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Original Article

Sensory control as a control mechanism in accuracy movements of athletes

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Abstract.
Purpose: to establish the dependence of the accuracy of motor actions of athletes on the level of sensory functions. **Participants in the study:** basketball players of 18–26 years old of masters team with a level of qualification of candidates of masters and masters of sports participated in the study. **Research methods:** differential sensometry of kinesthetic, visual, auditory sensory systems and vestibular stability. The use of mathematical methods of multiple regression analysis allowed us to establish the most important functions of sensory systems in controlling the precision actions of basketball players. **Results:** It was established that the level of functional activity of sensory systems changes during the training session, depending on the degree of impact of the loads. Depending on the level of stability of sensory functions, the accuracy of the performance of motor actions also changes. **Conclusions:** The level of sensory perception depends on a certain intensity of heart contractions. The optimal heart rate is 145-155 beats / min. Indicators of accuracy actions depend on individual sensory functions that need to be developed in conditions close to sports activities.
Keywords: basketball, training, sensory systems, accuracy movements, heart rate.

Introduction.

Research materials in domestic and foreign literature indicate that the study of mechanisms for controlling voluntary movements is an actual problem (Cafarelli, 1992; Zawatsky, 1993). As modern sports activity is saturated with complexly coordinating motor actions, characterized by high accuracy of motor acts, committed under time pressure conditions against the background of physical and psycho-emotional tension (Anokhin, 1973; Boloban, 1990; Ashanin, Golos, & Gorbatenko, 2010; Rovniy Anatoly, Pasko Vladlena, & Galimskyi Volodymyr, 2017).

Since, based on the accuracy of reproduction of sensory functions, coordination abilities are formed, this is the basis for controlling the movements of athletes in competitive activities (Vedyaev, Zavatsky, & Rovny, 1975; Pidorya, 1992, Zavyalov, 1990, Rovniy et al., 2018)

The modern level of development of sports games is characterized by high-precision motor actions, which are carried out on the basis of perception, processing of information and on this basis the reproduction of certain movement parameters (Makarenko, 1995; Maglevaniy, Huskivadze, Kravchuk, & Strelbitsky, 2010; Kozina, 2009; Maglovykh, Yavorsky, & Tjorlo, 2012; Nesen, et al., 2018; Tsos, et al., 2018). Therefore, the accuracy of reproduction of motor actions depends on the exact sensory perception and their individual parameters (Tkachuk, & Khadzhinov, 1992; Rovniy, 2000; Malkov, 2008; Pasko, 2008).

In the formation of precision movements, a rational construction of the training process is necessary, the conditions of which will facilitate accurate perception and reproduction of sensory information.

In the process of improving the technique of competitive exercises, it is necessary to create conditions of proximity to the high-intensity nature of competitive activity so that the level of reproduction of sensory information corresponds to the level of perception (Sudkov, 1987; Komissarov, 1988) and can be maintained throughout the competitive activity.

Analysis of the scientific and methodological literature did not reveal recommendations for improving the system of sensory functions, as the basis for controlling precision movements in the course of training sessions, which determined the subject of our research.

Methods and study participants. The study was conducted on the basketball team of the highest league of Ukraine at the age of 18-26 years old, with a level of preparedness of candidates and masters of sports.

With the help of well-known research methods, various functions of the kinesthetic sensory system have been studied. Differential sensitivity - was determined by the number of thresholds of sensations of weight gain with the main hand from 30 to 1030 grams and average differential threshold (Rovniy, 2000). In order to

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study the characteristics of coordination abilities, the accuracy of reproduction of a given effort with eyes closed was 50% of the maximum, and the ability to reproduce the spatial parameter of motion – a given angle of 60°.

To study the characteristics of the visual sensory system, the following functions were determined: differential sensitivity – determining the number of different thresholds for increasing the brightness of light from 4.33 Nit to 800 Nit on the ADM-2 adaptometer; dark adaptation – the subject was looking at an adaptometer ball with a brightness of 1250 apostilles for 2 minutes. Then the light was turned off and the time of the disappearance of the object on the screen of the adaptometer in the dark was recorded; the study of deep vision was carried out on the Best apparatus using the Saxen-Weger technique, when the test subject, against the background of matte white illumination, determined the sensations of approaching and removing the black rod.

The sensitivity of the auditory sensory system was determined by the AP-02 audiometer to establish the ability to distinguish the intensity of sound tones at frequencies from 250 to 3000 Hz. The number of thresholds of sensation and determined the auditory activity. To characterize the vestibular sensitivity, the position of the nystagmus was recorded at a certain speed of the rotational chair.

Design of the study.

The training process was constructed in such a way as to establish at what mode the heart rate (125-135; 145-155; 165-175 beats / min) the subject most accurately manifests his sensory abilities in the process of making 40 shots of the ball into the ring in 4 minutes. Determined the number of points scored when throwing the ball and the most important sensory functions in achieving ball throwing accuracy.

Results of the study and their equipment.

The main motive goal in basketball is accurate throwing the ball into the ring, which are performed in conditions of confrontation with a rival and an acute shortage of time. This is the main motive goal of the players achieved by a number of complex technical techniques during the rapid movement around the sports field. Therefore, a test of 40 shots in 4 minutes is applied to characterize the level of accuracy of shots. The test is performed on the background of the average game heart rate indicator. Studies were conducted during the training session at the beginning and at the end of the training camp (Table 1)

Table 1

The dynamics of the accuracy of throwing the ball into the ring by basketball players in the process of training sessions (number of times)

Research stages	Measurement frequency	$\overline{X} \pm m$	Max	Min	Range	V, %
At the beginning of training camp	At the beginning of training sessions	26,75±0,42 (66,8%)	32	24	8	6,95
	In the middle of training sessions	31,55±0,46 (78,8%)	36	29	7	6,54
	At the end of the lesson training sessions	27,65±0,38 (69,1%)	31	25	6	6,86
At the end of training camp	At the beginning of training sessions	27,40±0,36 (68,6%)	32	25	7	6,19
	In the middle of training sessions	34,81±0,61 (87,0%)	39	30	9	7,88
	At the end of the lesson training sessions	31,15±0,48 (87,0%)	34	28	6	5,23

The presented results of the accuracy of throwing the ball indicate that with an increase in the level of fitness of the players, the accuracy of throwing the ball into the ring also increases. The main mechanism of precision movements is afferent synthesis. Based on his information, decisions are made on the relationship of vegetative, somatic and humoral components and a program of motor actions is created.

For the theory and practice of sports training, of great interest is the construction of mathematical models of the dependence of the accuracy of motor actions on the state of various body functions of athletes - for this purpose, the multiple regression method was used, which determines the analytical dependence of the ball throwing accuracy into the basket and the stepwise inverse regression method, which determines the significance of certain sensory functions in the performance of throwing the ball into the basket. Also, mathematical models were developed for the basketball team of the highest league of Ukraine and were used during the training session at the beginning and at the end of the pre-competition training camp.

At the beginning of the training camp, the throwing accuracy model shows numerical parameters, the level of which determined the significance of the influence of each sensory function, assuming that the initial constant in the multiple regression equation is zero.

The calculated coefficient of determination indicates that the mathematical model explains 99.47% of the variation of the studied parameter of the accuracy of throwing the ball into the basket at the beginning of the training camp (formula 1).

Formula 1

$$TS=3{,}52\times CHS+4{,}06\times FS+0{,}11\times GS-0{,}44\times KS+1{,}09\times PS-0{,}17\times SS+0{,}81\times \times VS+0{,}08\times LRT-0{,}1\times LTT-0{,}09\times ZS,$$

where TS – ball throwing accuracy at the beginning of the training camp; CHS – vestibular sensitivity; FS – accuracy of the specified effort; GS – threshold of deep vision; KS – kinesthetic sensitivity; PS – accuracy of a given spatial parameter of movements; SS – auditory sensitivity; VS – vestibular stability; LTT – latent muscle tension time; LRT – latent muscle relaxation time ZS – differential visual sensitivity.

The above equation allows us to estimate the role of each sensory function in achieving the accuracy of throwing the ball into the basket. The use of the method of inverse step-by-step regression makes it possible to identify the most significant of the above functions in the control of precision movements (formula 2).

Formula 2

$$TS=2{,}059\times CHS+4{,}387\times FS,$$

where TS – ball throwing accuracy at the beginning of the training camp; CHS – vestibular sensitivity; FS – reproduction accuracy of a given effort.

The reduced inverse step-by-step regression equation determined two main factors in achieving ball throwing accuracy.

At the end of the collection, a mathematical model of multiple regression has this form at the end of the training collection (formula 3).

Formula 3

$$TF=3{,}78\times CHF+8{,}06\times FF+2{,}09\times GF-0{,}46\times KF-0{,}27\times PF-0{,}93\times SF+3{,}05\times \times VF+0{,}07\times LTT+0{,}17\times LRT-0{,}14\times ZF,$$

where TF – ball throwing accuracy at the end of the training camp; CHF – vestibular sensitivity; FF – reproduction accuracy of a given effort; CF – threshold of deep vision; KF – kinesthetic sensitivity; PF – accuracy of a given spatial parameter of movements; SF – auditory sensitivity; VF – vestibular stability; LTT – latent muscle tension time; LRT – latent muscle relaxation time: ZF – visual sensitivity at the end of the training camp.

Analysis of this equation suggests that vestibular sensitivity of CHF and accuracy of reproduction of a given effort remain the main factors in controlling the accuracy of ball throws. At the same time, the level of significance of vestibular VF resistance increases. The final value of the factors in the accuracy control is determined by the step-by-step inverse regression (formula 4).

Formula 4

$$TF=10{,}45\times FF+0{,}52\times SF,$$

where TF – ball throwing accuracy at the end of the training camp; FF – reproduction accuracy of a given effort; SF– auditory sensitivity.

Analyzing the models of multiple regression analysis, it is clear that all sensory functions are interconnected and play a certain role in regulating the accuracy of the ball throws into the basket and is the basis of motion control based on which the inverse step regression model determines the most important functions governing the accuracy of the ball throws. Therefore, to consider the dynamics of mathematical models in the process of training at the beginning and at the end of the collection, we will bring inverse step-by-step regression controls, which will show the most important sensory functions in controlling precision movements.

At the beginning of the training session at the beginning of the training camp, the inverse step-by-step regression equation determines two important factors in the regulation of ball throwing accuracy (formula 5).

Formula 5

$$TS_1=3{,}066\times GS_1+0{,}243\times SS_1,$$

where TS_1 – ball throwing accuracy at the beginning of the training session at the beginning of the training camp; GS_1 – threshold of deep vision; SS_1 – auditory sensitivity .

In the middle of the training session, there is a significant increase in motor activity and metabolic processes in the body, which caused a change in the sensory control of the athletes' accuracy movements (formula 6).

Formula 6

$$TS_2=1{,}864\times GS_2-5{,}748\times VS_2+0{,}273\times LRT,$$

where TS_2 – ball throwing accuracy in the middle of the training session at the beginning of the training camp; GS_2 – threshold of deep vision; VS_2 – vestibular stability; LRT – latent muscle relaxation time.

At the end of the training session, the equation of the inverse stepwise regression shows that with the accumulation of fatigue, the accuracy of the ball throws depends on the speed of muscle relaxation (formula 7).

Formula 7

$$TS_3 = 0{,}146\times LRT_3,$$

where TS_3 – ball throwing accuracy at the end of the training session at the beginning of the training camp; LRT_3 – latent muscle relaxation time.

At the end of the training camp, the system of sensory control of movement accuracy varies considerably. At the beginning of the training session at the end of the training camp, the inverse step-by-step regression equation defines five basic sensory functions (formula 8).

Formula 8

$$TF_1=2,472\times CHF_1+4,744\times FF_1+1,826\times GF_1+0,380\times KF_1++0,114\times LTT_1,$$

where TF_1 – ball throwing accuracy at the beginning of the training session at the end of the training camp; CHF_1 – vestibular sensitivity; FF_1 – reproduction accuracy of a given effort; GF_1 – threshold of deep vision; KF_1 – difference sensitivity of kinesthetic sensory system; LTT_1– latent muscle tension time.

Training sessions in the final stages of the training camp are characterized by increased intensity. Therefore, already in the middle of the training session, the inverse step-by-step regression equation determines the latent time of muscle relaxation (formula 9) as the main factor controlling the ball throwing accuracy.

Formula 9

$$TF_2 = 0,194\times LTTF_2,$$

where TF_2 – ball throwing accuracy in the middle of the training session at the end of the training camp; $LTTF_2$ – latent muscle tension time in the middle of the training session at the end of the training camp.

At the end of the training session, there is an accumulation of fatigue in athletes, which causes a decrease in the functional activity of sensory systems, as well as latent periods of tension and muscle relaxation.

Performance of various training tasks in sports games takes place at the level of constant vestibular irritation. Therefore, the stepwise inverse regression equation predetermines vestibular sensitivity by the primary factors in controlling the accuracy of ball throws (formula 10).

Formula 10

$$TF_3 = 3649\times CHF_3,$$

where TF_3 – ball throwing accuracy at the end of the training session at the end of the training camp; CHF_3 – vestibular sensitivity at the end of the training session at the end of the training camp.

Thus, gaming activity contributes to increasing the sensitivity and stability of the vestibular sensory system, and this, in turn, determines the impact on the accuracy of motor actions of athletes.

Analysis of the research results indicates that each of the sensory functions studied is involved in the control of precision movements and varies throughout the training session depending on their intensity.

Discussion.

The process of controlling movements and especially precision ones is carried out due to the gradual incorporation of various functional systems of the body, which primarily provide timely adaptation (Platonov, 2007; Pashkov, 2008; Pasko, 2014; Pasko, Podoliaka, & Martyrosyan, 2013).

The main condition in the mechanism of adaptation to the influence of the external environment is feedback, which, through sensory systems, informs the brain centers of the degree of exposure (Rovniy, 2015). Despite the number of studies of the role of sensory systems in the formation and management of motor skills (Roll, & Vedal, 1982; Rovnaya, Ilyin, & Rovniy, 2010), the study of the systemic organization of sensory control precision of movement remains relevant in current research.

It is established that the specificity of motor activity affects the functions of sensory systems (Rovniy, & Pasko, 2017) and, depending on the complexity of motor actions, are carried out on the basis of perception, information processing.

The level of functional activity of sensory systems depends on the degree of physical activity. So in the preparatory part of the training session, the load should be optimal and contribute to a high level of perception by sensory systems (Rovniy, 2015; Rovniy et al., 2018). In the future, for quick perception and processing of information and making an instant decision in competitive activities, it is necessary to apply training sessions in conditions close to competitive ones (Strelets, & Gorelov,1995).

Defining the leading sensory systems in the formation of motor skills (Rovniy, & Rovnaya, 2014; Rovniy, & Lizogub, 2016) it has been established that the role of the leading sensory system is alternately played by the visual and kinesthetic. However, in these studies, the leading functions of these systems are not shown. After all, those methods mainly characterize the state of functional activity by their distinctive ability.

Therefore, to establish specific control functions in our studies, special techniques were used to study specific sensory functions.

Conclusions.

The results of the study indicate that each of the sensory systems studied was involved in the control of precision movements and changes throughout the training session and collection relative to the intensity of the training loads.

The leading physiological mechanism for controlling precision movements is their instant correction based on the constant interaction between the nervous system starters and skeletal muscles (the principle of sensory corrections).

When analyzing individual characteristics of movements, the auditory sensory system is important. It perceives a variety of micro intervals of time between the auditory signals that are perceived by the auditory receptors, for example, basketball players are guided based on the auditory signals (hitting the ball from the parquet, approaching the opponent).

The studies found that in the state of rest, the dependence of the accuracy of movements on the visual sensory system is observed. However, under load, its role is reduced due to a decrease in oxygen consumption. Therefore, the distinctive ability of the visual system plays the role of a general orientation. A major role in managing precision movements is played by the function of the visual system – *deep vision*, which perceives information about the approach and removal of objects (the ball), as well as finding a player from the basketball basket.

Of great importance in controlling precision movements is vestibular sensitivity, an indicator of which is nystagmus. Systematic training sessions reduce vestibular sensitivity and increase vestibular resistance. This is confirmed in our studies where it is shown that at the beginning and at the end of the training collection, the accuracy of the throws of the ball depends on the level of vestibular sensitivity and stability.

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