the dive with pelvic lift
	Motion control system	
Structural-phase mechanisms of motion control	Psychological mechanisms of movement control	Perception, self-control and self-assessment of movement
Leading element of functional leg training Wide extension of the free leg from the hip (bent at the knee) with subsequent capture of the ground when placing	Automated control mechanisms fixed in rhythm (rhythm has accentuated leading structural elements that ensure the efficiency of performing the main dynamic part of the jump-toss) and reflected in the sensual image of a holistic motor act	They are determined by the content of the installation and are based on: 1. On sensory control 2. On logical control, which is based on cause-and-effect relationships in the system of a holistic motor act. The first one provides automated regulation of movements in the process of performing a motor act.

it on a support		
Active pulling of the pelvis with simultaneous extension of the push leg bent at the knee from the hip	Working propulsion system, an intelligent component that programs the execution of the upcoming action	The second, in combination with sensory control, provides correction in subsequent attempts (in competition and in the process of improvement).
Quick send of the pelvis to the foot of the push leg Send of the far arm and shoulder through the bar down and to the fly leg	The content of the installation reflects the semantic structure of the problem being solved with an emphasis on the final target action (toss)	

One of the most important indicators of the exercise is the presence of leading, control elements in connection with switching coordination in the chain of movements.

When considering the leading elements of coordination in an integral system of movements, not only their optimal subordination to each other according to the semantic structure of the action and its ultimate goal was taken into account, but also the relationship with accompanying elements, such as the work of the hands, which have an important connecting role between parts and phases of movements. This work of the hands provides a greater unity and strength of the transition of their phases, and to a greater extent, contributes to the development of the optimal rhythm-tempo structure of a holistic motor action and the efficiency of the push and bar transition.

All this determines the structural-motor basis for the formation of sports activities management skills and, in general, the process of technical mastery formation.

When an athlete focuses his attention on the movement itself, and even more so on some part of it, deautomatization immediately occurs, the integrity of the movements is destroyed and the results are reduced. In the practical activity of even qualified athletes, such facts of changing the set, switching the level of movement control during the competition are not rare. At this time, there is a technical breakthrough, incomprehensible to the observer from the outside, a sharp deterioration in the technique of movements. Violation of the stable hierarchy of the level structure of motion control is a fundamental mistake of the central control.

That is why it is also important to form the athlete's stable central control skills (ideomotor movement program) in combination with the skills of sensory perception and control of one's own movements.

In this regard, an interesting fact can be cited, when an athlete with high technical skill avoids visual perception of his own movements from film records and film loops. In this fact, we see the athlete's fear of destroying with information about the external characteristics of the movement the sensual image of movements that has developed in him, the system of sensorimotor processes of control and control.

Summing up what has been said, it can be noted that all errors, both fixed in the skill and appearing suddenly, although they differ in the mechanism of occurrence, are the result of errors contained in the central processes and in the structural-phase mechanisms of movement control.

4 Discussions

Based on the system-structural approach to the problem of motion control and specific data obtained in our research, we can consider three categories of errors:

1. Structural construction of movements;
2. Structural-phase control mechanism;

3.Central control mechanisms,

Basically, the most coverage, although without a deep causal analysis, received errors of the first category - structural errors.

The main drawback in the existing developments is the lack of analysis of the connection between technical errors and the semantic structure of an integral motor action. In the systematization proposed below, the errors of the first category have the following form:

- insufficiently complete correspondence of the structure and characteristics of movements to the semantic structure of a holistic motor action, namely: discrepancy between background structures /run-up structure/, preparatory structures /transition to repulsion/ main /repulsion/ and final actions /transition through the bar/;
- construction of movements according to the principle of "brute force" and the corresponding two-step rhythm-tempo structure of the run;
- non-compliance of the variants and characteristics of the technique of movements with the individual characteristics of the athlete;
- inconsistency of the intensity / motor activity / performance of motor actions with the athlete's ability to control movements under these conditions, an excessively high tempo level of the run;
- inefficient working postures and starting positions /especially serious starting position errors in the final effort phase/.

The functional capabilities and physical performance of those involved are much higher in comparison with those who are not involved.

Game forms of physical culture have a great influence on the psycho-emotional state of a person. During the game, there is often a feeling of joy, fun, which are the main motivation for many involved in running. After a workout, as a rule, a good mood, self-confidence, a surge of vigor, and an increase in mental performance appear. This condition is associated with the release of endorphins, which circulate in the blood for about a day.

As a result of the assumption of structural errors, especially the distortion of the characteristics of the relationship between accompanying and leading elements, there are shortcomings in the rhythm-tempo structure. As the experiment proved, this is especially associated with a violation of the structure and time of execution of accompanying elements (arm movements) in connection with the leading elements of coordination of the movement of the pelvis in the phase of preparation for the final effort and for the final effort in repulsion.

Of exceptional importance in the practice of sports is the problem of error recognition. The complexity of this problem is due to many reasons, but first of all, to the fact that errors are never single and, as a rule, there are whole complexes of erroneous movements in causal relationships, which can be very difficult to understand for the "naked eye". The difficulty of recognizing mistakes is aggravated by the fact that the coach does not have enough objective information about the main characteristics of the movement technique. For example, registration of rhythm and tempo characteristics, video recording, etc.

Our studies have shown an extremely complex, intricate causal relationship between a set of errors. All this has: an integral reflection in the rhythm-tempo structure of movements and leads to ineffective options.

As a result of the generalization of our work in the data of experimental studies, errors and their generating conditions can be divided into:

1. Background errors, run-up errors, which are caused by inefficient starting structures and characteristics of the running step;
2. Errors of the determinant, for example, errors in the preparatory phase of the run-up cause shortcomings in the take-off;

3. Derivative/consequence errors: first derivative, second, third, etc. with derivative determinants;
4. Errors / interferences are not determined by themselves, but create conditions that hinder the development of effective technology. In this case, the correction of an error/interference does not entail the direct correction of another one, but the possibility of mastering a more advanced technique is provided;
5. Autonomous errors (not affecting and not dependent) mainly refer to the final phases of movements in the transition through the bar.

An extremely important reason for the possible occurrence of errors and deviations in the technique of movements is the lack of the required level of versatile and especially special development in an athlete, sometimes a lag in the development of separately important muscle groups can lead to imperfection of the motor structure, to the inability to fully use a strong link in the kinematic chain of a holistic motor act . The correction of this particular shortcoming in the athlete's physical preparation opens the way for the elimination of shortcomings in the technique of movements.

5 Conclusions

After analyzing the results of our study, we can conclude that the reserves for improving technical skills should be sought:
1. in the motor structure itself, exercises in order to increase the degree of use of “free forces” (reactive and inertial);
2. in structural-phase mechanisms of motion control; in / in the relationship of motor and semantic structures;
3. in central deprivation management mechanisms;
4. in the formation of skills of self-control and self-regulation of movements;
5. in increasing the level of physical fitness of athletes, in increasing the motor potential of an athlete.

Speaking about the formation of technical mastery, one should emphasize the organic interconnection of all aspects of an athlete's training, which constitutes a complex dynamic system of conjugated interaction of structures and functions, due to the specifics of a high jump. After all, mastery is not limited to automated motor skills, although they play a big role in its development.

The main thing is that in the process of mastery formation, the personality of an athlete changes, the goals of sports improvement, of all sports activities in individual motor actions change. In order to accelerate this process of “maturation” of the athlete's personality, the athlete himself should not remain a blind executor of the programmed training influences; only in creative collaboration with a coach, with an ever-developing ability for active self-improvement and self-management of one's own actions, can optimal ways to achieve high sports results be found.

In this regard, it is necessary to emphasize the importance of the methodological principle put forward by us, which can be briefly formulated as follows: "improving the technique of movements, it is necessary to train not the movements themselves, but the mechanisms of movement control." To do this, it is important to focus the athlete's attention on the key moments of the semantic structure of the action, on the results of the action. The result of an action should be understood not as a sports result itself, but as a result of the procedural solution of motor tasks by phases in the chain of movements, which should lead to the final sports result.

Only on this basis should an athlete form a generalized sensory model/image of a holistic movement and sensory control, in the systems of which there can be only a

minimum number of control points that determine the accuracy of movements and their dynamic affect.

Sensory control as a feedback is of exceptional importance for the regulation of movement control while improving technical skills. No less important for increasing the efficiency of the process of improving skills and stabilizing its characteristics is logical control. The basis of its development is motor thinking, a deep understanding of the mechanisms of interconnection between the elements of the movement system, their cause-and-effect relationship and the organic connection of methods for solving technical problems with the semantic side of the motor action.

However, despite the importance of self-control processes in the athlete's motor activity, they are not given enough attention in the practice of sports training, the regulation of self-control skills in complex motor actions has not yet become a subject of training and occurs more spontaneously, based on the athlete's personal experience.

Here it can be noted that the content of self-control, its semantic side, must be in unity with the semantic side of the athlete's attitude to the upcoming motor action.

It should also be noted the dynamism of the installation itself, the variability of its content as the technical skill increases and the automation of motor actions increases. In accordance with this, the self-control program also changes.

There are quite a few examples in sports showing how, as the athlete's motor thinking developed, the ability to correctly program and control the leading parameters of the motor act, the technique of movements improved and stabilized sharply.

It should be emphasized that, as in physical training, the utmost consistency must be observed in improving technical skills before one can move on to intense high jumps and especially to participation in competitions with increasing responsibility.

Note that the increase in intensity in jumps is not a "frontal" process. In essence, it has two main stages: the first is the improvement of the movement structure and the rhythm-tempo structure, the correction of technique shortcomings and the development of more effective structures and fixing them in a rational movement rhythm. Without this, it is impossible to proceed to the second stage - the development of high speeds. As a rule, this is fraught with overloads of the knee joint and its injuries. Particularly dangerous in this regard is the locking push that is still common among coaches and athletes. An equally gross mistake is the power or it is also called the "press" repulsion. Athletes with a weak foot, as a rule, use a similar repulsion character. In general, even our leading jumpers have an insufficiently high level of technical preparedness. Unfortunately,

As the study showed, in this state of affairs, radical retraining has a greater effect in improving technical skills than correcting individual mistakes.

In addition to the integral readiness/assessment in terms of technical efficiency, the integral technical criterion is the rhythm-tempo structure of the run-up steps. The rational implementation of reactive-fly repulsion with a ricochet effect corresponds to a structure with a three-step acceleration of pre-push steps with a contrasting increasing increase in tempo.

A less rational, power version of the push, in the presence of a power plant, corresponds to a two-step rhythm of accelerating the pace of pre-push steps, which are characterized by the jumper squatting on the fly leg.

Only after mastering the rational technique is it possible to solve the tasks of the second stage of improving technical skills - to increase the intensity of jumping over the bar in the zone of submaximal and maximum heights. At the same time, the higher the qualification of the jumper and the greater his technical skill, the greater the percentage of the total number of jumps performed in these zones.

For the new replenishment of the national team, the team in the first year, the improvement of technical skills should be based on the improvement of the structural side

of the jump in the zones of medium and high intensity. In the next two years, training jumps should be performed already in the zone of submaximal and maximum intensity, which should reach a volume of 25-30% of their total number.

As high technical mastery is mastered, the number of jumps performed in the zone of highest intensity should constantly increase. In the main period of preparation, you can bring these jumps up to 40%.

In this regard, it is very important to increase the intensity of the training load in women. The analysis shows that they do not perform loads with great intensity, especially in plank jumps, preferring to carry out special training with a significantly lower level of physical activity than is necessary for jumping from competitive conditions. This discrepancy, developed by the training stereotype, leads to a slowdown, and sometimes even a regression, in the growth of technical mastery (this applies equally to men).
This means that increasing the intensity in all sections of the training work is the main requirement for solving the set tasks.

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References

1. E. V. Khromin, All-Russian physical education and sport GTO complex: municipal management innovations, Theory and Practice of Physical Culture, **1**, 3-5 (2019)
2. A. V. Voronkov, Academic physical fitness rating by GTO complex tests, Theory and Practice of Physical Culture, **5**, 11 (2019)
3. T. J. Kauh, Building a culture of health through research: The role of the physical activity research center, Preventive Medicine, **130**, 105894 (2020)
4. S. G. Farris, Development and initial validation of the Exercise Sensitivity Questionnaire, Mental Health and Physical Activity, **19**, 100346 (2020)
5. P. S. Tandon, Short term impact of physical activity vs. sedentary behavior on preschoolers' cognitive functions, Mental Health and Physical Activity, **15**, 17-21 (2018)
6. A. Ivanova, Mathematical analysis of individual physical fitness test rates and functionality forecasts, Physical education: education, training, **2(79)**, 53-56 (2019)
7. A. Ivanova, Adaptation and development of the physical culture and sports complex of the GTO in accordance with changes in society, In the collection: Innovative transformations in the field of physical culture, sports and tourism. Collection of materials of the XXI All-Russian scientific and practical conference, 287-292 (2018)
8. P. S. Tandon, Short term impact of physical activity vs. sedentary behavior on preschoolers' cognitive functions, Mental Health and Physical Activity, **15**, 17-21 (2018)
9. S. Rahimi, Long-term exercise from adolescence to adulthood reduces anxiety- and depression-like behaviors following maternal immune activation in offspring Samira Rahimi, Maghsoud Peeri, Mohammad Ali Azarbayjani, Leila Anoosheh, Physiology & Behavior, **226**, 113130 (2020)

10. T. Stepanova, Physical education and sports sector progress in rostov region, Theory and practice of physical culture, **8**, 98-99 (2018)
11. J. E. Simon, Health-related quality of life is decreased in middle-aged adults with chronic ankle instability, Journal of Science and Medicine in Sport, **21(12)**, 1206-1209 (2018)
12. T. Wisbey-Roth, Prescribing exercise like the medicine it is, Journal of Science and Medicine in Sport, **22(1)**, 1 (2019)
13. B. S. Frank, Movement profile influences systemic stress and biomechanical resilience to high training load exposure, Journal of Science and Medicine in Sport, **22(1)**, 29-34 (2019)
14. J. L. Pryor, Intermittent exercise-heat exposures and intense physical activity sustain heat acclimation adaptations, Journal of Science and Medicine in Sport, **22(1)**, 117-122 (2019)
15. M. Shestakov, Content and ways of improving the physical education of students mastering management specialties, Scientific notes of the University, P.F. Lesgaft, **5(147)**, 199-203 (2017)