Biomechanics, physics and energy modelling of motion control

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Abstract. Free throws in basketball were chosen to search for regularities of motion control. Ten female basketball students took part in the experiment, each of whom performed a series of throws up to 10 hits. Using the method of high-speed video shooting and numerical simulation, the analysis of kinematic characteristics of the throws, biomechanics, physics and energy modelling of motion control was performed. As a result of the study the regularity was revealed, consisting in the fact that during repeated throws the motion control is carried out by correcting ballistic parameters from the boundary of the effective hit zone to the central zone of the most reliable hit. Sportswomen with a high degree of accuracy determined the direction of correction, but they could hardly determine the quantitative value of the correction itself. By analyzing the parameters of each individual throw directly, the second general regularity of motion control was found. A throw as a movement regularity is divided into two parts: preparatory – when an athlete from any game situation strives to take a standard (maximally familiar and maximally stereotypical) position with minimal uncertainty; and the main one – when from a standard position, based on motor memory according to the principle of the “reflex ring”, targeted movement correction is carried out. The second part of the movement allows for the possibility of random errors and excessive corrections occurrence.

1. Introduction

Both in everyday life and in sports, stereotypic movements make up the majority of motor activity. The modern science of motion does not give an exact answer to how similar and how different such movements are; of even greater interest is the question of whether these movement inaccuracies are systemic or random in nature as well as how a person controls such movements. The principle formulated by N.A. Bernstein “recurrence without repetition” exactly reflects the nature of the phenomenon of human movements [1]. At the same time, the motion control algorithm remains not quite clear. Analyzing literary sources on the topic under research, we got convinced that in many works devoted to the biomechanics of sports movements, the authors analyze the kinematics or dynamics of a single movement, without trying to explain the control algorithm from a system related viewpoint.

Object of study: kinematic characteristics of free throws in basketball. Subject of research: motion control system while performing free throws in basketball. The aim of our study was to identify regularities of motion control on the example of shooting in basketball. Research objectives: – to study the problem of research on literature data; – to make an experiment; – to form a primary data set of kinematic characteristics; – to analyze data. Hypothesis: starting the study, we assumed that there are regularities of motion control in accurate movements that can be identified from the registration and analysis of the kinematic characteristics of the movement.
In any, even the most familiar movement, some inaccuracy of implementation is inherent. Movement inaccuracy is an integral part of motor activity [2]. The key factor is to understand how big and how significant these inaccuracies are for accomplishment of actions. In order to detect inaccuracies in the movements visually, they must become rather significant in value, at the same time an undesirable deviation of the result from the intended actions must occur [3]. However, if movements with deviations make it possible to solve the motor problem, they should be considered equal effective options for technique. It is possible to fix the smallest details of performing a large number of sequential movements using modern methods of biomechanical control. Movement errors – are such deviations in the parameters of the technique that do not allow solving the movement action. The movement error is relative in meaning: the feature of the technique that for the master of sports is a gross mistake, for a beginner this feature is not considered at all and could not be corrected. This is a certain paradox, having overcome one mistake an athlete with the growth of skills is forced to overcome other new movement errors. With the growth of the athlete’s sportsmanship, requirements for the quality of performance increase, so less significant inaccuracies fall into the category of movement errors [4].

There are several reasons for movement errors: 1) muscle tremors caused by inaccurate intramuscular coordination; 2) the inconstancy of the nervous and muscle systems. Inaccuracy of movements is detected by proprioceptors and corrections are made to movements; 3) kinematic inaccuracies associated with the deviation of kinematic characteristics from the planned program of action; 4) the sensory systems that control movements (reverse afferent activity) are functioning with errors [5]. Elimination of movement errors is one of the most important tasks of sports training [6]. A successful struggle against errors can reduce the likelihood of their occurrence and their average value. Movement errors are complex in nature [7]. So, one mistake can lead to another, creating a chain reaction, which is multi-factorial and complex. There are various classifications of movement errors depending on the causes of their occurrence [8].

N.A. Bernstein found out that when repeating a movement, for example, striking with a hammer, he hits the intended target each time, but the trajectories of the hand and hammer are always different. Even multiple repetitions do not allow achieving absolute similarity of movements. N. A. Bernstein called this principle of motion control “recurrence without repetition” [1]. Consequently, the nervous system does not re-send the same “commands” to the muscles. Each subsequent movement is made in conditions different from the previous ones [9-10]. Therefore, other commands and muscle corrections are needed. There is no absolute program of action, but there is an “image of a needful future”. Before the advent of research work in biomechanics and physiology of movements, it was believed that the execution of the movement was a consequence of the work of muscles and motor nerves that transmit impulses from the spinal cord and brain to the muscles. Currently, there is an understanding that sensory systems are equally loaded as motor systems. The muscles, while contracting, act on the sensory systems, which immediately send signals about this to the brain [3, 11, 12]. Each subsequent nerve impulse is a direct cause of a new nerve impulse going in the opposite direction [13]. This is the basis for making corrections to the movement, which, in turn, is the cause of new impulses coming to the muscles [14-15]. Thus, motion control is a closed ring process which is called a reflex ring in physiology. Violation of the work of such a ring leads to the destruction of motion and incorrectness in its work leads to movement inaccuracies, errors [16], and sometimes even to injuries [17-18]. Free throws in basketball were chosen to study the regularities of motion control. [19, 20]. Such movements relate to spatial stereotypic accurate ballistic movements [21–24], the final result in which depends on the correctness of the initial flight parameters [25]. Some researchers state that hit effectiveness also depends on prediction [26–28]. An athlete shooting a throw bases his movements on the model of the desired future and the prediction of the results of his action [29–31]. Free throws are well standardized by rules and automated in management, therefore ideal for studying [32].
2. Materials and Methods
The experimental base and sample research. The experiment was attended by 10 female athletes of the student basketball team of Lipetsk State University named after P.P. Semenov-Tyan-Shansky (Russia). We have used the following research methods to solve the tasks of this study:

a. Literature sources analysis. In the course of our work, we studied sources from various branches of science: biomechanics, theories and methods of basketball, physics, physiology and neurophysiology. This analysis allowed us to get a complete picture on the topic of motion control.

b. Experiment with the implementation of free throws in basketball. Each of 10 basketball players performed a series of free throws up to 10 hits. The number of throws for each basketball player depended on the accuracy of hitting and ranged from 11 to 15 shots. The observer recorded on the video the moment the ball hit / missed the basket. The experimental data was recorded into the study protocol.

c. Slow-motion video. To create video files, we used a high-speed Fastec Inline camera with a maximum shooting speed of up to 1000 frames per second [33]. In our study, we limited ourselves to a speed of 250 frames per second, because throw is not referred to ultrafast sports movements. The film shooting took place in the gaming hall of the LSPU named after P.P. Semenov-Tyan-Shansky (Figure 1).

Figure 1. FastecInLine camera and constant-light spotlight in the process of shooting video of throw accomplishment in the laboratory conditions.

d. Method of computerized digitization of movement based on point training. To identify regularities for control of throwing into the basket, we determined the kinematic characteristics of the movement. The main condition for the throw was to set the exact “nothing but net” hit (hit from the glass backboard was considered as a miss). For analysis, we selected 5 most informative points on the athlete's body, which were marked with reflective markers [34]: 1. point on the athlete’s head by antilobium; 2. point corresponding to the shoulder joint; 3. point corresponding to the elbow joint; 4. point corresponding to the wrist joint; 5. point on the ball.

For tracking, we used the specialized Kinovea biomechanical analysis computer program with a convenient graphical interface and high accuracy of determining the kinematic characteristics [35]. Kinematic characteristics were determined for each point: displacement, speed and acceleration. The speed and angle of ball’s flight were also determined (Figure 2). The ball’s center point was considered when analyzing its flight. A similar procedure for determining the kinematic characteristics was repeated for all attempts of all 10 athletes.
Figure 2. Determination of flying out speed, flying out angle, throw height and horizontal displacement relative to the penalty line in the Kinovea program.

e. Numerical simulation method. To understand which combinations of the flying out angle and the flying out speed will be effective, we created a computer model based on the physical laws of the flight path of a freely thrown body [36]. Creating a computer model, we introduced the assumption that the aerodynamic resistance force arising from the flight of the ball is insignificant, that it can be neglected. As you know, the trajectory of a body thrown at a certain angle to the horizon has the shape of a parabola. Mathematically, this regularity is described by the equation:

$$y = x \tan a - \frac{gx^2}{2v_0^2 \cos^2 a},$$  \hspace{1cm} (1)

where $y$ is the vertical coordinate of the centre of the ball; $x$ is the horizontal coordinate of the centre of the ball; $g$ is gravity acceleration; $\alpha$ is the angle of the ball flying out; $v$ is the speed of the ball flying out.

To clarify the operation of the model, the height of the ball flying out and the horizontal distance from the free throw line to the point of release of the ball. Using the Kinovea program, all 10 successful attempts were digitized. The average value for the flying out height was resulted after the sum of the athlete’s height and raising height of the ball above her own height. For example, with an athlete’s height of 175 cm and 39 cm raising height of the ball above her own height, the flying out height was 2.14 m. The horizontal displacement of the flying out point relative to the penalty line was also determined. In order to simulate the linear parameters of the glass backboard and the ring, linear indicators were measured that met the accepted standards for basketball. The width of the ring is 45 cm, the height of the ring is 305 cm, 15 cm distance from the ring to the glass backboard, 460 cm distance from the penalty line to the glass backboard horizontally, 400 cm from the penalty line to the front arch of the ring. Using the MS Excel program, a mathematical model was built showing the trajectory of the ball, the coordinates of the ring and the glass backboard (Figure 3).

Figure 3. Calculation of the flight path of the ball according to the source data using a mathematical model.
On the graph, the coordinates of the glass backboard and the ring are presented in projection in the form of straight lines. The ball’s flight path is presented for its centre, correspondingly coinciding with the common center of mass.

Study scope: the study of the problem according to literature data; experiment organization; analysis of videos, protocols; digitization of video and obtaining kinematic data; numerical simulation of the kinematic parameters of the throw; comparison of experimental and theoretical (model) characteristics in order to identify regularities of motion control.

3. Results
Analysis of primary data on the speed and angle of the ball’s flying out. To obtain the primary data array, all attempts to make a free throw in basketball by 10 athletes were digitized, including unsuccessful attempts when the ball did not hit the basket. For all attempts, the basic kinematic characteristics were determined. An example of a protocol for digitizing video files is presented in Table 1.

Table 1. An example of the presentation of data on the ball’s flying out speed and angle in each attempt of a basketball player Daria Petrukhina.

| Attempt No. | Angle of the ball’s flying out, degrees | Speed of flying out, m/s | Hit/miss |
|-------------|----------------------------------------|--------------------------|---------|
| 1           | 58.2                                   | 7.57                     | ✔️      |
| 2           | 58.7                                   | 7.31                     | ✔️      |
| 3           | 49.3                                   | 7.22                     | ✔️      |
| 4           | 54.6                                   | 7.44                     | ✔️      |
| 5           | 50.6                                   | 7.30                     | ✔️      |
| 6           | 48.3                                   | 8.12                     | ✔️      |
| 7           | 56.0                                   | 8.02                     | ✔️      |
| 8           | 56.1                                   | 5.83                     | ✔️      |
| 9           | 55.1                                   | 7.42                     | ✔️      |
| 10          | 52.4                                   | 7.24                     | ✔️      |
| 11          | 60.9                                   | 6.43                     | ✔️      |
| 12          | 65.0                                   | 7.11                     | ✔️      |
| 13          | 55.1                                   | 7.21                     | ✔️      |
| 14          | 52.2                                   | 7.39                     | ✔️      |

In the presented example, to build a numerical model of the effective execution of a free throw, attempts 4, 7, 8, 11 were discarded from the analysis and the statistical description was based on 10 successful attempts. Descriptive analysis was performed using the “descriptive statistics” function of the Excel MS Office analysis package. Descriptive analysis results are presented in the Table 2.

Table 2. The results of a descriptive analysis of data on the flying out angle and speed of a basketball player Daria Petrukhina.

| Speed, m/s | Angle of the ball’s flying out, degree |
|------------|----------------------------------------|
| Mean value | 7.389                                  |
| Standard error | 0.09                                  |
| Median    | 7.305                                  |
| Mode      | -                                      |
| Standard deflection | 0.287                              |
| Sample variance | 0.082                         |
| Excess    | 5.11                                   |
| Asymmetry | 2.10                                   |
| Interval  | 1.01                                   |
| Minimum   | 7.11                                   |
| Maximum   | 8.12                                   |
| Variations coefficient | 3.9%                      |

| Mean value | 54.49 |
| Standard error | 1.60 |
| Median    | 53.75 |
| Mode      | 55.1  |
| Standard deflection | 5.084 |
| Sample variance | 25.854 |
| Excess    | 0.615 |
| Asymmetry | 0.876 |
| Interval  | 16.7  |
| Minimum   | 48.3  |
| Maximum   | 65    |
| Variations coefficient | 9.3%  |
Descriptive analysis which was done for 10 basketball players showed:

- for all 10 athletes, both in speed of flying out and in angle of flying out of the mode, mean and median do not match, and there is also asymmetry, which may indicate a distribution other than the normal distribution;
- for all 10 athletes, the coefficient of variation of the angle of flying out is significantly greater than the speed of flying out, which suggests that this indicator is less stable and more difficult to control, or that it is, on the contrary, used for the final correction of the throw;
- the average numerical models of the free throw of a specific athlete depend on anthropometric data (height, arm length). At the same time, the averaged digital models lie in the range: ball’s flying out speed – from 7.1 m/s to 7.6 m/s, flying out angle from 48 to 57 degrees.

3.1. Mathematical modelling of the flight path of the ball

The mathematical model made it possible to conduct virtual experiments and visually assess the accuracy of hitting the ball at given initial parameters.

**Table 3.** Input and output data of a computer model of a ball’s flight during a free throw: example, with a special case of modelling.

| Initial data | Estimated data |
|--------------|----------------|
| parameter    | value | units | parameter | value | units |
| Speed of flying out | 7.20 m/s | | velocity component along X-axis | 4.18 m/s | |
| angle of flying out | 54.5 degree | | velocity component along Y-axis | 5.86 m/s | |
| height of flying out | 2.15 m | | range of flight | 5.00 m | |
| | | | time of flight | 1.19 s | |
| | | | maximum flight height | 3.83 m | |
| | | | speed at maximum height | 4.18 m/s | |

Carrying out virtual experiments, we evaluated whether the path of the ball passes through the line of the ring. As a result, we obtained acceptable limits in terms of angle and flying out speed for each athlete (table 3), taking into account her anthropometric data. As a result, we obtained acceptable limits in terms of angle and flying out speed for each athlete (Tabl. 4) taking into account her anthropometric data.

**Table 4.** A numerical array of simulation results of initial parameters for a ball hitting a ring from the penalty line.

| Speed of ball's flying out, m/s | Minimum angle of hit, degrees | Maximum angle of hit, degrees | Speed of ball's flying out, m/s | Minimum angle of hit, degrees | Maximum angle of hit, degrees |
|---------------------------------|-------------------------------|-------------------------------|---------------------------------|-------------------------------|-------------------------------|
| 10.1                            | ceiling height is exceeded    | ceiling height is exceeded    | 8.2                            | 67                            | 69                            |
| 10                              | 76                            | 77                            | 8.1                            | 66                            | 68                            |
| 9.2                             | 73                            | 74                            | 8                              | 65                            | 67                            |
| 9.1                             | 72                            | 73                            | 7.9                            | 64                            | 66                            |
| 9                               | 72                            | 73                            | 7.8                            | 62                            | 65                            |
| 8.9                             | 72                            | 73                            | 7.7                            | 61                            | 64                            |
| 8.8                             | 71                            | 72                            | 7.6                            | 59                            | 63                            |
| 8.7                             | 71                            | 72                            | 7.5                            | 58                            | 62                            |
| 8.6                             | 70                            | 71                            | 7.4                            | 54                            | 60                            |
| 8.5                             | 69                            | 71                            | 7.3                            | 45                            | 59                            |
| 8.4                             | 69                            | 70                            | 7.2                            | 48                            | 56                            |
| 8.3                             | 68                            | 69                            | 7.1                            | miss                          | miss                          |
4. Discussion

4.1. Comparison of model and empirical data
We built a graph of limit values for productive shots for each athlete using the method of numerical modelling.

![Figure 4. Limit values for the angle and speed of ball’s flying out for a successful hit by an athlete Daria Petrukhina.](image)

Figure 4 shows that there is a rather large range of effective combinations of the flying out angles and the ball’s flying out speed. This range is not uniform; there is the widest area, which theoretically should be considered optimal, because it allows some inaccuracies in the initial parameters of the ballistic motion. We also suggested that athletes, empirically, determine this optimal zone, and furthermore, while performing free throws they would strive for these parameters. Using the laws of ballistics, the boundary kinematic values of the throws were calculated for all 10 athletes. All 10 graphs, built on the calculated values had a similar discriminating loop contour. To identify regularities of motion control during the free throw shots in basketball, we overlaid real angles and speeds of flying out defined in the Kinovea program on model (theoretical) values (Figure 5).

![Figure 5. Overlay of experimental parameters of throws on the effective hit zone of the athlete Daria Petrukhina.](image)
Figure 5 shows that experimental data are very well correlated with theoretically calculated values for the speed and angle of the ball’s flying out. However, there were some discrepancies that need clarification.

An attempt of free throw No.4 with parameters of a flying out angle of 54.6 degrees and a speed of flying out of 7.44 m/s gets into the effective hit zone, however, during the experiment a miss was recorded. This can be explained by the fact that we consider a somewhat simplified model of the throw in our study. In reality, in addition to the angle and speed of flying out, the height of flying out, the accuracy of hitting is also determined by the angle of the throw direction. If the athlete is mistaken with this angle, the ball deviates to the left or to the right and, as a result, does not hit the basket. An attempt to do free throw by No.6, on the contrary, should not be effective, because according to parameters this throw is outside of the limits of the effective hit zone. A detailed analysis of the primary research protocols showed that even though the ball hit the basket, the hit was a rebound from the glass backboard. The attempt of free throw by No.14 slightly goes beyond the limits of the effective hit zone. At the same time, the experiment recorded a hit. This can be explained by the action of the aerodynamic resistance force, which reduces the flight speed and reduces the throwing distance. This combination of aerodynamic force and gravity was effective in this case.

4.2. Identification of regularities of motion control between repetitions

To identify regularities of motion control between attempts, we connected of successive attempts to make throws by the lines, the direction of which indicates the direction of correction. It is difficult to say whether such corrections are conscious or unconscious, whether they are random or systemic. The most reliable throw in terms of scoring will be a throw with parameters corresponding to the parameters of the center of the effective hit zone. We believe that the athlete unconsciously feels this point, and when completing a throw, getting the parameters into the boundary area of the effective hit zone, strives to adjust the movement towards the centre of the effective hit zone. The fact that the throw parameters have boundary values gives information that an athlete can judge using his visual control. “Boundary” throws are always obtained on the verge of being hit, i.e. from the arch of the basket ring. Shots made with parameters close to the centre of the effective hit zone, on the contrary, look like a “nothing but net” hit.

![Figure 6. Directions for correcting ballistic parameters during free throws.](image)

Figure 6 shows, for example, that after the “boundary” attempt No.1, the “boundary” attempt No.2 follows. However, if attempt No. 1 was on the verge of an overshoot, then attempt No.2 was on the verge of undershoot. Correction occurred through the center of the comfort zone. Attempts: No.2 – No.3; No.3 – No.4, No.4 – No.5, No.7 – No.8, No.8 – No.9, No.9 – No. 10, No.13 – No.14 correspond to the described regularity. Thus, out of 13 corrections that we can analyze at 14 throws, 7 corrections are subjected to the general rule: “Throws are controlled by correcting ballistic parameters from the
boundary zone to the central zone of the most reliable hit. When determining the direction of correction to a high degree of accuracy, the athlete hardly determines the quantitative value of the correction itself”.

Correction No.5 and No.6 is interesting because the athlete, in an attempt No.5, have chosen the most reliable ballistic parameters, having got the points at the graph as close as possible to the center of the scoring area. Such success would have to be recorded in memory, and all subsequent attempts will be repeated. However, such a hit leads to the first serious distortion of the parameters, and as a result, in an attempt No. 6, the ball flies further than the basket ring and hits it only from the glass of the backboard. Based on this, it can be assumed that understanding the exact correction vector leads to the most significant movement errors Correction No.10 and No.11, which is not explained by the above correction logic, is also interesting, and is apparently explained by a random movement error.

4.3. Identification of regularities of motion control during the throw

We initially used visual analysis to search for regularities of motion control. We used the function of matching (Figure 7) and frames overlaying (Figure 8), as well as motion shot-by-shot breakdown.

Figure 7. Visual comparison of throwing techniques in various attempts.

Figure 8. Visual overlay of throwing technique in various attempts.

Visual analysis revealed only the fact that each attempt to make a free throw is unique according to kinematic characteristics. At the same time, only a certain combination of angle and flying out speed can ensure the effectiveness of the throw. Thus, control and correction supposes some variation in movement.

We determined the kinematic characteristics of the throws for a more detailed analysis. The main condition for the throw was to set the exact “nothing but net” hit (hit from the backboard glass was considered as a miss). For analysis, we selected 5 most informative points on the athlete's body, which were marked with reflective markers:

1. Point on the athlete's head by antilobium;
2. Point corresponding to the shoulder joint;
3. Point corresponding to the elbow joint;
4. Point corresponding to the wrist joint.
5. Point on the ball.
To create video files, we used a high-speed Fastec Inline camera with a maximum shooting speed of up to 1000 frames per second. Kinematic characteristics were determined for each point: displacement, speed and acceleration (Figure 9).

Figure 9. Determination of the kinematic characteristics of the throwing technique in the Kinovea program.

Separate movements and speeds graphs themselves characterize the features of the motion technique, but do not reveal regularities of motion control (Figure 10).

Figure 10. Ball speed before the throw.

To identify the features of motion control, the trajectories of the points of all attempts of each basketball player were overlapped on one graph. In order not to overload the graph, we left the trajectories of points in 5 arbitrary successful attempts. On the graph you can see the points of convergence of the trajectories, where the trajectories of the elbow joint point and the wrist joint point merge into a single line. This fact suggests that in this position there is a minimal discrepancy in the coordinates in various attempts, i.e. minimum entropy (Figure 11).

Figure 11. Overlapping the trajectory of points when performing free throws in basketball in several attempts.
A similar convergence is observed with all 10 basketball players at the beginning of the movement. Thus, we can formulate a general rule of motion control during the throw: “The movement can be divided into two parts: preparatory – when an athlete from any game situation strives for a standard (maximally familiar and maximally stereotypical) position with minimal entropy; and, the main one – when from the standard position, based on the motor memory according to the principle of the “reflex ring”, targeted movement correction is carried out”. The second part of the movement makes a greater probability of random errors and excessive corrections. Thus, our study confirmed that there are regularities of motion control in stereotyped accurate movements that can be identified from registration and analysis of the kinematic characteristics of movement.

5. Conclusions
Any sports movement is possible only thanks to a systematic combination of conscious or unconscious control. Every human movement throughout life is unique and inimitable. Brilliantly formulated in the mid-20th century N.A. Bernstein’s principle of “recurrence without repetition” exactly reflects the nature of this phenomenon. At the same time, the motion control system itself is not entirely clear: are the regularities individual or universal; how do the conscious and subconscious control centers interact with each other? Basketball free throws were chosen to search for regularities of motion control. This movement is relatively simple to implement and well standardized, therefore it is the most accessible for study. The experiment was attended by 10 female students of the university basketball team of the Institute of Physical Culture and Sports of Lipetsk State University named after P.P. Semenov-Tyan-Shansky (Russia), each of them performed a series of shots up to 10 hits. Taking the values of the speed and angle of ball’s flying out of all successful attempts, using a descriptive analysis for each athlete, the average numerical model of the effective execution of a free throw in basketball was calculated. To understand which combinations of the ball’s flying out angle and speed will be effective, we built a computer model based on the physical laws of the flight path of a freely thrown body. The mathematical model allowed us to conduct virtual experiments and visually assess the accuracy of hitting the basket by a ball at given initial parameters. In addition, the area of the effective combination of ball’s flying out angles and speed was determined. By comparison, we found that the experimental data is in good well correlated with the theoretically calculated values.

Analyzing the correction of the kinematic parameters between the throws regularity was revealed consisting in the fact that control is carried out by correcting the ballistic parameters from the boundary of the effective hit zone to the central zone of the most reliable hit. An athlete determines the direction of correction with a high degree of accuracy, but he can hardly determine the quantitative value of the correction itself. Having studied all attempts to shoot by 10 basketball players, a general regularity of motion control was found. A throw as a movement pattern is divided into two parts: preparatory – when an athlete from any game situation strives to take a standard (maximally familiar and maximally stereotypical) position with minimal uncertainty; and the main one – when from a standard position, based on motor memory according to the principle of the “reflex ring”, targeted movement correction is carried out. The second part of the movement allows for the greater possibility of random errors and excessive corrections occurrence.

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