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DOCTORAL THESIS

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DOCTORAL THESIS

TITLE: Study on the use of modern information technology in the optimization of free throws in basketball

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Doctoral field: Sport science and physical education

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CONTENT

INTRODUCTION

The topicality of the thesis is due to the specific features and trends of dynamization and expansion of the use of innovative information technologies in the training process with focus on improving the technique of game actions, in this case the improvement of free throws and implicitly in the optimization of sports performance specific to the game of basketball.

The topicality of the thesis is to design and implement a system for analyzing and monitoring free throws, so that players become aware and correct their errors in real time, improve their technical execution and the effectiveness of these completion procedures with a great impact on the adjudication of sporting success.

Our investigative approach is aimed at basketball game and the specialised training of players. Basketball is a sport, a team game, and during the game frequent physical contact is made between players attacking and defending individually. Contact between attacking and defending players is allowed and stipulated by the rules of the game, and committing errors may result in the referee awarding free throws or sets of free throws to the player on whom the error was committed.

With this thesis we want to address conceptually and practically the defining aspects of specialized basketball-specific free throw preparation using innovative information technologies with a focus on improving technical execution and the percentage of successful executions completed with a basket. We will also implement novel evaluation tests that we believe will highlight the impact of the effectiveness of the innovative technology designed and implemented in the training process of athletes, male - junior.

Information technologies using real-time video and analysis of executions have been an ongoing concern of specialists in recent decades. Shooting as an individual activity of a shooter is considered by many specialists (Argaj, 2005; Katuna, 2008; Mačura - Potocký, 2009; Tománek, 2008; Tománek - Vencúrik, 2008) as having an important role in sports training with direct effects on performance in basketball games.

Successfully making kinograms, filming or using free-throw photography can have a significant influence in preparing and perfecting throws and other technical actions. The use of these technologies can condition the preparation and victory in a game (Mačura, 2007). The success of free throws is considered a major factor influencing the achievement of victory in a basketball game.

The main purpose of the research was to improve the efficiency of free throws in basketball by implementing a system designed by us and called "System and device for sport-specific motor learning and mode of use", at the junior level as well as the design and selection of tests to evaluate the effectiveness of free throws and implicitly the innovative information technology system implemented in the training and research approach.

The overall objective of the research is to verify the effectiveness of the innovative device called "System and device for sport-specific motor learning and mode of use" in the process of perfecting free throws in the game of basketball at junior level and implicitly in optimizing the effectiveness of the free throw success rate.

As specific objectives we aimed to:

- integrating the innovative device into training;
- Verify the effectiveness of the device by selecting and designing evaluation tests adapted to the proposed purpose;
- to streamline the sports training process specific to the optimization of free throw shooting in basketball by designing and implementing a specific technical system and device;
- ensuring the continuity of the training means using the innovative device throughout the experimental approach;
- improvement of free-throw shooting technique, as reflected in the effectiveness of the throws.

General hypothesis of the research **-** we started from the assumption that through a specialized approach to implement the innovative device designed and intended to improve the free throw, called "System and device for sport-specific motor learning and mode of use - System and technical device for motor learning process in the field of sport science and physical education with direct applicability in basketball-specific training - free-throw improvement" can optimize the technique and efficiency of free throws and implicitly of the sport training process in order to improve the specific free-throw finishing procedures in the game of basketball.

In this PhD thesis, we have addressed a complex scientific problem aimed at optimizing free throws by improving the execution technique following the implementation of innovative information technologies dedicated to the preparation process of these technical finishing actions.

We believe that the application value of this paper lies in presenting the innovative technology we have designed and highlighting its role and impact on increasing the technicality and efficiency of basketball-specific free throws.

This innovative technology is dedicated to the training process of all categories of basketball athletes, and can provide both real-time monitoring and correction of execution errors in order to optimise and improve the free-throw shooting and therefore the ratio between the number of executions and the number of successes.

1.1 **Sport training in basketball - conceptual delimitations**

Sports training is a complex process of adaptation to high physical and mental efforts, led by coaches specialized in a sport branch who coordinate the way of applying modern methodologies in the preparation of athletes to achieve sporting excellence.

The game of basketball requires from the specialists a complex approach to training through a harmonious and efficient combination of components aimed at physical, technical, tactical, theoretical and psychological preparation. The optimisation of the technical and tactical performance of basketball players is conditional on the implementation of an efficient and individualised game preparation process in relation to age and level of specialised sports training.

Sport training can be analyzed from a multidimensional perspective as a specialized pedagogical, instructive, sport and educational process, which involves a systematic longitudinal sequencing of contents in order to develop the potentialities, specialized knowledge, technical skills and aptitudes of athletes in order to obtain valuable results in sport competitions (Dumitrescu Gh., 2011, p.4; Sava C., Jercălău T., Hagimă M.,2014, p.134).

Bompa T.O. (2003, p.23) considers that sport training aims at manipulating various specific methods to bring about physical adaptive changes in order to achieve sport improvement.

A special mention is made to highlight the new conceptual trends of extending specific terminology by introducing a new concept, that of total training, as a result of the interrelation between sports performance, medicine, psychology, technology. Total training is not limited to simple biological development based on motor skills, technical skills, etc., but is linked to the process of integral and complex development of the personality, the behavioural system from the perspective of social, sporting and individual integration, based on biological adaptations of a plastic and functional nature.

1.2 Structure, objectives, characteristics and principles of sports training in basketball

1.2.1 Structure of sports training in basketball

We believe that sports training is a special and specialized process of training athletes based on scientific principles aimed at optimizing performance capacity in order to achieve goals and achieve excellence in various sports. Sport training is focused on achieving high sport performance based on the development of all specific physical, technical, tactical and psychological components.

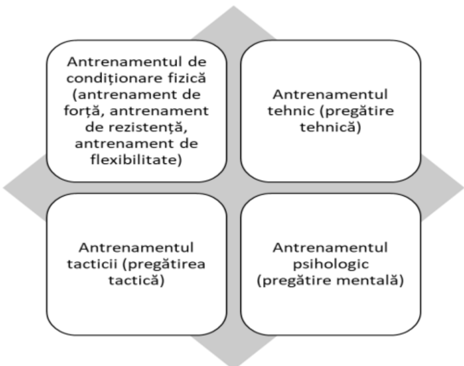


Figure 1. Specific structural elements of sports training

1.2.2 The objectives of sports training in basketball

Specialists have delineated two major goals of the sport training process namely (Klusemann MJ, Pyne DB, Foster C, and Drinkwater EJ., 2012; Petway AJ, Freitas TT, Calleja-González J, Medina Leal D, Alcaraz PE, 2020):

- development of the athlete's motor performance capacity to the maximum level;
- development of the athlete's personality components and traits in the training and competitive process.

Sports training, being a complex process, is also focused on the following specific objectives:

- optimising physical fitness;
- acquisition of fundamental motor and technical skills specific to the sport or branch of sport practised;
- improving tactical efficiency;
- improving mental skills specific to sporting activity.

1.2.3 Characteristics of sports training in basketball

Specialists have highlighted a number of defining characteristics of sports training based on practical experimentation and the dynamics of development of the phenomenon of performance sports, among which we highlight:

- sports training is specifically individualized - according to individual needs and capabilities in order to achieve the high level of adaptation and sports performance demanded by current sports performance;
- achieving high performance in sports competitions - the training process is a long and focused process of achieving high performance results in sports competitions;
- sport training is a scientific process - the dynamics of scientific research determine and condition the content and methods of current sport training;
- the coach has a major and determining role - sports performance is directly conditioned by the coach's expertise, involvement and progressive thinking in designing, directing and monitoring the training and performance of athletes;
- Optimal development of the sports career - the conduct of sports performance training in optimal conditions requires systematic and scientific planning using different means and methods adapted to the sports contexts and performance objectives set;
- sports training is an educational process - the interrelationship with coaches and team influences the development of athletes' personality and behaviour through self-discipline, prioritisation of goals and motivations, and expansion of human knowledge and experience;

– discovering talented individuals for motor sports activities - through the selection and training process, athletes' talents are highlighted and developed to achieve motor and competitive performance.

1.2.4 Components of sports training in basketball

The components of the training process in basketball are varied and cover all aspects of sports performance.

The components of sport training are adapted to the specificities of the game of basketball and refer to the specificity, individualization aspects of training, prevention and recovery aspects after exertion, as well as overload and overtraining (Vieira de Castro AC, Araújo Â, Fonseca A, Olsson IAS, 2021; Tarragó, J. R., Seirullo, F. & Cos, F., 2019, p. 104-124).

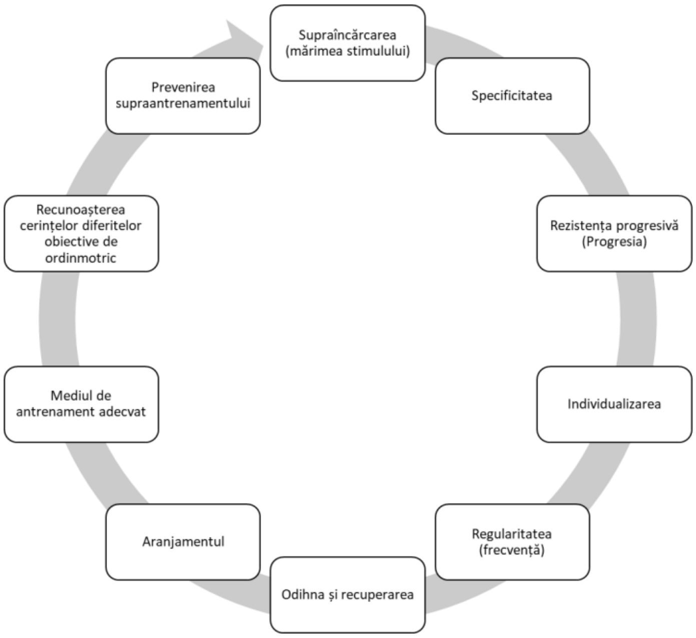


Figure 2. Components of the sport training process

1.2.5 Principles of sports training in basketball

Training principles are rules that guide the process of sports training.

The most important principles reflected in sports training and which determine the optimization of the entire sports process and sports performance are (Deckard, Lucas R., 2014, p. 27; Ghițescu, I.G.; Moanță, A., 2005, p 78-112):

– Continuity of training - the recording of sports performance is conditional on a systematic and continuous process, without long pauses involving the replay of the entire adaptive process;

- gradually increasing the physical demand - in order to ensure an optimal ratio between the motor load and the adaptation process, the whole training process must be dosed progressively;
- Proactive participation - the athlete must understand and make every effort to be actively involved in carrying out training tasks and meeting the demands of sporting life;
- Accurate and systematic planning of training - training must be planned to achieve the proposed performance objectives and this process involves systematic and accurate planning in relation to the performance requirements of the sport;
- the right approach to general and specific training - coaches must place great importance on both general and specific training in order to ensure continuity in sports performance; general training conditions specific training, and this process leads to the optimisation of sports training;
- clarity - in the selection of methods, means and techniques specific to the sport practised;
- the cyclicity of sports training - looking at the interdependence between the three major cycles: the macrocycle (2-12 months), the mesocycle (2-6 weeks) and the microcycle (5-12 days);
- ensuring results - thinking and implementing the right training process should aim for high sporting results;
- critical training load - the training process must facilitate the adaptation of athletes to the extreme conditions that may arise in competitive sport;
- Adaptability - the planning of the effort must follow the recovery requirements so as to ensure the continuation of the sports training process;
- uniformity and differentiated treatment - refers to the duration of training and the content adapted to the specificities and peculiarities of the individual and team;
- Feasibility of sports training - the planning and implementation of the training process should aim to achieve relevant sports performances.

1.3 Typology, programming and planning of sports training

The type of sports training depends on the specifics of the sport, in most cases several types of training are combined throughout the training process.

The most popular types of sports training are:

- continuous training - consists of exertion for longer periods of time in which the heart rate is maintained in the 60-80% range throughout the training session in order to optimise cardiovascular endurance and breathing capacity;

- Fartlek training - combines two types of training, continuous and interval, aerobic and anaerobic effort to optimise the speed and endurance of athletes;
- circuit training - aims to activate the major muscle groups by alternating exercises and intensity of effort and includes resistance exercises, strength exercises and speed exercises to increase muscle strength and endurance;
- interval training - combines short, high-intensity efforts in the anaerobic zone with periods of rest and recovery;
- weight training - the use of external loads in the form of weights to increase strength with a direct impact on increasing skeletal muscle size;
- plyometric training - includes rapid muscle extension and contraction movements to improve muscle strength;
- speed, agility and reaction training - aims to reprogram the athlete's neuromuscular components to perform multidimensional movements.

Sport training is based on three complex processes through which content is quantified and scaled to achieve set performance goals, namely:

- design;
- planning;
- periodization.

The competition calendar summarizes all internal and/or external competitions by age category and level of training at national level, the reference competition is the National Championship scheduled annually with a view to designating the national champion. The National Championship ranks the values every year, and the competition calendar is established according to it (Enoiu R, 2014, p.10).

The relevant planning features are:

- the specific objectives stipulated in the training plans are identifiable by: numerical indicators, which provide quantitative evidence that can be represented graphically in order to identify intuitive and relevant aspects in case of control and comparison;
- the planning process ensures the action and interrelationship connections between the defining values of its model, the current plan and those of the programme, which show its dynamics over several consecutive years, on the one hand, and those of the operational plans, which distribute them in smaller sequences, on the other;
- the more time-restrictive they are, the more elaborate and detailed the specific components and elements of sport planning are, drawn up to highlight the functional links between them (Alexe, N, 1992, p. 134-156).

The comparison of the contents planned and concretized in planning documents with the reality of sports training and competitions requires a rigorous record, which thus ensures the conditions for critical analysis, the acquired efficiency and the only prerequisite for their subsequent re-editing on a scientific and practically experienced basis.

1.4. Trends to boost training in basketball

Basketball is a sport game with a wide variety of technical-tactical actions that contribute to the multilateral development of players. The succession and complexity of the phases of the game of basketball stimulates the creativity of the players in terms of the expression of their physical, technical and tactical potential.

The dynamism of the game is conditioned by the regulations, the creativity of the coaches, the dynamics of specific information technologies, the scientific and modern approach of the training methodology.

The game of basketball is subject to a continuous process of modernization both in terms of preparation and specific technique and tactics in attack and defense (Popescu F, 2012, p. 36).

Among the trends in the development and modernization of sports training specific to the game of basketball we list:

- Anthropometric aspects of the players, for example the increase in the average height of the players which is an important criterion in the selection and continuity of the team's preparation in the game of basketball;
- integrative approach to general and specific training by combining physical, technical and tactical training components specific to the game of basketball;
- The attack is manifested by technicality and efficiency and by performing the game actions quickly;
- the defence has become more dynamic in terms of aggressiveness and flow in response to the increased technical and tactical level of the players and the offensive and defensive play;
- raising awareness and motivation for training at all levels of basketball training;
- to make individual tactics and collective tactics more effective by using the motor, technical and tactical potential of basketball players;
- increasing the ability to adapt to the increased performance requirements and the specifics of sporting confrontations in relation to the collective and personal physical and technical possibilities of the players and the team;
- the dynamic manifestation of players' creativity in solving and adapting technical skills to the increased demands of today's basketball game;
- expansion of information technologies for monitoring and training the effort capacity and technical-tactical potential of athletes playing basketball;
- design and implementation of devices adapted to the learning and improvement of basketball technique with a major impact on sports performance;
- media coverage of the game in order to motivate children to play the sport.

1.5. Technical training in basketball

Technique customises sports games and influences sports performance. "Technique represents a system of motor structures specific to each branch of sport, carried out rationally and economically, in order to achieve maximum performance in competitions" (Dragnea A. and Mate-Teodorescu S., 2002).

The performance level of basketball players is influenced and determined by the importance and quality of technical-tactical training, together with physical, psychological and theoretical training in all categories of children and juniors. The technical training of juniors should focus on increasing the level of technicality and efficiency of technical procedures in relation to the multilateral sports training (Bădău D., 2006, p. 5).

The technical training of basketball players must be correlated with the dynamic trends of the game and the specific characteristics and performance objectives of basketball.

Raising the level of technical mastery of the sport must be a priority objective for specialists, especially in the initiation and junior period.

The increased biometric level of the players, from the initiation stage, facilitates the emergence of new variants of the basic technical procedures, which means the permanent adaptation of the training process on the principle of efficiency.

Increasing the pace of the game requires optimising the level of physical training and especially the technique of basketball players. The technical level of the players is best reflected in the moments of high commitment specific to current sports competitions.

Improving ball handling ability and possibilities in relation to technical and competitive requirements is an important concern for specialists and players. A good technical level coordinated with a capacity for anticipation and motor creativity are essential elements in making the process of technical expression more efficient in the game of basketball, at all levels of training.

In this respect, technical training must be carried out through a continuous and ongoing process on a scientific basis and in relation to current methodological and technological trends in sport. Sporting results are important, but in order to make them permanent, the entire training process must be based on expanding the physical and technical capabilities of basketball athletes.

The level of technicality is dependent on biomotor characteristics, motor skill level and sporting experience.

The technical training process should stimulate players towards continuous self-improvement and in this regard should target the following aspects (Guimarães, E., Baxter-Jones, A., Williams, A. M., Tavares, F., Janeira, M. A., & Maia, J. ,2021), Te Wierike SCM, Huijgen BCH, Jonker L, Elferink-Gemser MT, Visscher C., 2018):

- be stimulating and challenging for the athlete;

- to be carried out under the most varied conditions;
- create a concrete link between theory and practice;
- facilitate the transfer of technical skills to playing conditions;
- provide corrective and real-time feedback.

In basketball, which is a sport characterized by the execution of actions such as catching, shooting, passing, dribbling, etc., it is essential for players to possess excellent technical skills from an early age, which leads to a lower age of selection (Guimarães, E., Baxter-Jones, A., Williams, A. M., Tavares, F., Janeira, M. A., & Maia, J. (2021).

Chapter 2. DEFINING ASPECTS OF MOTOR LEARNING IN BASKETBALL

2.1. Motor learning - conceptual delimitations

The development of the athlete's personality involves a complex learning process that has direct influences on all aspects of behaviour. The learning process focuses on the acquisition of general and specialist knowledge, the formation of motor skills, the development of specific and transversal competences, etc. Learning underpins the development of all human spheres: emotional, intellectual, motor, language, etc. (Balint L., 2009, p. 5).

In the literature there are a multitude of interpretations of the phenomenon of learning. Correspondingly, there is also a multitude of definitions of this process. Among the multitude of these definitions can be cited that of the Russian psychologist Leontiev A.N. (1981), according to which: 'learning is the process of thinking about individual behavioural experience'.

This definition highlights several important characteristics. Thus through learning information and knowledge is accumulated, but at the same time through learning the thinking, feelings and will develop, and therefore the whole personality of the individual develops. It should also be noted that the entire psyche is involved in the human learning process.

The areas in which motor learning operates (Dragnea A., Bota A., 1999) are:

- automatic identification of sensory information (stimuli);
- selection and structuring of responses (improving the way choices are made and the particular parameters of motor action are determined);
- designing training programmes and implementing them in order to break in motor circuits;
- identify those systems that can constitute benchmarks for the level and fidelity of technical execution;
- control of all energy and mental resources by involving muscle mechanisms and analysers.

The performance of a movement is the result of interaction with the environment through which the movement repertoire is adjusted and adapted to the variation and change of environmental stimuli (external and internal). In motor learning, the subject develops rules for establishing movement parameters which allow him/her to reproduce and reconstruct the motor act or action whenever necessary, which facilitates the recording of motor progress in sport.

Schmidt, (apod A. Dragnea and Aura Bota, 1999), considers that the main parameters as component parts of a motor program are:

- cumulative duration of movement;
- the force developed to perform the movement;
- main direction of movement;
- amplitude and smoothness of movement.

2.2. Types of motor learning

The most effective types of motor learning specific to performance sport are: perceptual motor learning, effective motor learning and intelligent motor learning.

Perceptual-motor learning, also called sensory-motor learning, results in motor behavioural changes in relation to concrete exercise contexts specific to sports training. The subject who practises sporting activities reacts in the form of a preferred motor response, which can be perfected (e.g.: shooting the ball on the counter-attack in basketball). Perceptual images programme and regulate motor action. Correction of movements is achieved by performing a large number of movements based on sensory, kinaesthetic or proprioceptive components (Pew, R.W., 2021, p. 46-72; Rosalie SM, Müller S.A., 2012).

Actual or actual motor learning is based on a cognitive program as a result of the formation of dynamic stereotypes at the cortical level and involves a complex training process with an extensive number of repetitions that facilitates the formation of a higher technical level of practice (Dhawale AK, Smith MA, Ölveczky BP., 2017, Čoh, M., Jovanović-Golubović, D., Milovan, B. (2004).

Intelligent motor learning is characteristic of sports with elements of heuristic, creative action, such as sports games in which the subject must adapt his or her motor and technical behaviour to a series of specific, variable and dynamic factors such as: opponent, teammates, playing space, etc. (Apache, R., 2005; Bransford, J., Brown, A., & Cocking, R., 2000).

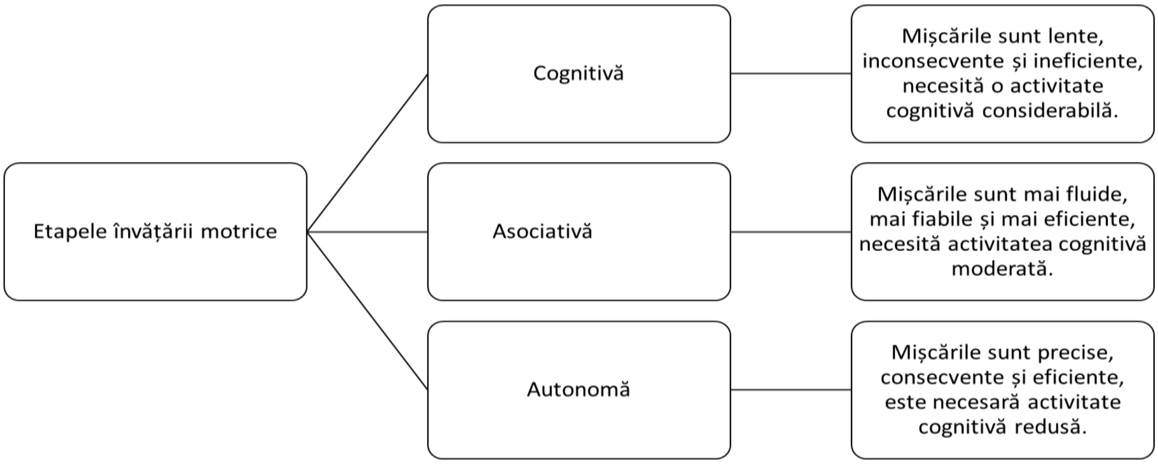


Figure 3. Stages of motor learning (Fitts, Posner, https://www.psia-rm.org/download/resources/fall_training/PSIA-RM%20&%20Fitts%20&%20Posner%20Stages.pdf)

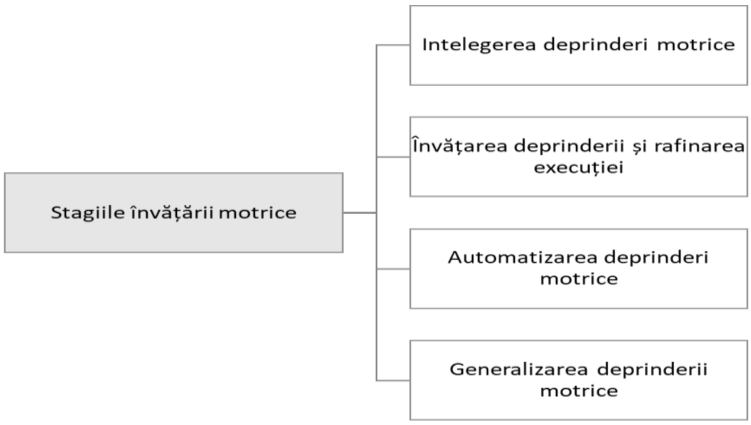


Figure 4. Stages of motor learning (Sigmundsson H., Trana L, Polman R., Haga M., 2017)

In addition to the three types of learning mentioned above: motor, perceptual motor and intelligent motor, we can and should also consider learning through awareness for learning sports technique, especially in competitive athletes.

This type of learning is carried out in three phases (Boulch Le J., 1995, p. 25-36):

- Exploration, which consists of becoming aware of the process and possible errors that may occur and shaping the overall picture in actions. The athlete processes the information through his/her own bodily experience, without a demonstration by the coach;
- dissociation, the phase in which the information is structured, based on previous motor experience, according to an overall scheme of the technical process;
- stabilisation, the phase in which action becomes automated and emancipated. These automatisms become flexible only through intelligent motor learning.

Learning can be facilitated by improving the athletes' ability to process information, i.e. the uncertainties that can enter into the composition of a task.

To accurately assess the degree of spatial uncertainty of a task, J. P. Famouse, 1985 (as cited by Balint L, 2015), has devised a spatial uncertainty scale:

1.high uncertainty - the target moves simultaneously in three spatial dimensions;

2.medium uncertainty - the target moves in two spatial dimensions.

3.low uncertainty - the target moves in one spatial dimension;

4.no uncertainty - the target is immobile.

The usefulness of this scale lies in the fact that it allows the level of difficulty of a task to be identified, so that steps can be taken up or down according to what is desired, in order to make the motor task easier or more complex.

In conclusion, it can be said that when an athlete acquires a motor skill, he does not learn the specific movement, but a set of criteria and methodical rules that allow him to adapt to the possible variations of the task and the application environment. To be able to respond appropriately to a task, the athlete must learn to identify very precisely the initial conditions of the task, choose the generalised programme and specify the parameters of these programmes.

2.3. Determinants of motor learning

Attention

General attention and especially the selective one plays an important role in motor learning, as it allows the senses to be directed towards important events that occur as the action unfolds and to avoid information that hinders the achievement of the goal (for example, when receiving a pass from a teammate it is important that attention is directed towards the ball until it is caught and only then should it be focused on another action - moving zone, passing feint, pass, etc.), thus ignoring a source of information likely to interfere with the main action).

Selective attention directs information with reference to short-term memory (SMM), which is a kind of workspace in which controlled information processing activities apply only to those stimuli that are significant at a given time.

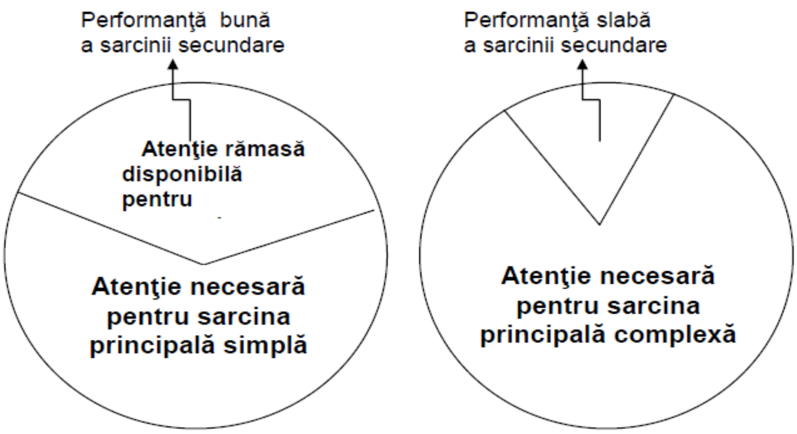


Figure 5. The attention available for a secondary task is lower when the primary task is more complex (J.P.Famouse, 1985, cited by Balint L., 2015)

It is difficult to focus on two motor tasks at the same time. Figure 5 shows how attention capacity should be distributed between a primary and a secondary task. When the primary task is relatively simple - meaning it does not require too much attention - more attention capacity remains for other tasks (Smidt, 1999, cited by Balint L., 2015, p.71).

2.4. Memory in motor learning

Memory is the basis of motor learning based on a complex process of analysis and comparison of previous experiences and motor skills with those achieved in real time. Mnemonic processes underpin learning and are essential in sporting activity, especially in performance. Motor learning is highly dependent on memory processes, which ensure the stability of information acquisition and motor skill acquisition.

Specialized literature nominalizes three different memory systems involved in human motor behavior and implicitly in motor learning: immediate sensory memory, short or short duration memory and extended or long duration memory (Figure 6., Smidt, 1999, cited by Balint L., 2015, p.69).

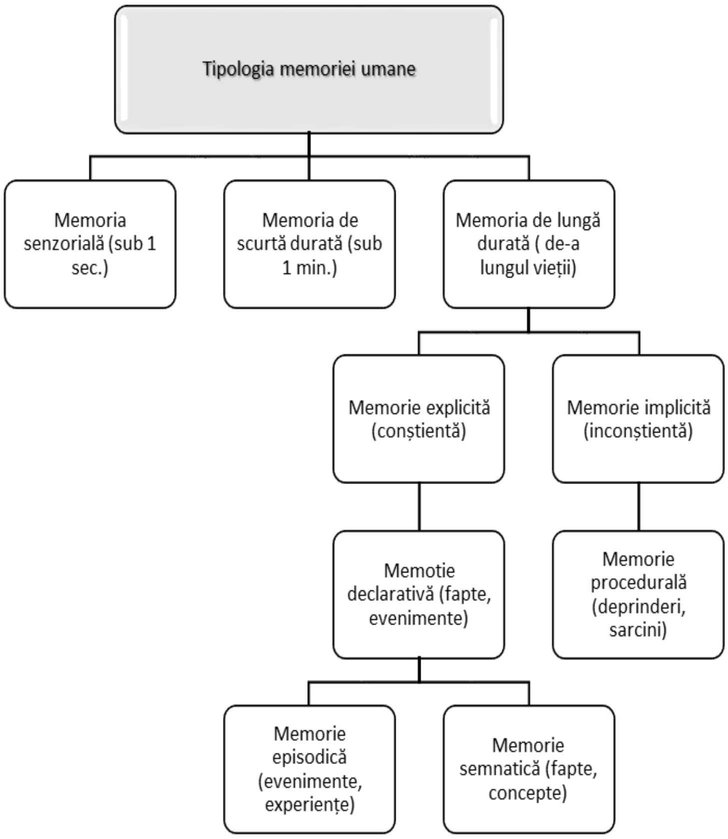


Figure 6. Typology of human memory (Smidt, 1999, cited by Balint L., 2015)

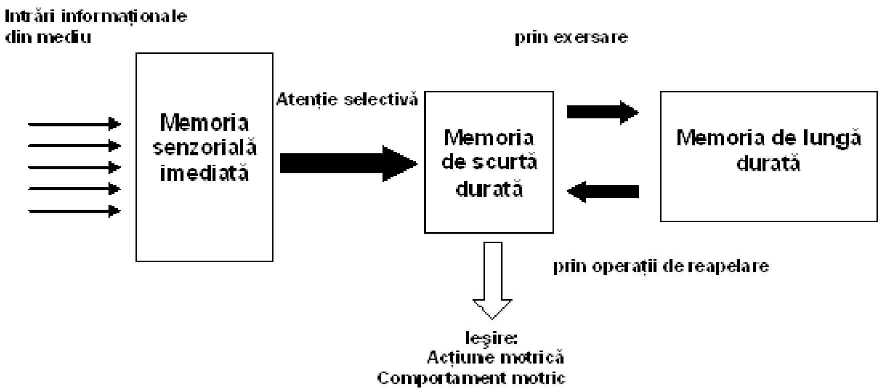


Figure 7. Components of human memory (Smidt, 1999, cited by Balint L., 2015,)

Immediate sensory memory (ISM)- ultra short-term memory plays a role in recording and retaining relatively short-term information from human analysers that facilitates the selection of optimal information in relation to the existing motor context. MSI represents the peripheral, sensory aspect of memory.

Short-term memory (STM) - limited time memory

It represents a level of filtering in the recording and provisional storage of information facilitating the transition between sensory and long-term memory. However, not all information in sensory storage is lost/deleted, some of it - in fact a small amount of it - reaches the level of consciousness for further processing through a selective attention mechanism.

The rest of the information - contained in the MSI - is indeed lost, being replaced by more recent sensory information. The final selection for further information processing, depends on the relevance, significance or interest that the stimulus represents, in relation to the individual's current action (Smidt, 1999, cited by Balint L., 2015, p. 70).

Extensive long-term memory (ELM) - long-term memory ("memory - repertoire")

This type of memory is characteristic of the third compartment of memory, which is concerned with the mnemonic aspects of extended duration (MLD) and comprises stable, learned and systematically repeated information.

Experiments show that MLD is limitless in its capacity, a fact also confirmed by the enormous amount of information that can be stored for very long periods of time, much of which is never forgotten, even after many years of not being practiced (Balint L.,TIM, 2015, p. 73).

CHAPTER 3. FREE THROWS IN BASKETBALL - TECHNICAL AND METHODICAL ASPECTS

3.1. Technical aspects of free throws in basketball

Successful free throwing requires a focus of concentration against a backdrop of efficient biomechanics in the execution of the various procedures. However, biomechanical movement alone cannot be responsible for success in basketball-specific free throws, arguing that the percentage of valid throws in training is significantly higher than in the official game Kozar B. et al, 1995, p. 123-129). Rist C. (2000, p. 34-36) considers that there are two basic styles used in free throws:

- a throw that causes the ball to be pushed with the hand underneath it (overhand push shot);
- two-handed shot, with the ball supported from the top of the ball (underhand loop shot).

Experts believe that both throwing techniques should be learned. Two-handed shooting has a considerably lower angle of entry into the basket, but gives the ball better stability and can give it a more efficient backspin, supported with both hands. The reason for not adopting this technique of free-throw shooting is that players are more concerned with their image while shooting than with the efficiency of the free-throw.

The actual technique of free-throw shooting in the game of basketball, of pushing the ball from the bottom up is divided by the Canadian Basketball Coaches Association (1980, p. 111-112) into 5 phases:

- preliminary moves;
- initial position;
- the moment of force production;
- final position ;
- the follow throught movement - following the throw.

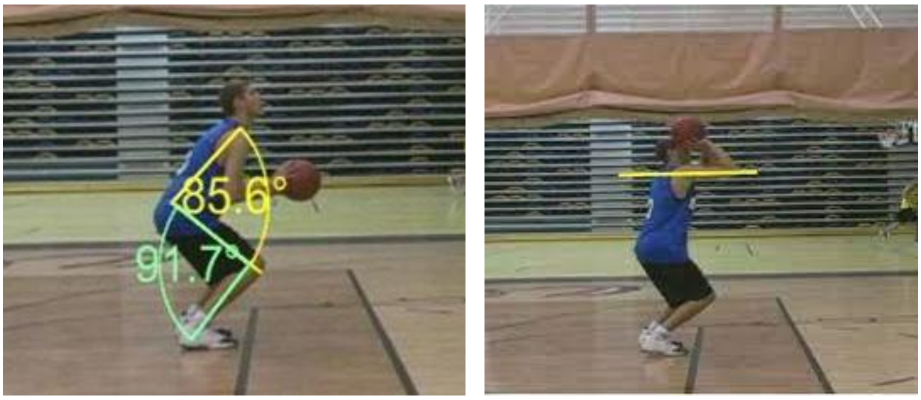


Figure 9,10 Free throw overhand push shot/underhand loop shot

3.2. Efficiency aspects of free throws

The success of a free throw is ensured by the coordination of specific movements in relation to the anthropometric aspects of the players, the posture during the throw, the trajectory of the throw and the different levels of consistency between the angle of the joints involved in the movement and the speed of the throw (Pakosz, P., Domaszewski, P., Konieczny, M., Bączkowicz, D., 2021; Verhoeven FM, Newell KM., 2016; Barzykina, I., 2017). The efficiency of free throws is dependent on the correctness of the throwing technique and the minimization of execution errors.

The main execution errors identified by specialists are (Verhoeven, FM., Newell, KM., Okubo, H. & Hubbard, M., 2006; Tran, C. M., & Silverberg, L. M., 2008); Stankovic, R., Simonovic, C., & Herodek, K., 2006):

- Poor body alignment - many free-throw specialists fail to align their hip, knee, shoulder and elbow with a line through the ball to the basket. If any of these joints are not aligned, the shot is more likely to be poorly executed and miss;
- lack of backspin - players often sidespin the ball on release; or otherwise do not apply any spin on release. Both errors will affect the flight of the ball and can cause the ball's trajectory to deviate on its way to the basket or to come back off the backboard and not fall into the hoop;

- wrong positioning of players who do not have enough flexion: shoulders, elbows, torso manifested by insufficient extension or flexion during the release of the ball and the trajectory often becomes too flat; a large body arch is necessary to ensure the trajectory of the ball so that the maximum area of the basket is used when the ball enters the basket;
- insufficient relaxation of the throwing arm, which should be fully relaxed during the finishing motion; too much contractile tension in the throwing arm muscles will interfere with the smooth release of the ball and shorten the follow-through;
- Incomplete follow-through after the shot - players should finish the position of the throwing hand completely, with the arm pointing up and the hand pointing directly at the basket. Interference from the non-throwing hand, so the free hand is pronated or supinated on release and may deflect the ball out of alignment with the basket;
- the throwing force is too high. When a player is excited or tired, they can release the ball hard and fast and it will usually bounce off the hoop and miss the basket;
- too much tension in the throwing arm, so the throwing arm should be in full shoulder flexion, with elbow extension and wrist flexion facilitating release of the ball. If the muscles are strained it can decrease the range of motion of these joints and interfere with the success of the throw;
- momentum when jumping at the wrong angle, the player takes off or lands at an angle to the floor - either forward or backward - which will cause an off-center jump and cause non-vertical forces to be applied to the ball. The jump and landing should occur on the same tracks;
- torso lean when releasing the ball, so the player leans either forward, backward or sideways during the release of the ball which will produce an off-centre force on the ball on release.

Real-time correction and elimination of execution errors is the essential prerequisite for making the free-throw motor learning process more efficient. The more execution errors are reduced, the greater the chance of scoring free throws.

3.3. Basketball free throw biomechanics

The analysis of the technical elements specific to basketball must be carried out in relation to the regulatory provisions, the interrelation between the components of sports training and the dynamics of evolution and development of the technique and tactics of the game of basketball (Ghițescu I.G, 2016, p. 15).

The shot is the main finishing action and the one that makes the basketball game so spectacular. The technical execution of free throws requires complex body and neuromuscular coordination.

According to the regulations, the free throw may be made from the ground and with the release from the ground, but it is not allowed to cross the free throw line.

The free throw is usually made from the middle fundamental position with the ball supported manually with an asymmetrical grip on the chest in front of the chin. The throwing arm is flexed at a 90 degree angle and the other hand supports the ball from the side for balance. The head position is neutral with the gaze focused on the ring on the basketball backboard. The lower limbs in full plantar contact with the ground are shoulder-width apart, and the leg on the dominant arm side may be placed slightly anterior to the other leg, and the bipod distribution of body weight is symmetrical and equal.

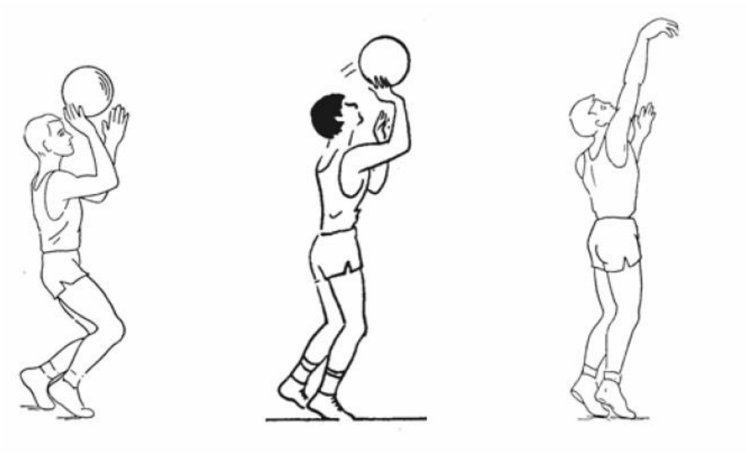
The actual execution is initiated by a triple flexion of the lower limbs, simultaneously with the upper limbs being brought up and the correct positioning of the ball in the palm is sought. With a controlled thrust, the ball is pushed as a result of a sharp palmar flexion followed by the whipping specific to the free-throw throw with the non-dominant arm providing protection.

The end of the free-throw movement consists of the full extension of the body with a slight lift on the toes and with the body oriented forward - upwards, the palm of the hand has the fingers turned towards the ground, the index and middle fingers are oriented in the direction of execution of the throw, being the last ones to be in contact with the ball.

The entire muscular system is involved in making free throws in basketball, influencing the power, accuracy and effectiveness of the shot. The forces involved in the shot initiate in the lower limbs, running through the entire body, and end in the arms, specifically the fingers to determine the optimal speed and force of throwing the ball into the basketball hoop (Blazevich, A. J., 2013; Hubbard, H., & Okubo, M., 2006).

Table 2. Percentage contributions of body movements to ball speed during free throws. (Miller, S. and Bartlett, R.M.,1996).

Movement	Percentage share
Flexion of the fist joint	59%
Elbow joint extension	8%
Flexion of the scapulohumeral joint	14%
Flexion of the hip joint	6%
Knee joint extension	-2%
Ankle joint extension	15%



a) b) c)

a) poziție inițială, b) poziție intermediară, c)poziție finală

Figure 11. Shooting from the spot (Haba S., 2010, p. 35)

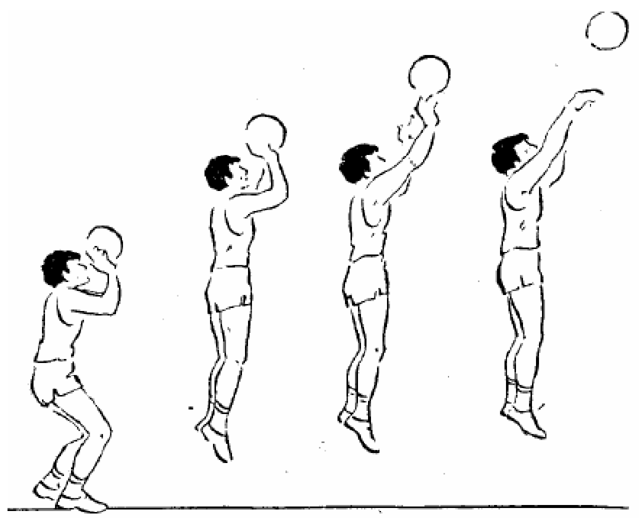


Figure 12. The jump shot (Haba S., 2010, p. 43)

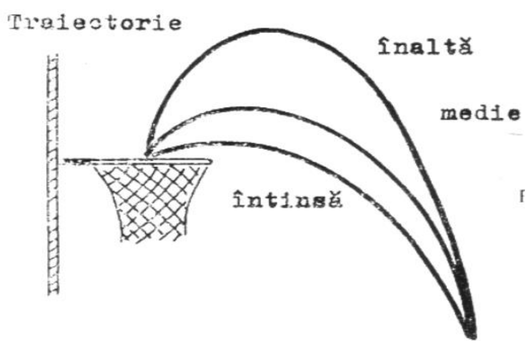


Figure 13. Types of trajectory of the shot

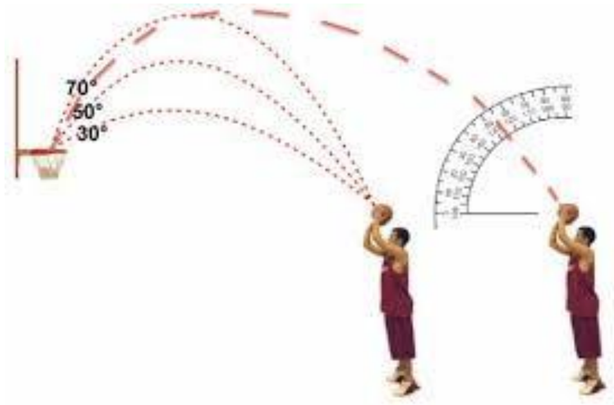


Figure 14. Angular variations of the ball trajectory in free throws (http://biomechanicsbasketballjumpshot.blogspot.com/2015/06/blog-post.html)

3.4. Graphical analysis of the initial position of free throws

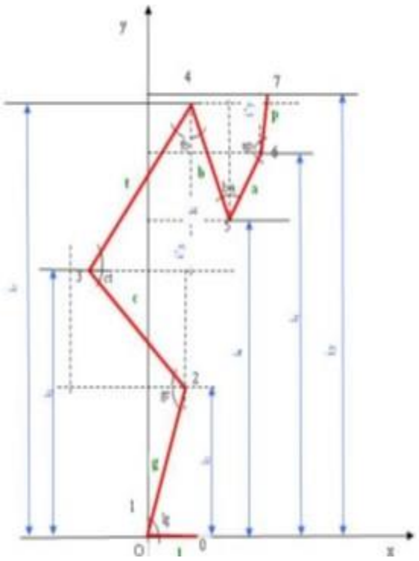


Figure 15. Graphical representation of segments in initial position at free-throw

The graphical analysis of basketball free throws is predominantly marked by initial position, segmental position analysis, body angles, and the usual elevations and heights are as follows:

l - the length of the foot;

- the angular value between the paw and the leg;

g - length of the calf;

c - thigh length;

- the angular value between the leg and the thigh;

t - the length of the trunk;

- the angular value between the thigh and the torso;

b - the length of the throwing arm;

a - the length of the throwing forearm;

- the angular value between the arm and the forearm;

p - the length of the throwing palm;

- angular value between forearm and palm;

i3-7 - Pi - height of knee, pelvis, elbow, shoulder, fingertips and ball in relation to the line of support (ground).

3.5. Forces on the ball in free throws

The main forces that are manifested on the ball in basketball shooting are (Barzykina, I., 2017):

- gravity;
- buoyancy;
- air resistance;
- Magnus force.

The force of gravity on the basketball is equivalent to the Earth's gravitational acceleration where g = 9.81 m/s.

Buoyancy or buoyancy force acts in the opposite direction to gravitational force and is conditioned by the air pressure above and below the basketball. Buoyancy has the effect of offsetting gravity by 1.5% (Beuoy M., 2015). Gravity and buoyancy act on the basketball regardless of how it is moved.

The air resistance force, also called air drag, is opposite to the direction of the ball and is determined by the throwing speed, the air density and the contact area of the hand on the ball.

The Magnus force has been identified as the force manifested perpendicular to the direction of translation and aims at unbalancing the ball, manifesting itself as a non-uniform frictional force. The non-uniform friction of the Magnus foul is caused by the different pressures manifested on the side where the ball is in contact with the player's hand relative to the free side of the ball.

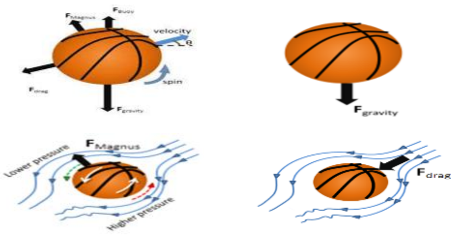


Figure 16. Forces acting on the ball in free throws (Cruz-Garza, J. G. 2014, https://physicsofbasketball.wordpress.com/2014/05/18/forces-acting-on-a-basketball-in-flight/)

3.6. Technical execution errors in making free throws

Execution technique is essential in making free throws more efficient, and players focus in practice on the aspects of correct body alignment and optimal shot making in terms of trajectory, speed and accuracy of execution. In this context the identification of execution errors requires concrete and rapid intervention to optimise free throws. We will try to identify them and systematise them according to two elements: body alignment and technical form of the free throws.

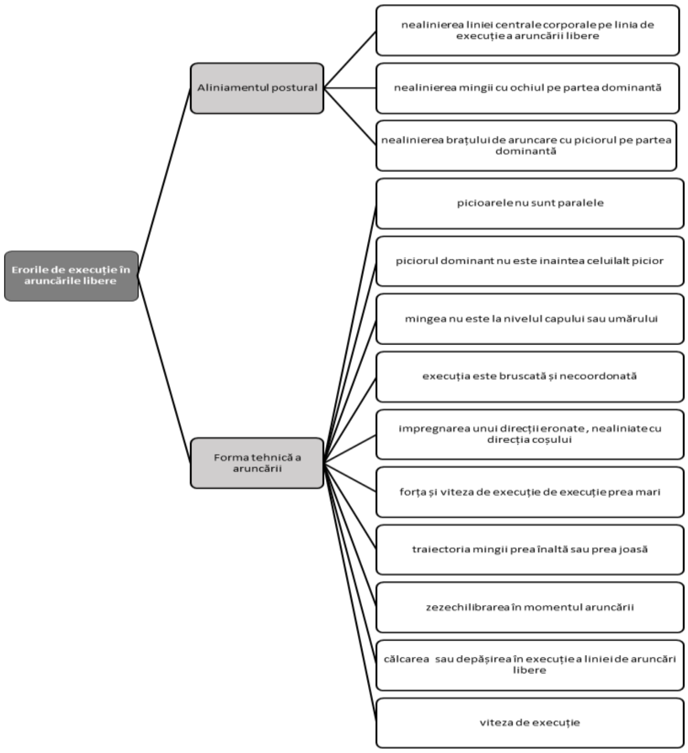


Figure 17. Execution errors in free throws (personal contribution)

3.7. Regulatory aspects of shooting free throws in basketball

In making free throws, players aim to achieve technical perfection and score the point. Free throws in basketball are regulated in a special chapter in the rules concerning both the positioning of the shooter and the players in the chase, the time of execution and positioning during execution, etc..

According to the rules of the game of basketball, a free throw is a chance given by the referee to score one or two extra points as a result of an error by the opposing team's players.

As a rule, the free-throw is taken by the player who has been fouled, without the intervention of the opponents and without their opposition. According to the rules in force, the throw is made from behind the free-throw line, from a distance of 5.80 cm from the inside edge of the baseline. The main variants of the free-throw procedures are:

- with two hands from below;
- with two hands at chest level;

– with a hand from shoulder level and others.

The total number of free throws as well as possession of the ball is defined as a set of free throws as a result of a single personal and unsportsmanlike error by an opposing player. The free throw may be made as a rule by the fouled athlete or by another teammate under special conditions stipulated in the rules.

The execution of free throws must comply with a number of regulatory guidelines among which we mention the ones we consider the main ones:

- the execution of the shot is behind the free-throw line inside the half-court of the basketball court;
- the shot can be made by any method so that the ball is directed directly to the basket;
- execution must be within 5 sec after the referee's bid;
- the player is not allowed to touch or step on the free throw line before the ball touches or enters the basket;
- simulations are prohibited;
- players to chase a maximum of 5, can be placed as shown in the following figure (Figure 19);
- Players in pursuit are not allowed to enter the restricted area until the ball is released;
- in the case of a set of free throws, the rebounding players are not allowed to enter the restricted area.

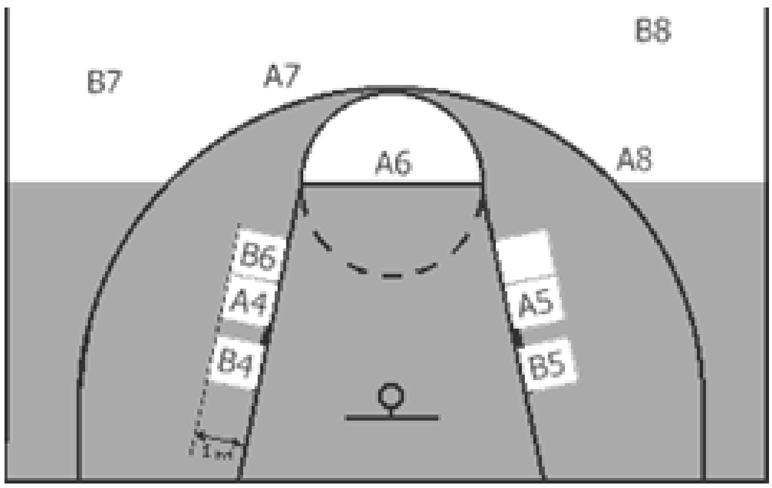


Figure 18. Players' positions during free throws (https://fny.scrieunblog.com/articles/aruncare-libera-in-baschet-cultura-fizica-si-sport.html

6. Final conclusions

General conclusions of the research itself

The processing and analysis of the results of the research itself allowed us to formulate the following relevant conclusions to the topic:

- The general hypothesis of the research was confirmed**,** thus the implementation of the innovative device designed and intended to improve the free throw, called "System and device for sport-specific motor learning and how to use it - System and technical device for motor learning process in the field of sport science and physical education with direct applicability in basketball-specific training - improvement of free throws" in the training program at junior level has led to significant improvements in the technique of execution, which is reflected in the efficiency of basketball-specific free throws at the level of U14, U16 and U18 male and female juniors.
- Following the analysis of the final research results, the specific hypotheses were confirmed, as follows:
  - Through the implementation of the innovative device designed for motor learning, the efficiency of free throw shooting under test conditions has improved at U14, U16, U18, male and female junior level;
  - Comparative analysis of three categories of male and female junior samples showed a positive dynamic in the efficiency and progress of the experimental groups compared to the control groups following the implementation of the innovative device designed to improve free throw shooting;
  - Heart rate dynamics assessed by a pulse oximeter decreased during the motor tests in the male and female experimental groups, indicating good physical condition;
  - The identification of execution errors of the male and female experimental groups allowed their correction in real time using the innovative system designed and implemented in this research;
- The effectiveness and timeliness of the implementation of our innovation was confirmed by the differences in efficiency and progress of the male and female experimental groups compared to the control groups in all age groups U14, U16 and U18;
- the implementation of our innovative system has facilitated the correction and reduction of the number of execution errors, which can have a positive and direct impact on the accuracy and therefore on the efficiency of free throw execution and on the increase of the players' technical mastery;
- Heart rate analysis highlights that heart rate decreased during the tests, showing that the male and female experimental groups are in good physical condition and have good recovery capacity after exercise.

Conclusions specific to the research itself

For all motor tests, statistical analysis of the recorded results shows that the results of the male and female experimental groups for the age categories U18, 16, U14 were statistically significant, with significance threshold values lower than the 0.05 reference value set for this final research.

In all motor tests, the male experimental groups showed superior progress compared to the male controls, which we will detail below.

Original thesis-specific contributions

Basketball training is a very complex theoretical, methodological, technological, evaluation etc. approach that is focused on performance objectives and on improving the motor capacity and technical level of each individual athlete and the basketball team as a whole.

In the theoretical part of the paper we have analysed and structured the main conceptual aspects that refer to free throws, namely: technical training in basketball, the motor learning process, the implications of information technologies in monitoring and improving free throws, etc.

As part of this investigative approach we identified and systematized a number of execution errors that negatively influence free throw shooting. We systematized the execution errors according to two elements:

- body alignment;
- the technical form of free throws.

Among the trends in the improvement of the game of basketball is the expansion of the possibilities of using information technologies with a focus on the analysis of essential parameters of the preparation specific to the game of basketball. Analysing the typology of information technologies used in basketball according to their specificity, we systematised them into two categories:

- specific;
- adapted.

We have also been able to establish the main benchmarks for free throw analysis with the help of information technologies that relate to:

- posture analysis;
- body movement analysis;
- ball trajectory analysis;
- analysis of optimum throwing distances;
- analysis of interaction forces;
- angular analysis of body segments and the ball;
- analysis of casting speed;
- analysis of throwing technique;
- analysis of execution errors.

Based on the literature review and scientific studies, we identified the impact of using information technologies in basketball contributing to:

- optimising motor performance;
- Improved execution and technical capacity;
- increase the effectiveness and efficiency of free throws;
- correction and elimination of execution errors;
- streamlining the process of specialised and individualised free-throw preparation;
- increasing the chances of winning matches.

In the preliminary research, as an evaluation tool we developed and implemented a questionnaire called - "Model Questionnaire of Specialist Opinion on the Impact of Free Throw Shooting in Basketball" which included 14 items and was applied to basketball specialists to highlight the role and necessity of using information technologies in the process of free throw shooting in basketball.

For the preliminary and final research we designed and implemented 3 motor tests to highlight the efficiency and progress of basketball-specific free throws in juniors in the experimental and control groups, which were as follows:

- Test 0 (personal contribution);
- Shoot - Run test (personal contribution);
- Test 10 experimental throws (personal contribution).

In the final research, as evaluation tools, we added two evaluation tools to the preliminary experiment:

- a functional test using a pulse oximeter to monitor heart rate during free throws
- an observational evaluation to identify the main execution errors, the causes and ways of correcting free throws.
- The functional and observational observational test was applied only to male and female experimental groups.

We consider that the most important contribution of the present thesis consists in the implementation and identification of the efficiency of the innovation that refers to a motor learning device characteristic of the sports training process (free throw in basketball) that realizes the real-time display of the trajectory of the ball to the basket in the flight phase, on a projection plane on which the optimal customized trajectory is graphically indicated.

The innovation concerns the development of a "System and technical device for motor learning process in the field of sport science and physical education with direct applicability in basketball specific training - free throw improvement" (see Annex 1). The innovation was applied only in the training process of all male and female experimental groups. It was also used in the initial and final motor testing process of the experimental and control sample towers. The results of the preliminary research and especially those of the final research helped to identify the effectiveness of the implementation of the innovative system in terms of improving the free-throw shooting efficiency of junior basketball groups in the categories: U14, U16 and U18, male and female.

Recommendations and research directions for future studies

The recommendations and future research directions that we consider opportune for the training of basketball athletes in the process of perfecting free throws in basketball that have emerged as a result of the analysis of the research approach of this PhD thesis are the following:

- Recognition of the innovative system proposed by us by the Romanian Basketball Federation and its implementation in the free-throw preparation of the junior and senior national teams;
- acceptance of the inclusion of the proposed and validated motor tests in the preliminary and final research approach within the FRB test battery;
- extension of the research to other age groups by implementing the innovative system and applying the validated novel motor tests in the preliminary and final research;
- Dissemination of our research results on the possibilities of improving free-throw shooting efficiency as a result of the implementation of the innovative device to sports academics and school and senior sports clubs;
- the use of our proposed innovative device in the process of sports training of juniors and seniors in order to become aware of and correct execution errors in real time in order to perfect sports mastery.

Research limitations

As a result of the research approach we identified the following research limitations:

- The study did not record the effectiveness of free throws in real game conditions as a result of the implementation of the experimental program using our patented innovative system;
- Another limitation of the research concerns the lack of other studies addressing the same theme and research structure in order to carry out a comparative analysis that would facilitate the validation of our results;
- the relatively short duration of the implementation of the pilot programme;
- The study investigated the effectiveness and progress of free throws through the implementation of the innovative system in the sports training process in the three age groups, without correlating these results with the competitive results recorded by the teams participating in the study.

Dissemination of results

1. **Olteanu M, Oancea BM, Badau D.** (2022) Improving Effectiveness of Basketball Free Throws through the Implementation of Technologies in the Technical Training Process. Applied Sciences. 2023; 13(4):2650. https://doi.org/10.3390/app13042650IF= 2.838
2. **Olteanu M, Oancea BM, Badău D**. (2022). A study on the dynamics of heart rate when executing free throws in basketball, Bulletin of the Transilvania University of Brașov, Series IX: Art - Science of Human Kinetics - Vol. 15 (64) No. 2 - 2022, ISSN2344-2018,p.29-36. https://webbut.unitbv.ro/index.php/Series_IX/article/view/2922/2312
3. **Olteanu M, Oancea BM, Badău D.** (2023) Impact of free throws in basketball, Health, Sports & Rehabilitation Medicine Vol. 24, no. 1, ISSN: 2668-2303, p. 16-21

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5. **Olteanu M., Bondoc-Ionescu D**., (2020). Comparative study regarding the importance of free throws in Romanian Superior basketball leagues, Bulletin of the Transilvania University of Brașov, Series IX: Art - Science of Human Kinetics - Vol. 12 (61) No. 1 - 2020, ISSN 2344-2018, p.73-78
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6. **Olteanu M., Bondoc-Ionescu D.,** (2020). Study about the impact of free throw in basketball games ended at the difference no greater than 2 points during the 2018-2019 Romanian's men's national basketball league season, Journal of Abstracts - International Scientific Conference - "Education, Sport and Health" ISSN: 2601-4998, p.34, http://www.defs.unibuc.ro/conferintaub/administrare/cpanel/file-manager/uploads/Revista%20conferinta%202020%20sport.pdf

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Annex 1. Application for a patent

OSIM Espacenet

Date bibliografice: RO136087 (A2) — 2022-11-29

SISTEM ŞI DISPOZITIV DESTINAT ÎNVĂŢĂRII MOTRICE SPECIFICE SPORTULUI ŞI MOD DE UTILIZARE

Inventator(i):	OANCEA BOGDAN [RO]; SERBAN IONEL [RO]; OLTEANU MIRCEA [RO] + (OANCEA BOGDAN, ; SERBAN IONEL, ; OLTEANU MIRCEA)
Solicitant(ţi):	UNIV TRANSILVANIA DIN BRASOV [RO] + (UNIVERSITATEA "TRANSILVANIA" DIN BRAŞOV)
Clasificare:	**- internaţional:** ***A63B69/00; A63B71/06*** **-cooperatve:**
Număr cerere de brevet	RO20210000228 20210506
Număr(numere) de prioritate:	RO20210000228 20210506

Rezumat al RO136087 (A2)

Invenţia se referă la un dispozitiv destinat învăţării motrice specifice sportului şi la modul său de utilizare. Dispozitivul, conform invenţiei, cuprinde o cameră video de mare viteză, care capturează traiectoriile unei mingi aruncate de utilizator, un soft destinat analizării şi înregistrării traiectoriei, un echipament de protecţie şi o suprafaţă de proiecţie a imaginilor capturate de camera video.

Annex 2. Agreement of the research team for the use of the patent

Acord

Prin prezenta declarăm că suntem de acord cu utilizarea propunerii de acordare a brevetului de invenție cu titlul „*Sistem si dispozitiv destinat învățării motrice specifice sportului și mod de utilizare*" de către colegul nostru Olteanu Mircea-Ionuț în realizarea tezei de doctorat cu titlul "**Studiu privind utilizarea tehnologiei informaționale moderne în optimizarea aruncărilor libere în jocul de baschet**".

Brevetul de invenție cu numărul de identificare la OSIM RO136087(A2) a fost conceput de către:

1. Oancea Bogdan, Universitatea Transilvania din Brașov
2. Șerban Ionel, Universitatea Transilvania din Brașov
3. Olteanu Mircea-Ionuț, Universitatea Transilvania din Brașov

Menționez că datele brevetului de invenție au fost menționate în conținutul tezei cu nominalizarea întregii echipe menționate anterior.

Semnatura de confirmare:

1. Oancea Bogdan
2. Șerban Ionel
3. Olteanu Mircea-Ionuț

16.05.2023

Annex 3. CS Magic Kids certificate

18/18.05.2023

ADEVERINTĂ

Se adeverește prin prezenta că domnul Olteanu Mircea-Ionut, student doctorand al Universității Transilvania din Brașov, a implementat propria strategie de îmbunătătire a procentajelor aruncărilor libere în perioada aprilie — iulie 2021 la sportivii componenți ai grupelor masculine de baschet cu vârsta cuprinsă între 14 și 16 ani din cadrul CS Magic Kids.

Prezenta s-a eliberat la cerere.

:: OPREA MARIANA

PRESEDINTE:

Annex 4. CSS Brasov certificate

INSPECTORATUL SCOLAR
AL JUDEȚULUI BRAȘOV

CLUBUL SPORTIV SCOIAR BRASOVIA

MINISTERUL, EDUCATIEI BRASOV

Nr. 424/18.05.2023

ADEVERINȚĂ

Se adeverește prin prezenta că domnul Olteanu Mircea-Ionuț, în calitate de student doctorand al Universității Transilvania din Brașov, a coordonat implementarea unui program experimental destinat îmbunătățirii procentajelor aruncărilor libere în perioada aprilie — iulie 2021, beneficiari flind sportivii componenti ai grupelor masculine feminine de baschet, cu vârstă cuprinsă între 12-18 ani.

Se eliberează prezenta spre a-i folosi la depunerea documentelor specifice elaborării tezei de doctorat.

DIRECTOR,
Prof. Leca-Negoi Ion-Bogdan

Leca B.