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MODERN TRAINING TECHNOLOGIES FOR THE OPTIMIZATION OF THE HURDLE RUNNING TECHNIQUE IN THE 110 HURDLES FOR JUNIOR ATHLETES

SUMMARY

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1.1.1 Hurdle sports training, complex instructive-educational process

The notion of sports training has taken on many meanings over time, some of them according to the author Ionescu-Bondoc D. (2008, p. 4):

- "physiologists often call training - the totality of the body's demands that determine a functional and morphological adaptation of it, materialized, in the end, by increasing the capacity for effort;
- more broadly, training means any highly organized training, with the aim of rapidly increasing physical, mental, intellectual, etc .;
- in sports, training means training athletes in order to obtain the best results in a certain sporting event ".

We can introduce the concept of sports training, which "includes the basics of training (the set of laws and principles that substantiate and condition the development of sports training) established by the theory of training, which structures the conduct and management of the training process". Ionescu-Bondoc D. (2008, p. 16):

According to Dragnea A. (1984, p. 21) sports training is a "complex bio-psycho-pedagogical process, planned, carried out systematically and continuously gradually, to adapt the athlete's body to intense physical and mental effort, necessary to achieve performance in competitions" .

In stage 1 of training, after selection, we point out that "children's trainability is the ability to adapt, more or less, the body, abilities that influence basic motor qualities, the cardio-respiratory system as a whole, especially the heart muscle, muscle metabolism as well as the psycho-physiological components. " E. Hahn, (1996, p. 89).

We also consider important the observation of T.O. Bompa (2002, p. 13) about sports training. He states that: "training is the manipulation of methods to induce adaptation. When adaptation reaches high levels, so does performance. Without a continuous increase of the physical adaptation of the athletes, the improvements are impossible "

1.3.2 Proprioceptive training in the athletic event of 110 m hurdles, the basis for the development of specific coordination capacity

Analyzing the coordinative abilities, it is indicated to study the role of the analyzers in achieving the psycho-neuro-motor efficiency that essentially plays the quality of everything we call human motor performance.

In all activities that require physical effort and coordination and even "in a broader sense, in everyday life, motor performance is based on the skills and flexibility of the sensorimotor system and the efficiency (accuracy and speed) of the relationships between perception and action. " (Salesse R., Temprado J. J., 2005)

Usually in athletics we talk about the following senses: hearing, seeing, tactile sense (kinesthetic). Please note that each of these senses is assigned to different cell types.

For "the sense of touch, five types of specialized receptors are considered: hair receptors, Merkel discs; Pacini corpuscles, Ruffini corpuscles and Meissner corpuscles (Sherwood, 2013) to which could be added Krause corpuscles sensitive to temperature variations, in the 110 m hurdle the sense of blockstart, the sense of the hurdle, the sense of the running surface (slag, material synthetic)."

Upon hearing, the receptors are of a single type called "hair cells", the sound quality and analysis are performed by the mechanical structure of the inner ear. Those cells also provide the sensitivity part when evaluating the movement of the head, which has a decisive role in developing the balance, related to the technical-tactical aspects that we perform.

Of the 5 senses that man has, without a doubt and perhaps sight is the most complex of all, which, apart from the receiving cells - cones and sticks, it also fulfills the role of analyzing the aspects it receives and by processing performed by neurons and performed by layers of Kolb cells.

1.5.5 Technical structure of the hurdle step – biomechanical aspects

In the vision of the authors Mihăilescu, L. and Mihăilescu, N., 2006 "hurdle runs are speed running events, which are characterized by interrupting the normal sequence of steps after a specified number of cycles, to introduce a characteristic element, namely the step over hurdle, it determines an efficient passage of the obstacles specific to these tests - the hurdles ".

The analysis of the technique of the sample of 110 meters hurdles highlights the following components: the technical element; technical style and basic mechanism.

The technical element is a "fundamental motor structure that underlies the practice of a branch of sport", Dragnea C. A. and Teodorescu, M. S., (2002, p. 166).

Mihăilescu, L. (2005, p. 25) conceives the current technique crystallized in two directions: "on the one hand due to the provisions of the regulation which fixes not only the height and number of hurdles, but also due to the need to cross obstacles without stopping".

The technical element is "an abstract notion" that is realized "through certain well-defined motor structures" (Dragnea C.A. and Teodorescu, M.S., 2002, p. 281 - 283).

1.6 Conclusions and theoretical considerations

We can note that during the sports training of hurdles in the junior category there were significant methodological changes in the approach to improving the technique, but especially in the introduction of modern methods and means of correcting and calibrating the running of hurdles. In this sense, we note the introduction of the means of proprioceptive training to influence coordination skills in order to optimize the passage over the hurdle.

These technical and biomechanical aspects are based on the detailed study of the specialized literature, of the latest appearances in the field and of the case study on the sample subjects of the 110 m hurdle test.

Due to its theoretical content, the chosen theme wants a modern approach to sports training in the 110 m hurdles category in the junior category, the optimal period for the accumulation of technical acquisitions in the specialization of the event.

The hurdle test, being an extremely technical one, the main causes of obtaining poor results in competitions are represented by the technical errors in the steps of the hurdle runners and by the lack of intervention means to improve and correct them.

We propose in the following to address the topic of optimizing the running of hurdles in the junior category through the prism of modern means of training, analysis and testing.

PART II
METHODOLOGICAL APPROACH TO PRELIMINARY EXPERIMENTAL RESEARCH ON THE TECHNICAL TRAINING IN THE 110 M HURDLES

2.1 Premises of some studies on the optimization of the technique in the 110 m hurdles

Sports training is a complex and procedural process, in which training

We can refer here, without a doubt, to the doctoral thesis of Mrs. University Lecturer. dr. Florentina Nechita, who under the guidance of Mrs. prof. univ. dr. Liliana Niculina Mihăilescu, from the University of Pitești, Faculty of Physical Education and Sports, opened, in 2011, in Romania, the road to the scientific research of the athletic event of 110 m. hurdles.

Publications with similarities in experimental research:

International kinematic studies of the hurdle running technique, which increase the efficiency of specific training for junior hurdle runners are not very numerous at present, but we can refer to an article by Lorenzo Arguello from 26.06.2012 entitled "The incredible motion capture technology olympic track star Lolo Jones uses to train will blow you away ", where a Red Bull research team led by director Andy Walshe with high-speed cameras up to 1500 fps support the technical preparation for the Lolo Olympics Jones in the 100 m hurdles. [6], a project also presented on youtube where we can notice the technology used as well as the methodology used. [7].

In this experiment, the famous athlete Lolo Jones states that if she can change something as small as crossing a hurdle, this means a small change to 10 hurdles, which can have a considerable impact on the final result.

The athlete's coach states that he brought the athlete to an excellent level of technique, and from now on the technical errors that cannot be seen with the naked eye must be corrected. That's why he thought of this experiment and slow-motion video analysis, to correct fine technical errors that can not be perceived at a glance.

2.2 The research approach through preliminary study

Starting from the main objective of verifying the effectiveness of the proprioceptive training program in basic research, we will use a preliminary study of the hurdle running step in which we will make kinematic recordings and analyze them using a high-performance software program, after which we will would like to establish the parameters, the phases of the hurdle running step that we will analyze, the number of subjects that we will study. After identifying these details in the preliminary experiment, we will use the analysis of kinematic recordings together with the coach and the junior category subjects, in order to identify the execution errors and to correct them in the next training program.

Based on these results obtained from the preliminary research, we will establish the purpose and objectives of the basic experiment, as well as the neural verification regarding the optimization of the hurdle running technique.

2.3 The purpose of the preliminary study

Pursuing the goal of improving training programs and the technique of hurdle runners, we resorted to the preliminary study using a proprioceptive development program, as well as kinematic recordings and their analysis using high-performance software. This analysis of the images allows us to identify the parameters of the phases of the technical execution of the hurdle running step and to identify the causes and solutions for the execution errors, in order to optimize it.

2.4 Preliminary research hypotheses

1. The optimization of the test technique of 110 m hurdles can be achieved by operational models from the age of junior in correlation with the requirements of high performance by the method of evaluation and monitoring of kinematic parameters with modern technology, method of identifying technical errors and accurately showing their causes .

2. The technique of hurdle running can be improved by optimizing coordination skills by introducing an individualized proprioceptive training program for junior hurdle runners.

The ability to balance in contact with the runway is the ability to keep the body in a stable position and to restore its balance after crossing the hurdle, with emphasis at the time of contact with the ground, on landing. It is decisive if the position of the body and the trajectory of the center of gravity, the grouping of the trailer leg allowing rebalancing from the moment of returning to the ground, the contact of the attack foot with the track being made exclusively on the track, the support surface being very small. of the running step.

2.5 Preliminary research tasks

From the point of view of the succession of the research process, the tasks we set out to pursue and accomplish are the following:

- establishing the model from the specialized literature;

- establishing research logistics;

- establishing the reference model in the preliminary research;

- elaboration of the recording activity and video analysis in the preliminary research;

- performing an analysis in which we will compare the subject of reference model and the subject of the experiment, recorded kinematically;

- elaboration of the individualized proprioceptive training program for optimizing the kinematic parameters that would contribute to the efficiency of the hurdle running step;

- observing the subject during the experiment;

- performing an analysis in which we will compare the parameters obtained by the subject after performing the individualized training program.

The training repeats a relatively small number of exercises, including those of a proprioceptive nature, designed to improve the aspects necessary for the required coordination skills. The means are close to the specifics of the test, thus allowing a more efficient training in order to participate in competitions.

The objective selection of means is made on the basis of measurements. There is a need to establish the degree of correlation.

"Objective selection is made by the modeling method that allows the schematic representation of a complex natural phenomenon through several essential characteristics, which generally condition the manifestation", Dotti, A. and Nicololini, J. (1992, p. 90).

The help of the modeling method consists in the possibility to appreciate a complex phenomenon, such as the one of preparation and participation in competitions, with the help of the quantitative evaluation on some main parameters (factors) of the respective activity.

2.6 Stages of preliminary research

Stage I - identification of scientific materials used to monitor technical training.

Stage II - identifying the equipment with which we will conduct the research.

Stage III - establishing the subjects

Stage IV - identification of the tools with which we will evaluate the kinematic parameters recorded video and processed by software, in the preliminary research.

Stage V - elaboration of a recording activity and video analysis of the reference subject in the preliminary research.

Stage VI - the analysis in which we will compare the subject of reference model with the subject of the experiment, videotaped.

Stage VII - elaboration of an individualized training program in the direction of improving the kinematic parameters in the hurdle running step.

Stage XI - the analysis in which we will compare the results obtained by the subject after going through the individualized training program.

2.7 Research methods

In order to achieve the proposed research and achieve the objectives, we will use a complex of representative methods. With their help and based on them, we will complete the proposed research:

- The method of studying the literature on the specialty of the research topic;

- Method of testing physical and morpho-functional development

- The method of pedagogical observation through video analysis

- Graphic comparative method of research results

- Method of pedagogical experiment and case study;

2.8 Concrete ways of implementing modern means of evaluation and monitoring in the technical training of the 110 m hurdles runner

The modern technological means with which we want to record and analyze the results are: a video camera that records and plays back images with a speed higher than 120 fps in FHD quality and a high-performance software with which to process and analyze video images in slow motion.

The video camera will be mounted according to articles and publications in the literature, so that it can provide the maximum capture efficiency of the frames that will be downloaded for analysis in a computer.

The video analysis software will insert the images in order to process them with the help of distance and angular vectors, so that concrete and relevant results can be obtained to correct the hurdle running technique in the junior athlete chosen as the preliminary research topic.

2.8.1 Organizing preliminary experimental research

The research was carried out within the Research Institute for quality of life and human performance within the Transilvania University of Brașov, represented by prof. Univ. dr. Carmen Gugu Gramatopol, Advanced Mechatronic Systems Research Center of Transilvania University of Brasov, represented by prof. univ. dr. eng. Marius Cristian Luculescu, in collaboration with specialist professor in mechatronic systems prof. univ. dr. Sorin Constantin Zamfira, product design, mechatronics and environment department, and prof. Doru Oprea, athletics coach and hurdle test specialist, in collaboration with Prof. Univ. Dr. Bondoc - Ionescu Dragoș.

Locations where the research was conducted:

- The junior training center, the sports base of the General School number 190, Bucharest, under the guidance of Prof. Doru Oprea, athletics coach and specialist in the 110 m hurdles.

- Poiana Brașov sports base, under the guidance of prof. Univ. dr. Dragoș Ionescu - Bondoc, athletics coach and specialist in the 110 m hurdles event, former coach of the Romanian national athletics team

2.9 Organizing and conducting preliminary research on a runner in the 110 m hurdles

2.9.1 The organization of preliminary research

- The video recordings take place on the athletics stadium of the Poiana Braşov sports base.

- The processing of video recordings is performed in the laboratory of the Faculty of Mechatronics within the "Transilvania" University of Braşov.

- The training locations of the athletes included in the research were: Athletics hall "Iolanda Balaş" Bucharest, gymnasium of school 190, Bucharest, athletics stadium of the sports base Poiana Brasov, training center of the National Olympic team.

We can say that we will complete the strategic planning proposed in the experiment, which is a relevant one and which needs a research based on evaluation, starting from the result, giving the possibility to compare the model subject and the subjects in the research. Basic.

The research used the initial evaluation, which includes an evaluation of the training of hurdle runners, and the final evaluation made in smaller stages, which makes it possible to identify and analyze the mistakes of technical procedures, as well as agreeing corrective measures for technical mistakes. and which are a generally valid expression at the end of the preparation stage.

We mention that these forms of evaluation are accompanied by monitoring the kinematic parameters involved in performing motor actions when crossing the hurdle, following the evolution of performance and factors involved in increasing it, and the evaluation data are a dynamic process with a permanent character.

The present analysis aims to highlight the interaction between the three moments, the hurdle attack, the crossing over the hurdle (flight) and the landing.

The measurements made with the help of these devices are important information in order to establish an optimal training regime and implicitly to optimal results of performances in the competition by eliminating wrong gestures and movements, forming new reflexes in the conditions of technical correction.

Mihăilescu, (2008, p. 24) defines the organization as a "managerial function through which are inventoried the actions of technical, managerial, economic, etc., managerial resources, ensures us a grouping and a rational combination of them at the level of the organization and of the work compartments within links of authority, cooperation and information in order to achieve the objectives in the best possible conditions ".

Strategic research planning involves a systemic process of establishing objectives, the strategy necessary to achieve them, as well as interdisciplinary actions carried out during research on the implementation of the strategy (Mihailescu, N. and Lador, I., 2008, p. 54) .

2.9.2 The elaboration of an individualized proprioceptive program for physical and morpho-functional development

The experiment was continued, after analyzing and evaluating the results of the records that made it possible to find and study errors in physical and technical training, to take corrective action for them. In order to make the corrections, we established an individualized training program, suitable for the specific physical training in the junior hurdle tests.

The training program in athletics sports training, the 110 m hurdles event, addresses a proposed model, which corresponds to individualized training according to age, applied by specific and non-specific means.

Keeping in touch with the subject's coach, this training program needs to be drawn up as faithfully as possible, so that the finality is the desired one.

The realization must have as objective the adaptation of the plan to the environmental conditions (running surface, temperature of the external environment, physical development apparatuses, supportive of effort, conditions of neuro-muscular and metabolic recovery). Nutrition must be in balance with the effort of athletes running hurdles.

2.9.3 Conducting the preliminary experiment

The period of conducting the research experiment: 01.03.2018 - 31.10.2018

The non-specific and specific training according to the proposed training plan took place at the Poiana Brașov sports base and the Metrom Brașov athletics hall.

Initial preliminary testing: 02.03.2018 at the Poiana Brașov sports base.

Preparation period: 05.03.2018 - 25.10.2018

Final preliminary testing: 26.10.2018, at the Poiana Brașov sports base.

2.9.7 Interpretation of kinematic recordings from the preliminary study

We made the recordings with a hurdle runner, junior champion in the 110 mg test. We specify that an individual characteristic of the athlete (M.R.O.) is his height of 1.96 m., Which requires a very important control for the contact foot and impulse, a correct attack with an optimal angle between the chest and the thigh of the attacking leg with a pass. as radiant as possible in which the height of the CGM must be appropriate to the plane of the hurdle hurdle and to the level of the runway.

Lateral recordings were made to capture as accurately as possible the angles and distances within the phases of crossing the hurdle.

The camera was placed at a distance of 7 m. From the hurdle and at a height of 1.20 m., Leaving the plane on the left 4.55 m. And on the right 5.05 m. In order to capture as much as possible. much more faithful from the phases of crossing the hurdle, and at 5 m. and 1.20 m. height for the frontal plane. (Ilie, M., 2010, p. 4).

All corrections were made during the preparation period (individualized proprioceptive training) starting with March and ending with the basic competition - the national championship.

The technical execution of the subject of the preliminary study in the initial test, compared to the technical execution in the final test, has the following parameters:

- Methodical instructions: 1. It is recommended to automate a detachment in front of the hurdle from a greater distance for a smoother flight and better control over it. 2. Lower ground contact when landing behind the hurdle.

- the distance from the impulse point to the hurdle plane is 2.12 m. initially and 2.28 m. final distance favoring the grazing passage. The subject ran better on the first part before the hurdle and the detachment was made from a greater distance from the hurdle, which determines a better control over the center of gravity of the body mass and a smoother passage.

- the initial pulse angle is 123°, compared to 120° in the final test, very little changed as a result of the distance from which the pulse is made. This will promote better control over the flight and a more balanced landing behind the hurdle. (fig. 19).

Fig. 19 - Comparative vector representation of the F1 distance and angular parameters of the preliminary study subject - initial testing vs. final test

- the vertical height of the CGM is 1.29 m. in the initial test, compared to 1.34 m. in the final test, we will find that the CGM does not go over the hurdle more quickly, which will determine a longer flight and a distance higher than the landing hurdle, but will favor a more controlled and balanced landing. (fig. 20).

Fig. 20 - Comparative vector representation of the F2 distance and angular parameters of the subject of the preliminary study – initial testing vs. final testing

- the landing after the hurdle is correct in terms of the angle of the landing leg at a distance of 1.05 m. initially, compared to 1.20 m. final, which denotes optimization in terms of space-time efficiency, but also of a more balanced landing due to better control of spatio-temporal parameters.

- also, the angle at which the subject lands in the final testing (82.4 degrees) compared to that in the initial testing (83.7 degrees) is closer to the absolute model. (fig. 21).

Fig. 21 - Reprezentarea vectorială comparativă a parametrilor distanțiali și unghiulari F3 ai subiectului studiului preliminar – testare inițială vs. testare finală

- we note that due to the more efficient landing, the departure angle in the second step after the hurdle is almost identical, at 127.9° initially compared to the final 130.4° angle, however still quite far compared to the model of the Olympic champion after Milan Coh, (2003) where the angle of the analyzed world champion has the value of 121.32°.

Fig. 22 - Comparative vector representation of the F4 distance and angular parameters of the subject of the preliminary study – initial testing vs. final testing

In order to have a better control and a more relevant representation of the evolution of the spatio-temporal and angular parameters, but also a more concrete framework in setting the objectives to be achieved, I chose the model of the world record holder in the 110 m hurdles event, analyzed by Milan Coh in 2003. [11]

Table 24 - Absolute model kinematic parameters

No.	**Kinematic parameters 110 m. hurdles**	**Values**
1	Raising the C.G.M. ground level (m.)	1,52
2	Maximum elevation of C.G.M. over the hurdle (m.)	0,45
3	Size of angle of attack (degrees)	107
4	Size of landing angle (degrees)	79
5	Flight time (sec.)	0,36
6	The horizontal distance from which the attack starts from the hurdle (m.)	2,09
7	Horizontal distance of the landing from the hurdle (m.)	1,58

In the athlete's training program, a program was introduced in the months of November-December twice a week, 20 minutes of special fencing exercises with the technical study of control and correction by the coach and conscious self-control by the athlete, with permanent communication through dialogue with the coach.

Table 25 – Comparison of preliminary subject kinematic parameters vs. absolute model

No.	Parametrii cinematici - 110mg.	IT	FT	Model values
1.	Raising the C.G.M. ground level (m.)	1,29	1,34	1,52
2.	Maximum elevation of C.G.M. over the hurdle (m.)	0,27	0,28	0,45
3.	Size of angle of attack (degrees)	123	120	107
4.	Size of landing angle (degrees)	84	82	79
5.	Flight time (sec.)	0,33	0,34	0,36
6.	The horizontal distance from which the attack starts from the hurdle (m.)	2,12	2,28	2,09
7.	Horizontal distance of the landing from the hurdle (m.)	1,05	1,20	1,58

2.10 Conclusions and recommendation of the preliminary research

2.10.1 The conclusions of the preliminary research

- We find that 6 out of 7 values of the kinematic parameters in the final testing of the subject of the preliminary testing are close to the values of the world champion model, and these, corroborated with the progress obtained in the specific tests, lead us to affirm that the first hypothesis regarding the objectification of training by establishing of a model and the correction of technique mistakes through analysis, observation and tracking of kinematic parameters considerably support the technical optimization of the hurdle runner's stride.

- We note that individualized proprioceptive training with correction and self-correction can be a condition for fixing the specific coordination capacities of technical tests and automatization of movements, which denotes more safety in the technique of the hurdle runner step and greater constancy in performances competitive, an aspect that confirms the second hypothesis of the preliminary testing.

- The evaluation and monitoring of technique are complex stages that involve the use of technologies to optimize motor structures at the level of kinematic parameters, through which to scientifically direct technical training, to be able to correct individual mistakes, in order to increase sports performance.

- The performance level at which they are now competing in the 110m event leads us to affirm that such performances require a long training process, which is based on some effective objectives at the level of the specific components of the 110m hurdles event, implicitly the technical training in hurdle runner step phase.

- The first hypothesis is confirmed, the use of an absolute model of the world champion in the 110 mg test is a useful method in monitoring the technical performance of junior hurdlers, and also analyzing and correcting technical execution errors using the kinematic records processed by powerful software.

- The second hypothesis is confirmed, with proprioceptive training tools proving extremely effective in increasing the performance of junior athletes in the hurdles, the most technical part of the 110m hurdles event, where balance and coordination capabilities play a role fundamental role.

2.10.2 Preliminary research recommendations

- We recommend the regular use of kinematic recordings processed with the help of high-performance software, which the coach should study with the athlete to find solutions for optimizing and streamlining performance in the junior category.

- The video recording method to be applied and capitalized in the training process in the hurdle test as an observational tool, but also as a tool to correct the technical mistakes of the hurdle running step in order to obtain sports performance. Optimizing the technical training of the hurdle runner at the level of the step over the hurdle, by using the video analysis of the kinematic parameters, is an objective and efficient method.

- We recommend that the research be continued on a sample of subjects to make the research more relevant and to confirm that a generalization of hypotheses can be created regarding the introduction of modern technologies in optimizing the hurdle running technique for junior athletes.

We consider that the recorded data can lead to a longitudinal research, paving the way for new approaches in sports training specific to the 110 m hurdles event.

PART III
PERSONAL CONTRIBUTION IN THE RESEARCH OF TECHNICAL TRAINING IN THE 110 M HURDLES

3.1 Argumentation of basic research

The athletic event of 110 m hurdles is an extremely technical one in which the performances are conditioned by the correctness of the execution throughout the distance. It was found that the hurdle runners in the junior category have a series of technical errors, because during the training sessions, the execution errors are not corrected and the motor skills and coordinative capacities are not formed, which correspond to or lead the execution technique to the desired model.

The technique of execution, especially crossing the hurdle, depends on the chain of motor actions: the impulse at the moment of attacking the hurdle, the flight with the specific position over the hurdle, the landing after crossing the hurdle followed by a new impulse to continue running between the hurdles, as well as the position of some points of the hurdler's body in relation to the hurdle plan, they can only be monitored and evaluated correctly by recording some biomechanical parameters of the execution, because monitoring and evaluation allow us to notice technical mistakes.

3.2 Porpose and objectives of basic research

Starting from the results of the preliminary research, following the realization of the preliminary operational approach and the conclusions regarding the working hypotheses, we note the biomechanical parameters focused on the phases and essential moments of the technical optimization in the junior category.

It is noted that the premises of the approach are confirmed, opening a new path in research, addressing the biomechanical aspects, the executions in this sample becoming individualized, thus outlining the objective of obtaining a progress in performance at the junior level in the perspective of obtaining high performances in competitions .

We start from the inclusion in the basic research of several subjects, 6 in number, and with the help of the information obtained from tests with modern technological means, we can advance more generalized conclusions based on numerous concrete and relevant data.

The general goal that we propose is to create a work that promotes the introduction of modern technological means of instruction in the sports training of fencing in juniors, to improve the evolution of the technical execution of the hurdle running step.

The general objective in our research regarding the 110 m hurdles event is aimed at identifying the causes of some technical execution errors, and by means of modern techniques to improve the technique of the hurdler step in junior athletes.

The operational objective of the basic research is oriented towards the optimization of the hurdle running technique through biomechanical analysis, carried out with the kinematic recording of spatio-temporal technical parameters and other technical parameters analyzed with the help of modern technologies, optimized through individualized proprioceptive training, monitored and evaluated with initial testing and finals.

Specific operational objectives:

- the kinematic recording of the spatio-temporal parameters, as well as the comparative graphic evaluation of the researched subjects
- analysis by comparison of the spatio-temporal parameters of each individual subject
- identification of technical mistakes
- the introduction of a proprioceptive training program between the initial testing and the final testing, individualized for each individual subject
- completing the analysis of kinematic parameters with testing using modern and efficient recording and testing methods
- the efficiency of the proprioceptive training program through the final results and the subjects' performances in competitions

3.3 Basic research hypotheses

1. The correction of technical execution mistakes by analyzing the kinematic parameters recorded by modern means can lead to the improvement of the technique of the hurdler's stride in the 110 m hurdles event.

2. The introduction of an individualized proprioceptive training program in sports training at the junior level will optimize the technique of the hurdler's step, by influencing the individual coordinative capacities of the hurdlers.

3. The use of CGM oscillation analysis sensors in the landing phase of the hurdler step will considerably support the process of improving the technique of the junior athletes running in the 110 m hurdles event.

3.4 Basic research methodology

In the framework of the basic research, we used methods characteristic of research in the field of performance to support our complex and objective investigations, valid in the case of hurdle runners in order to be able to follow the efficiency of the activity carried out and to positively influence the preparation in this test.

3.5 Organizing and conducting basic research

3.5.1 Monitoring the parameters recorded in the basic research

Within the research, the study is based on an analysis of the results of functional, non-specific and specific tests, as well as an analysis of kinematic recordings of spatio-temporal parameters.

We will compare the results of the initial and final functional tests in the case of the 6 subjects of the study, from the junior category.

The batteries of tests applied to the 6 subjects will be the following:

- Functional tests: HR at rest, VO2 max., Ruffier test

- Non-specific tests: Standing long jump, 50 m speed run, pull-ups on the bar, abs in 30 sec.

- Specific tests: 60 mg, start with passing 1 hurdle, start with passing 2 hurdles, start with passing 3 hurdles, start with passing 5 hurdles, best result 110 mg.

Several components of the biomechanics of stepping over the hurdle will be measured:

- raising the CGM from the ground

- the size of the angle of attack

- the size of the landing angle

- flight time

- the horizontal distance from which the attack is triggered in relation to the hurdle

- the horizontal distance of the landing from the hurdle

The research was carried out within the Mechatronics Research Center Univ. Transilvania, Braşov, represented by Prof. Univ. Dr. Eng. Marius Cristian Luculescu, in collaboration with Mr. prof. univ. Dr. Sorin Zamfira, Department of Product Design, Mechatronics and Environment. The contract with the research center can be found in annex 1.

The location of the research was the sports base of the secondary school no. 190, Bucharest and the Poiana Brașov sports base, in collaboration with teacher-coach Doru Oprea and Mr. prof. univ. Dr. Dragoș Ionescu – Bondoc.

Following the analysis and correlation of the recorded parameters and the kinematically recorded technical execution processed with the help of Dartfish software, it was found that based on a proprioceptive training program made individually according to the needs of each individual athlete, applied between 05.03.2018 and 25.11.2018, a improvement of technical execution in the 9 subjects of the study.

I had as a starting point arguments from the specialized literature that I had previously studied, and which refer to: the effectiveness of the impulse, the trajectory of the CGM in relation to the plane of the hurdle, impulse and the state of equilibrium in the flight phase, the role of proprioceptive training in optimizing coordinative capacities, the formation of technical execution automatisms.

3.5.2 Subjects of basic research

In the basic research, 6 subjects were involved in the junior category, close in age, similar levels of development and physical and technical training.

Table no. 26 – The subjects of the research

Nr.	INITIALS	YEAR OF BIRTH	CATEGORY	HIGH (cm)	WEIGHT (kg)	RESULT 110 M. H.
1.	C. I.	2004	J III	164	52	17,73
2.	T. S.	2002	J II	169	71	17,67
3.	D. I.	2002	J II	188	76	16,68
4.	S. R.	2001	J II	180	68	15,53

5.	D. A.	2001	J I	178	72	14,90
6.	M. R.	2000	J I	184	74	14,54

3.6 Carrying out the basic experiment by applying the training program

The basic research was carried out between 05.03.2018 (initial testing) - 25.11.2018 (final testing). During the mentioned period, the study, the analysis of the technique and the testing of the spatio-temporal parameters recorded and confirmed in the preliminary experiment, but also of some recordings using modern means of testing, were carried out.

The initial testing of the basic experiment was carried out between 05 and 10 March 2018 at the Poiana Brașov sports base, the athletics stadium and at the sports base of school no. 190 Bucharest, where the kinematic recordings were made with the video camera (Appendix 13) and processing and analysis with the Dartfish software (Appendix 12). I processed the images in the department D04 "Advanced Mechatronic Systems", with prof. Dr. Sorin Zamfira.

The recordings were made on hurdles with a height of 0.991 m, under the same conditions both in the initial and in the final testing and were assisted by Prof. Univ. dr. trainer specialist in athletics, Dragoș Ionescu-Bondoc.

According to the parameter records from the preliminary experiment, we performed the basic research on each individual subject.

Between the initial testing and the final testing, the following training program was applied, based on specific means of technique of the hurdle runner's step in the 110 m hurdles test, and non-specific ones, which we prepared in the preliminary testing. The planning of the dynamics of the effort was carried out during the individualized experiment, taking into account the individual personal somato-functional characteristics of each one, but also the recommendations for correcting technical mistakes made for each one by the trainer.

The proprioceptive training program will consist of 7 exercises, performed twice a week, during two training sessions. Exercises 1 – 4 will be performed during training on Monday and Thursday, and exercises 5 – 7 in training on Tuesday and Friday. Monthly, these will be carried out in 8 trainings, in a number of repetitions and with intensity according to the needs and individual potential of each subject.

3.6.1 The use of training modern technologies to optimize the technique of hurdles clearance technique

As part of the proprioceptive training program introduced in the training plan of the 6 studied subjects, a monitoring was resorted to in the months of April, July and October when tests were applied using two modern data recording means: 1. The movement and posture sensor Microgate's Gyko [12] (appendix 8), and 2. The OptoJump infrared cell platform [13] (appendix 9).

The monitoring was carried out 3 times, at an interval of approximately 3 months. The aspects that were followed in the framework of the monitoring activity were the following:

- Static balance within the 4 non-specific proprioceptive exercises, which used ergonomic balance development platforms

- Pushing power of the impulse leg

- The contact time of the landing leg

At each test-monitoring session of the athletes' training that took place at the sports hall of the 190 Bucharest school, the Metrom Brașov gym or the Poiana Brașov sports base, as part of the individualized proprioceptive training program, a number of 6 tests were used for each subject separately. We will present in the following a sequence of testing - monitoring within a training.

In these tests, 2 modern training technologies were used to optimize the technique of the hurdle runner, the Gyko inertial sensor and the Optojump platform. They had the role of measuring the parameters of balance, impulse power, contact times.

Table 64 - Sequence from the proprioceptive training test session

No.	Exercises	Recording technology	Lenght of recording
1.	From standing on the forward leg semi-flexed and full sole on the Bosu ball, and with the trailing leg with the knee bent on the fitness ball. Energetic arm movements are performed back and forth, while maintaining balance.  **Fig. 60** – Arm movements with maintaining balance	Gyko sensor	5 sec.
2.	From standing in forward semi-squat, one foot back on the fitness ball and the other forward on the Bosu ball, lift the opposite leg with a forward calf push – up  **Fig. 61** – Impulse leg lift with attack simulation	Gyko sensor	5 sec.

3.	From sitting with legs flexed to 90 degrees on the inverted Bosu balance ball, with support against the wall with your back on the fitness ball, raising one leg semi-flexed forward.  **Fig. 62** – Bending the knee of the driving leg and lifting the attacking leg	Gyko sensor	5 sec.
4.	Lying prone, support on the toes on the fitness ball and on the hands on the balance ball Bosu turned, flexing the thigh on the pelvis with the leg forward - to the side.  **Fig. 63** – Pulling the trailer leg to the side	Gyko sensor	5 sec.
5.	From a sitting position facing the hurdle, with the attacking leg resting on the hurdle post, energetic jumps are performed on the impulse leg for 15 seconds.	OptoJump	15 sec.

	 **Fig. 64** – OptoJump impulse leg test		
6.	From the sitting position with the back to the hurdle, with the trailing leg resting on the hurdle post, perform energetic jumps on the attacking leg (landing) for 15 seconds.  **Fig. 65** – OptoJump landing leg test	OptoJump	15 sec.

Within this proprioception development program of the 6 subjects, exercises 1 – 4 were monitored using the Gyko inertial sensor, which recorded a series of parameters presented in appendix 14 [14], for 5 seconds/test, from which we considered that are relevant for the most accurate interpretation of the results, the following:

- Length [D_L] (Length) – Represents the total length of the trajectory obtained as the sum of the distances from one point to the next. It is measured in cm.

- Mean Distance [D_MD] (Mean Distance) – Represents the average distance from the midpoint of the trajectory. It is measured in cm.

- Speed [D_V] (Velocity) - This is the average speed of the trajectory. It is measured in cm/s.

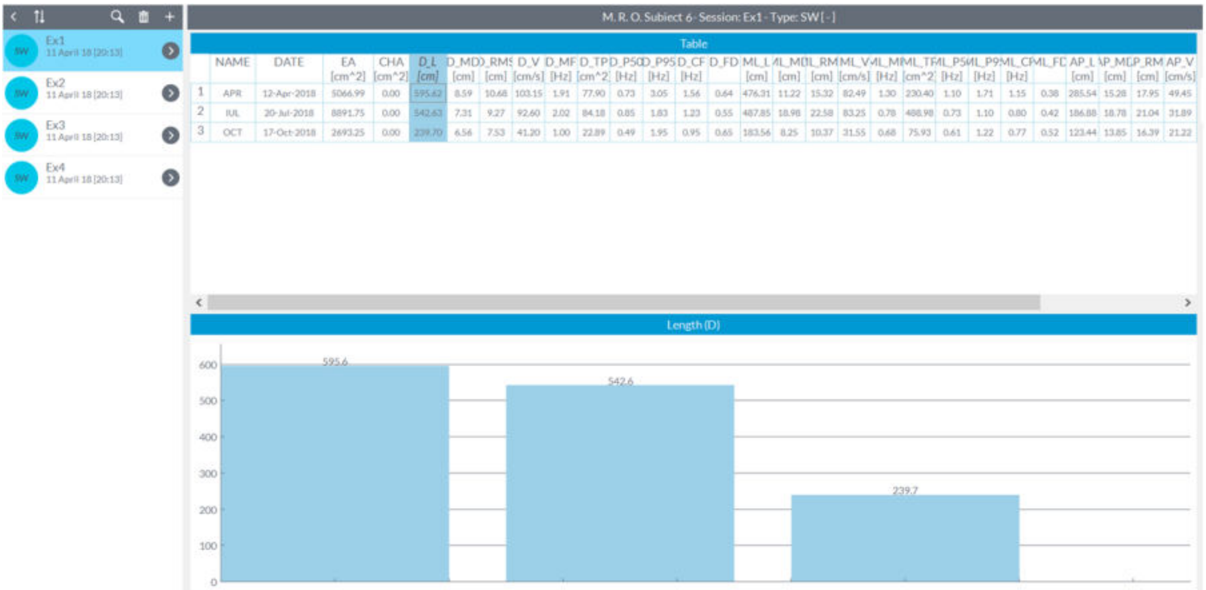
The Gyko inertial sensor, placed on the subject's chest, follows a trajectory in a 2D plane vertically and horizontally, plotting on the graph the trajectory followed by the subject during the execution and represented graphically in the figures in annex 15.

The longer the path length, the more unstable the balance can be said to be because the subject's body experiences wider and less controlled oscillations.

The larger the average distance, the greater the horizontal swing and the greater the deviation from the vertical midline, suggesting that the subject's stability is lower.

The higher the speed of movement of the trajectory, the higher the frequency of oscillatory movements will be and the higher their number, the balance of the subject being directly proportional to them.

We can see in the following the graphic and tabular representation of the parameters of subject 6 recorded following the monitoring tests of the 3 intermediate months of the individualized proprioceptive training program for the 4 chosen exercises.



	NAME	DATE	EA [cm^2]	CHA [cm^2]	D_L [cm]	D_MD [cm]	D_RMS [cm]	D_V [cm/s]	D_MF [Hz]	D_TP [cm^2]	D_P50 [Hz]	D_P95 [Hz]	D_CF [Hz]	D_FD	ML_L [cm]	ML_MD [cm]	ML_RM [cm]	ML_V [cm/s]	ML_M [Hz]	ML_TP [cm^2]	ML_P5 [Hz]	ML_P9 [Hz]	ML_CF [Hz]	ML_FD	AP_L [cm]	AP_MD [cm]	AP_RM [cm]	AP_V [cm/s]
1	APR	12-Apr-2018	5066.99	0.00	595.62	8.59	10.68	103.15	1.91	77.90	0.73	3.05	1.56	0.64	476.31	11.22	15.32	82.49	1.30	230.40	1.10	1.71	1.15	0.38	285.54	15.28	17.95	49.45
2	IUL	20-Jul-2018	8891.75	0.00	542.63	7.31	9.27	92.60	2.02	84.18	0.85	1.83	1.23	0.55	487.85	18.98	22.58	83.25	0.78	488.98	0.73	1.10	0.80	0.42	186.88	18.78	21.04	31.89
3	OCT	17-Oct-2018	2693.25	0.00	239.70	6.56	7.53	41.20	1.00	22.89	0.49	1.95	0.95	0.65	183.56	8.25	10.37	31.55	0.68	75.93	0.61	1.22	0.77	0.52	123.44	13.85	16.39	21.22

Fig. 66 – Path length for subject 6 exercise 1

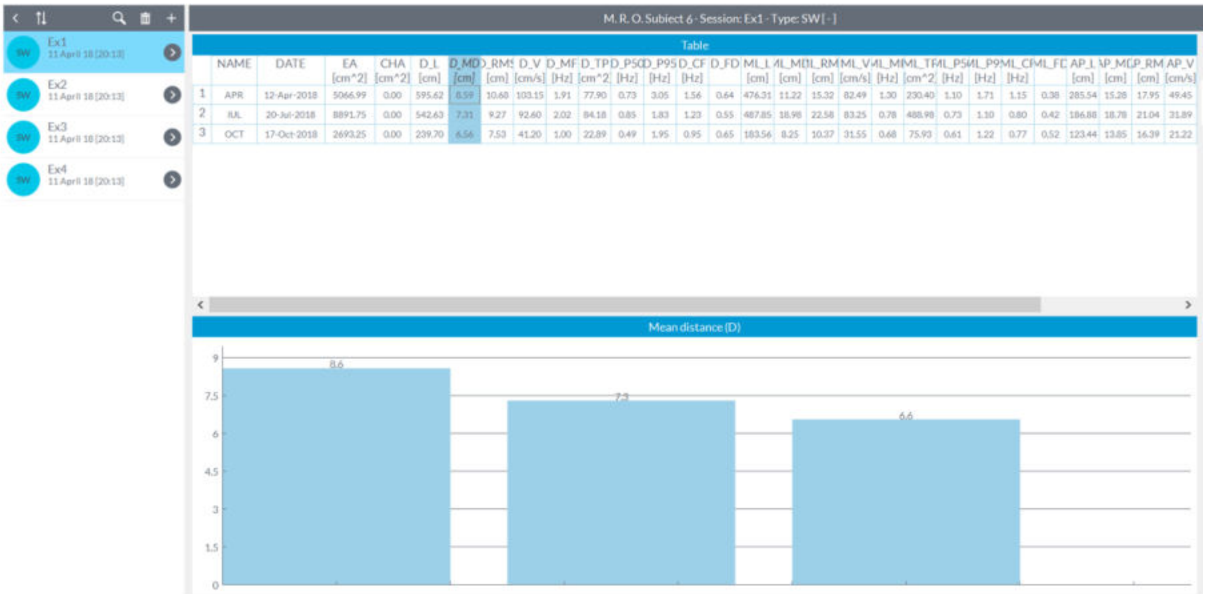


Fig. 67 – Average trajectory distance for subject 6 exercise 1

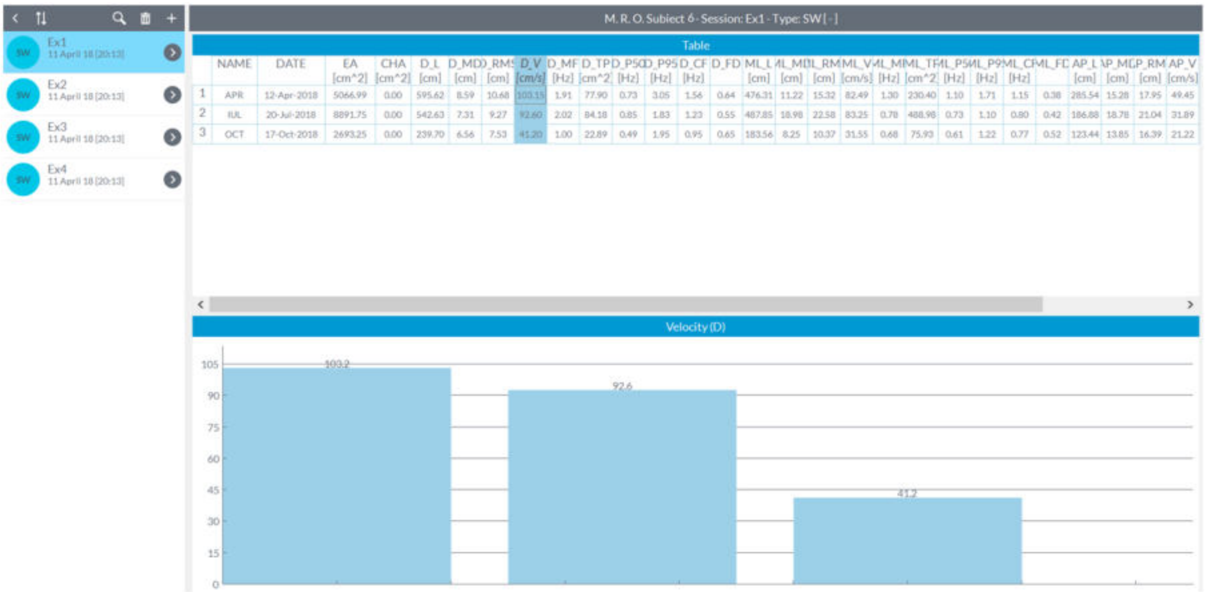


Fig. 68 – Trajectory travel speed for subject 6 exercise 1

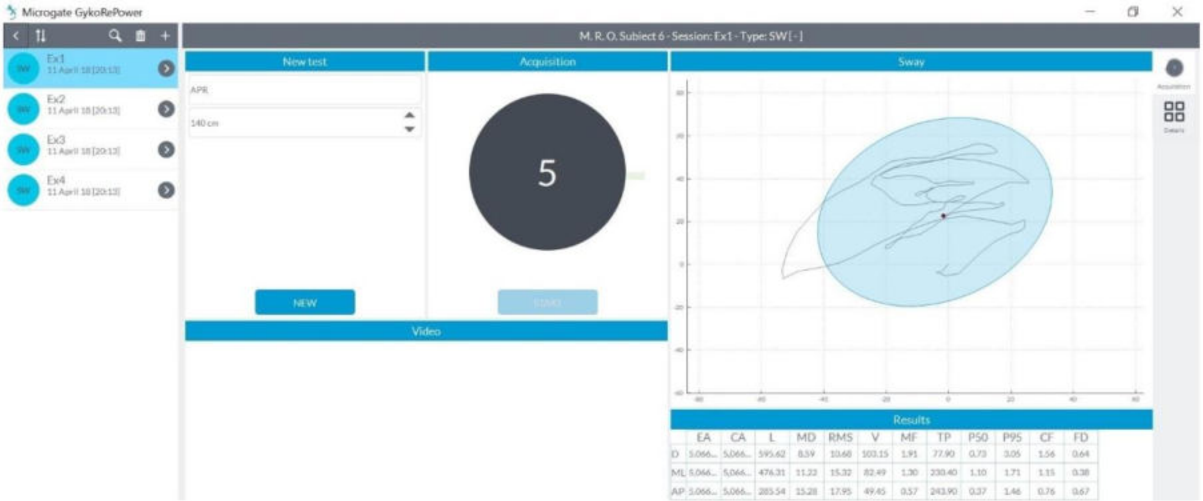


Fig. 69 – Graphic representation of the trajectory for subject 6 exercise 1 April 2018

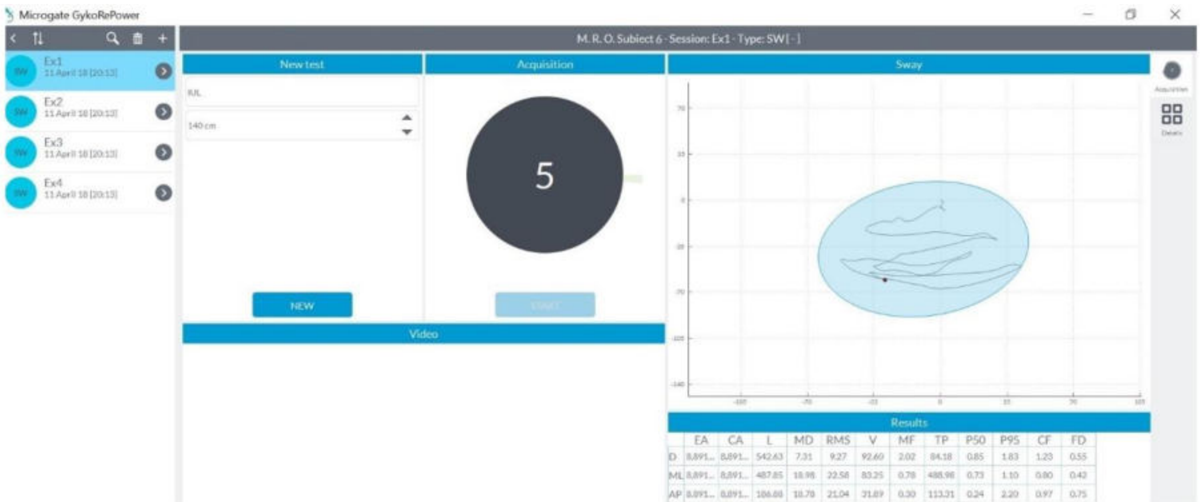


Fig. 70 – Graphic representation of the trajectory for subject 6 exercise 1 July 2018

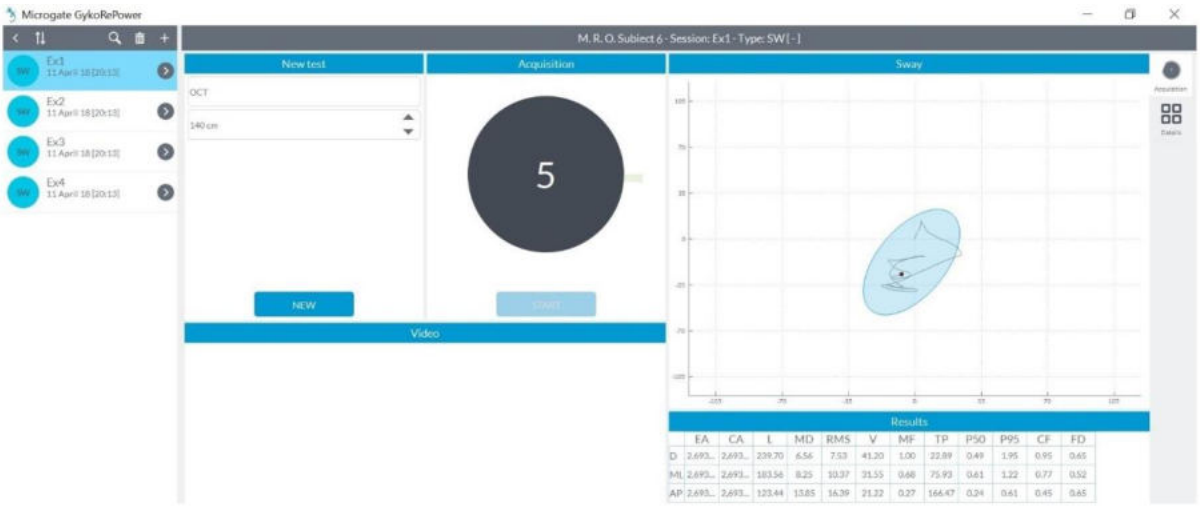


Fig. 71 – Graphic representation of the trajectory for subject 6 exercise 1 October 2018

From the above statistics we can note that in the case of the measurements of the 4 exercises included in the monitoring tests within the individualized proprioceptive training program, the values constantly improve as the subject athlete no. 6 advance and perfect their proprioceptive skills.

The other measured data for subjects 1 – 5 can be found in appendix no. 8.

In the following, we present the centralization of the results for exercises 1 - 4 where we used the Gyko sensor as a means of training in the optimization of the technique of the hurdle runner in the 6 junior subjects.

Table 65 - Centralization of the results obtained with the Gyko sensor

Nr.	Subjects		Exercise 1			Exercise 2			Exercise 3			Exercise 4		
			Leng	Dist.	Spe.	Leng	Dist.	Spe.	Leng	Dist.	Spe.	Leng	Dist.	Spe.
1.	S1	A	1361	11.9	216.8	1138	19	189.9	1011	12.5	161.7	357	3.11	59.4
		I	1161	27.7	185	796	16.9	138.5	439.3	7.48	69.7	159.4	4.3	26
		O	487.5	30.1	77.6	677	16.7	114.7	466.7	12	78.8	137.4	3.5	23.4
2.	S2	A	1147	17.4	189.7	1146	16.1	189.2	727	6.9	120.4	381.4	3.3	63.6
		I	737.4	11.8	121.2	739	10.8	114.9	411.2	7.9	67.6	176.4	5.7	28.1
		O	673.4	11.3	113	818.9	12.1	130.9	653.5	11.1	108.5	169.3	3.5	27.8

3.	S3	A	989.7	9.5	166.5	946.2	15.9	156.2	582	8.7	95.1	359.2	3.5	59.7
		I	653.3	11.5	108.7	754.8	14.2	126.7	529	10.5	86.8	176.2	5.8	29
		O	610.6	8.8	100.8	768.8	12.9	128.5	439	10	73.4	148.1	4.2	25.2
4.	S4	A	808.4	8.4	133.1	1081	15.2	170.2	633.4	9.8	103.3	203.5	2.5	32.6
		I	685.3	11.1	113.1	696.3	20.4	117.7	343.9	5.8	57.5	179.2	3.6	30.1
		O	633.9	8.1	109.1	830.5	14.4	136.1	506.9	8.3	85.7	169.9	4.5	29.5
5.	S5	A	978.2	10.6	160.9	784.2	13.7	132.6	530.3	6.2	89.6	295.5	2.7	49.5
		I	576.1	8.3	97.6	676.6	14.8	113.7	479.1	7.2	80	253.3	6.5	42.4
		O	518.9	7.6	86.5	427.9	10.7	69.9	399.1	5.2	66.9	136.2	5.3	23.4
6.	S6	A	595.6	8.6	103.2	810.6	16.9	132	498	6.8	82.4	164	2.9	26.9
		I	542.6	7.3	92.6	685.4	17.1	113.7	376.3	8.5	63.9	149.7	7.1	24.6
		O	239.7	6.6	41.2	384	11.8	65.2	271.9	5.8	45.2	96.5	5.4	15.9

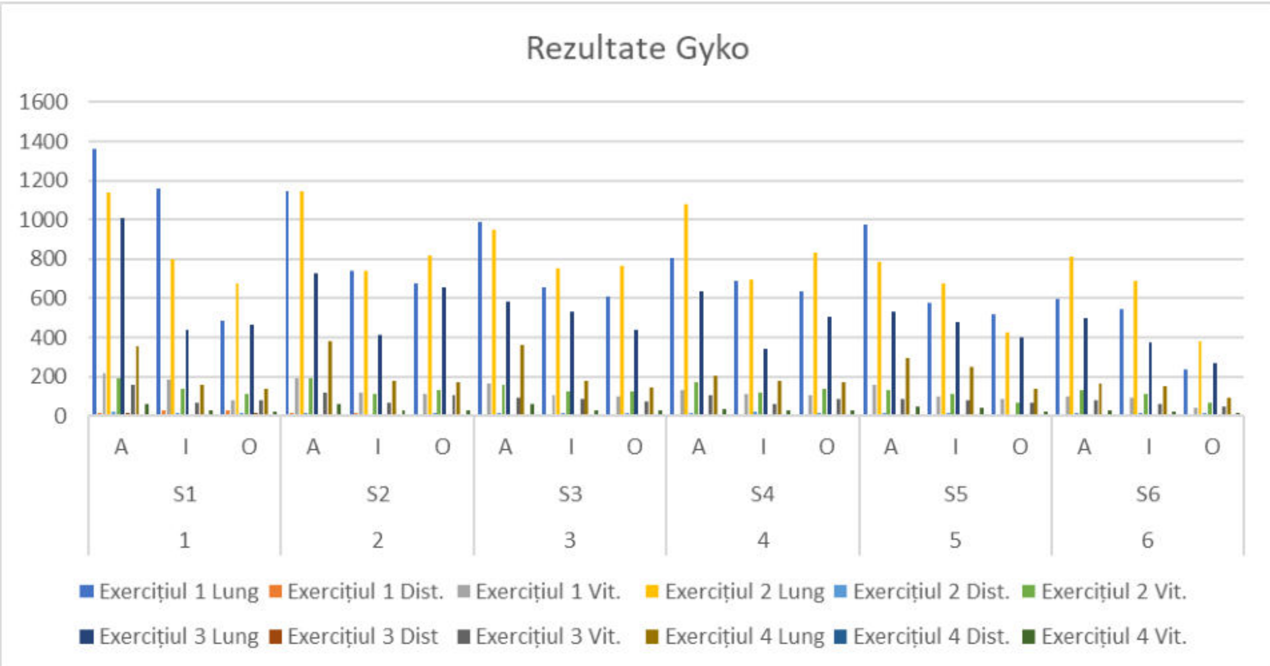


Fig. 72 – Centering results using Gyko for the 6 subjects

Exercises 5 – 6 were monitored using OptoJump, which recorded a series of parameters presented in annex 15, of which we considered relevant for the most accurate interpretation of the results, the following:

- Tcont. [s]: Contact times

- Power [W/kg]: Power

During the 3 monitoring sessions, the subjects performed the 2 tests using the OptoJump platform, and the results obtained by subject 6 are as follows:

In the case of parameter 1, contact times, we measured the duration of contact times of the sole of the foot with the ground for each jump, knowing that in order to obtain the best possible results in hurdles, the contact with the ground must be as short as possible.

In the case of parameter 2, the power, we measured the impulse power in the ground for the most efficient detachment. The higher the impulse power, the better the breakaway in the hurdle runner's stride.

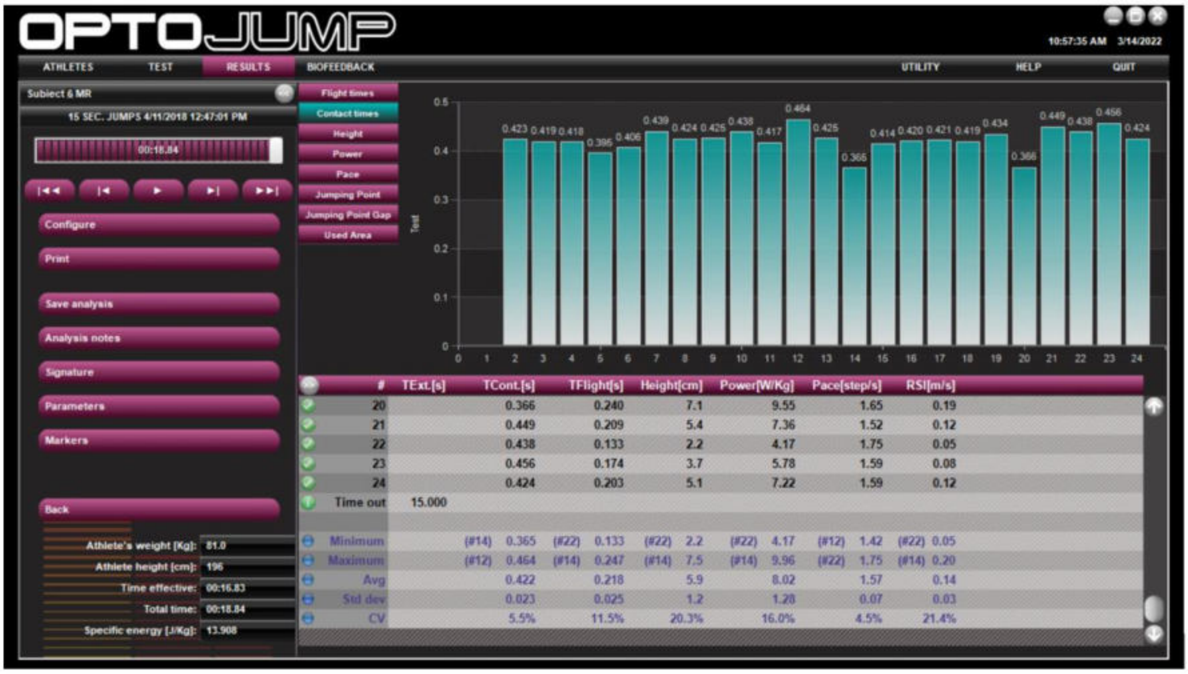


Fig. 73 – OptoJump test results for subject 6 exercise 4 – contact times 11.04.2018

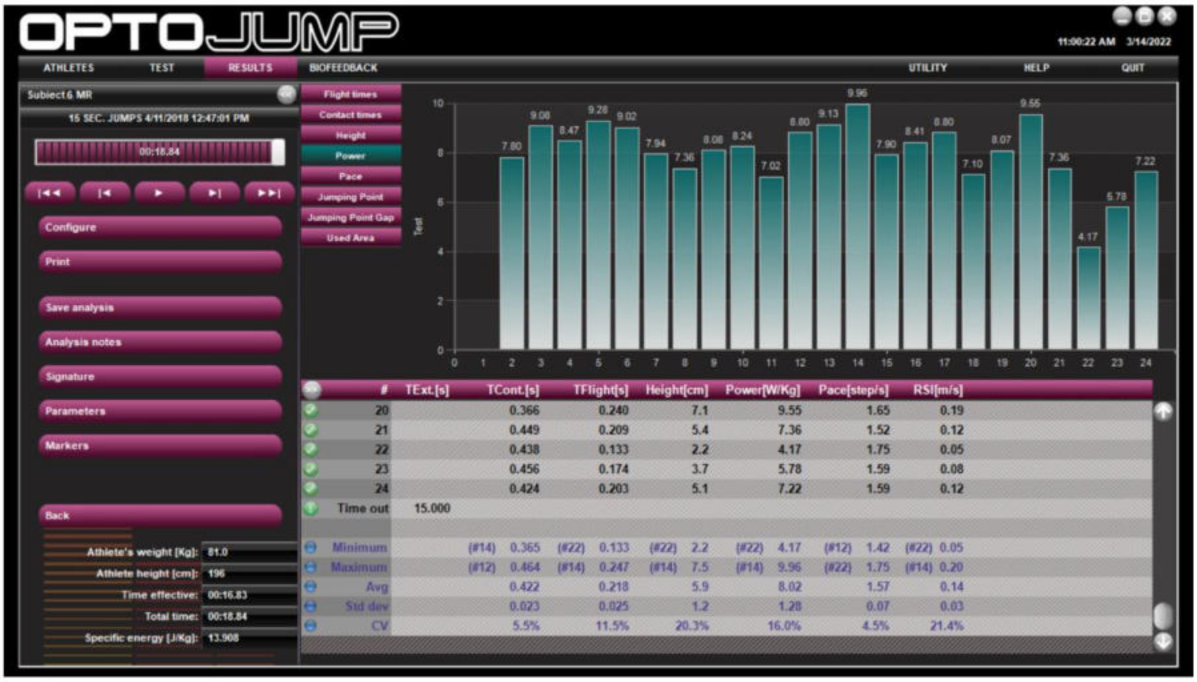


Fig. 74 – OptoJump test results for subject 6 exercise 4 – power 11.04.2018

It can be seen that in the case of the impulse power parameters, at the end of the 15-second test, the power registers a decrease, which leads us to state that subject 6 requires an optimization of resistance through longer impulse executions within the proprioceptive training program.

Fig. 75 – OptoJump test results for subject 6 exercise 4 – contact times 20.07.2018

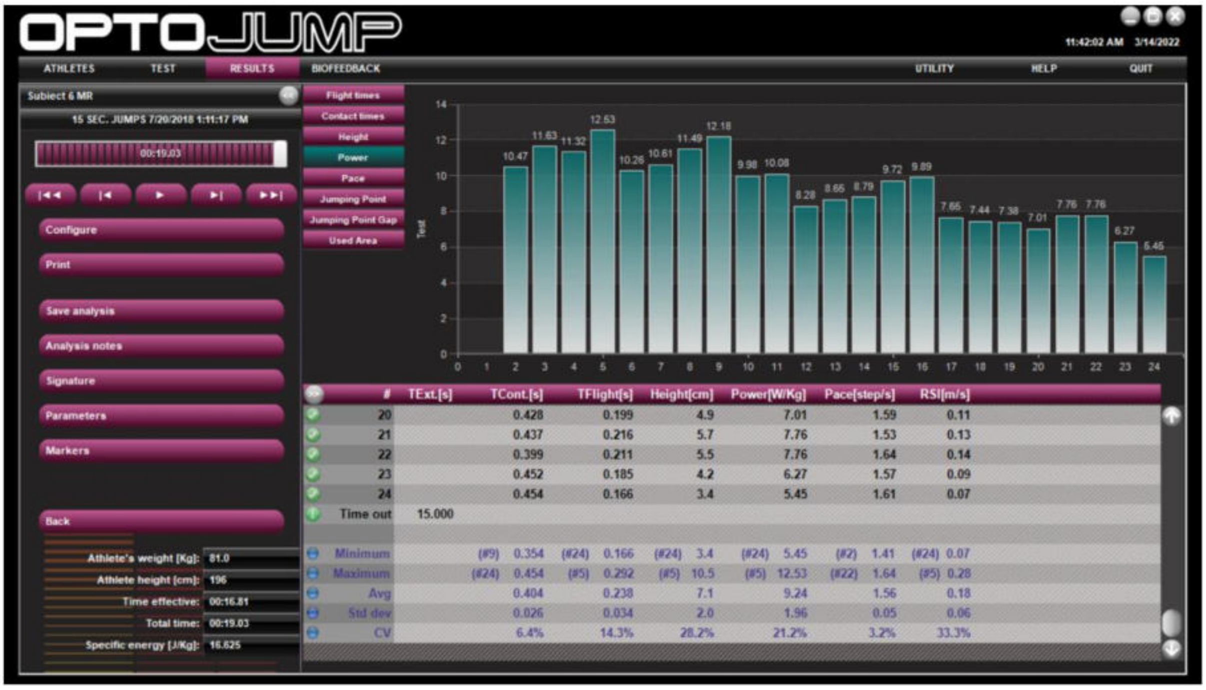


Fig. 76 – OptoJump test results for subject 6 exercise 4 – power 20.07.2018

During the tests of 20.07.2018, it was found that there were improvements in these measured parameters, but there are still deficiencies in the final part of the 15 seconds, when the athlete gets tired and the manifestation of power is no longer at optimal values.

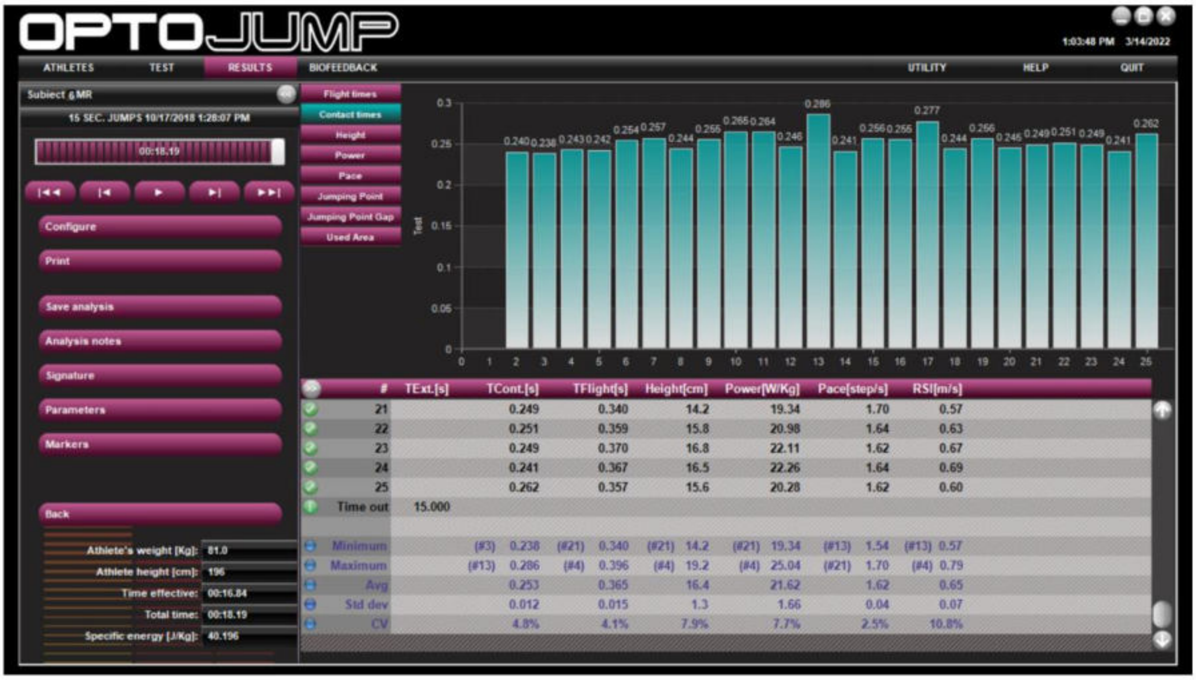


Fig. 77 – OptoJump test results for subject 6 exercise 4 – contact times 17.10.2018

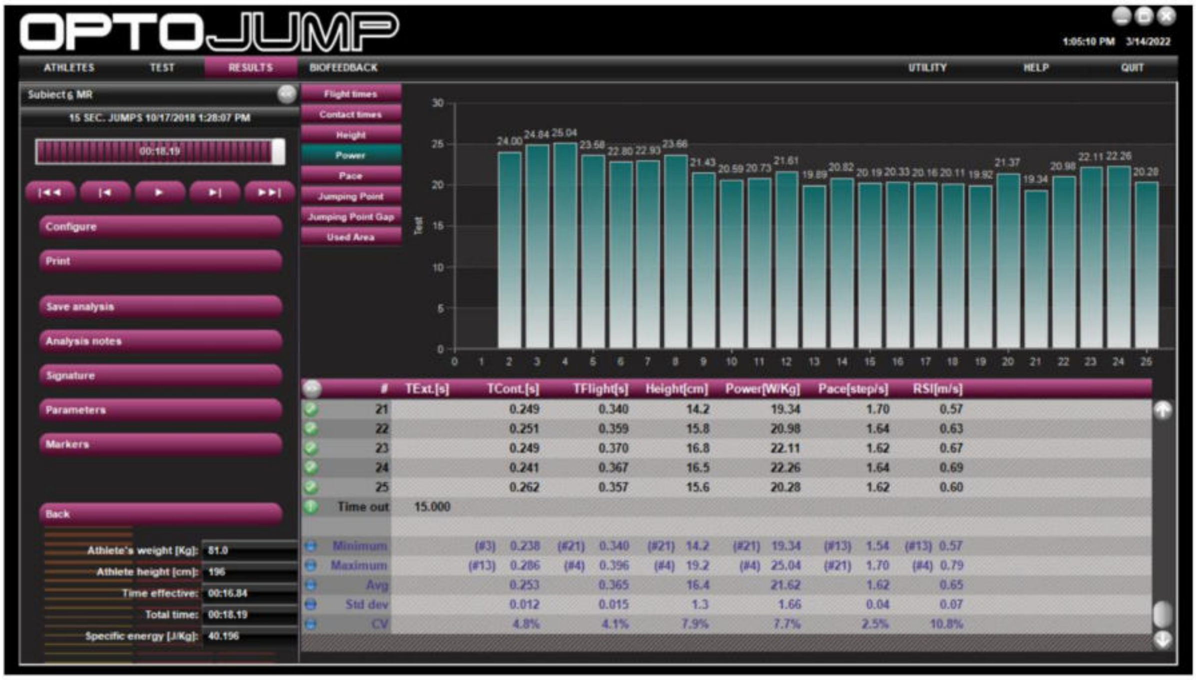


Fig. 78 – OptoJump test results for subject 6 exercise 4 – power 10/17/2018

As can be seen from the figures above, the power shows a significant improvement both within the values and in the aspect of optimizing the resistance within the execution on its end. The values are much more homogeneous.

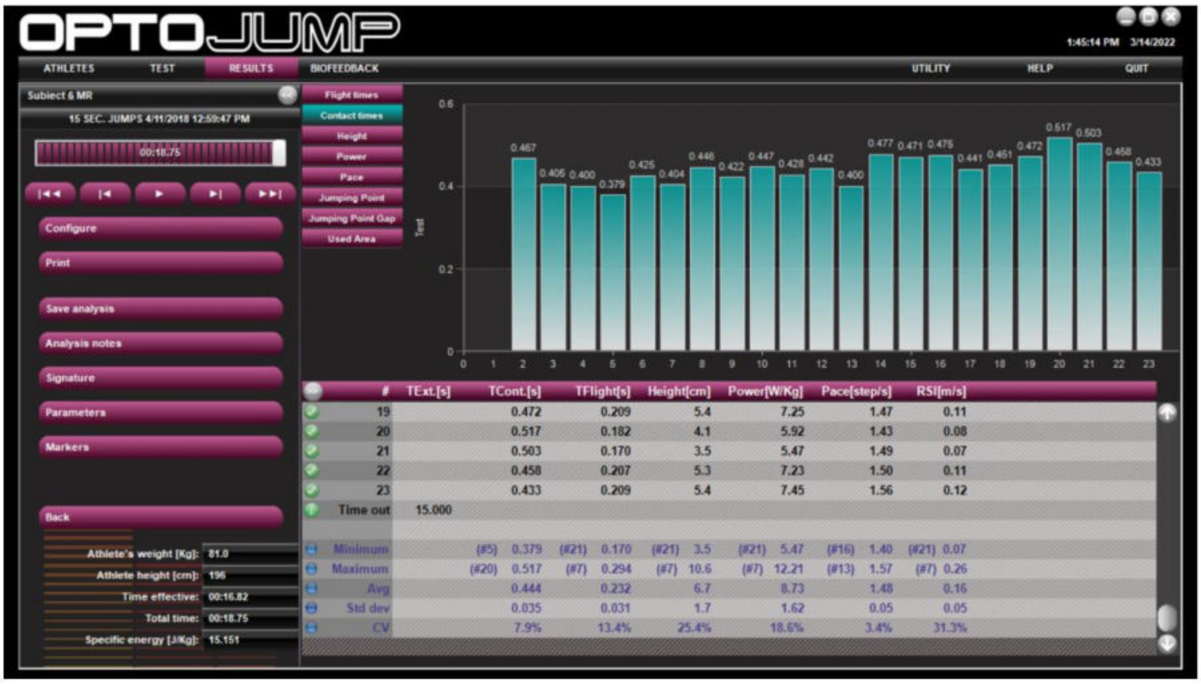


Fig. 79 – OptoJump test results for subject 6 exercise 5 – contact times 11.04.2018

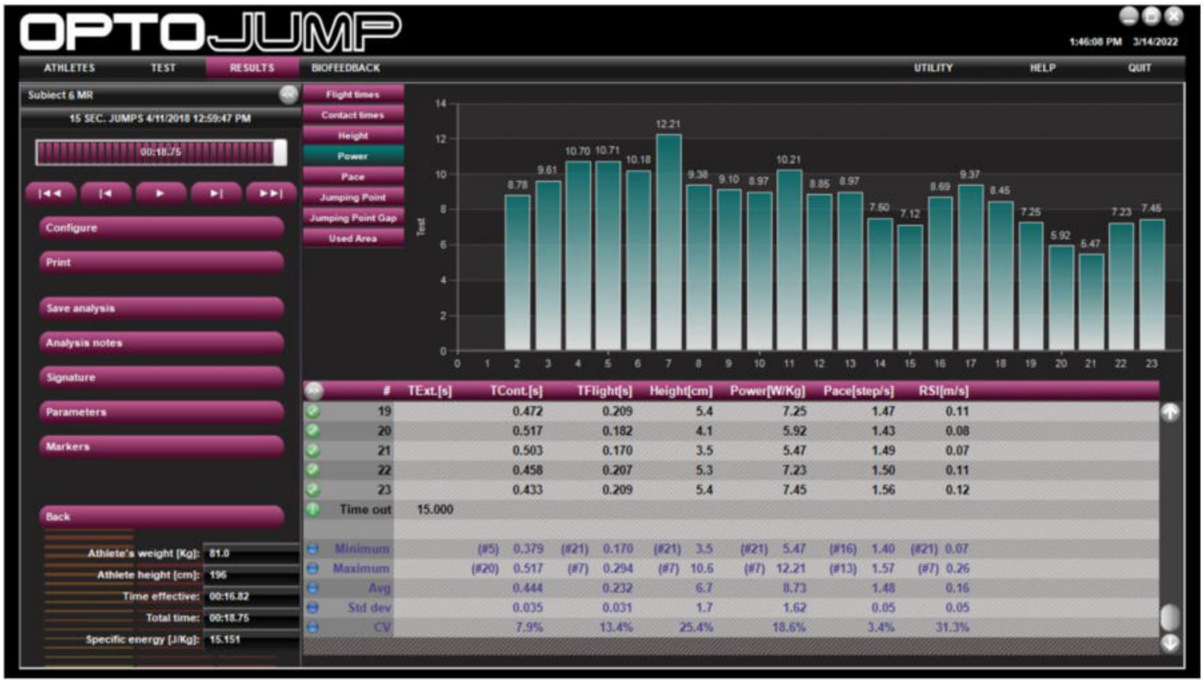


Fig. 80 – OptoJump test results for subject 6 exercise 5 – power 11.04.2018

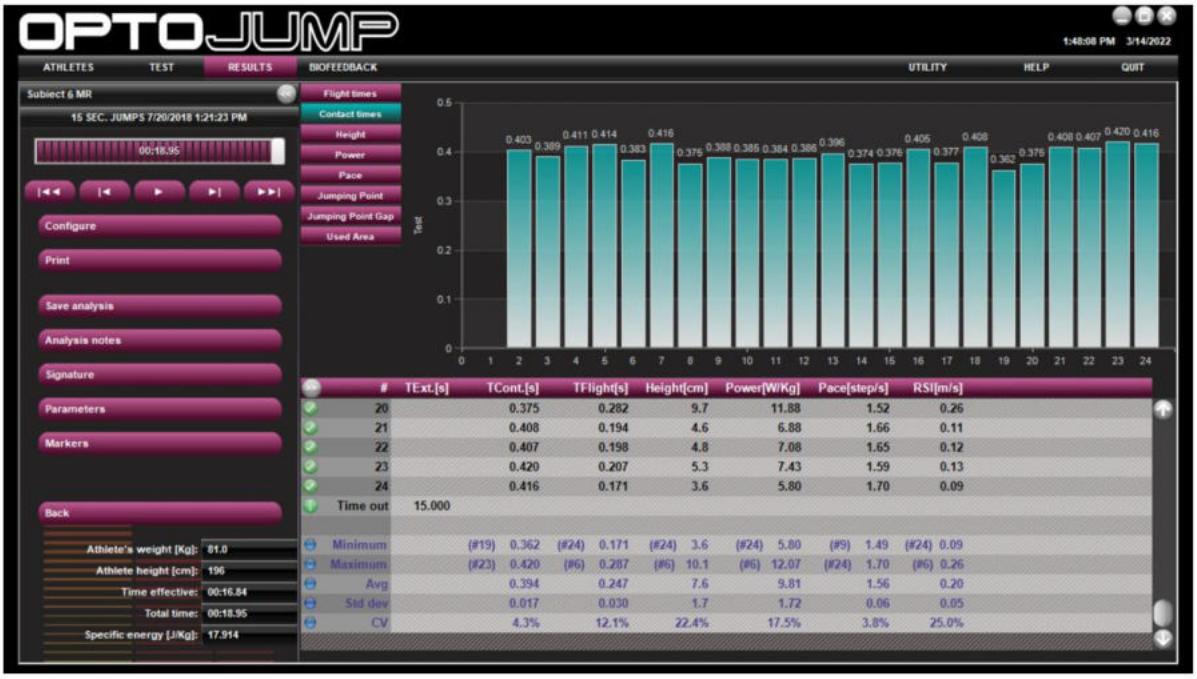


Fig. 81 – OptoJump test results for subject 6 exercise 5 – contact times 20.07.2018

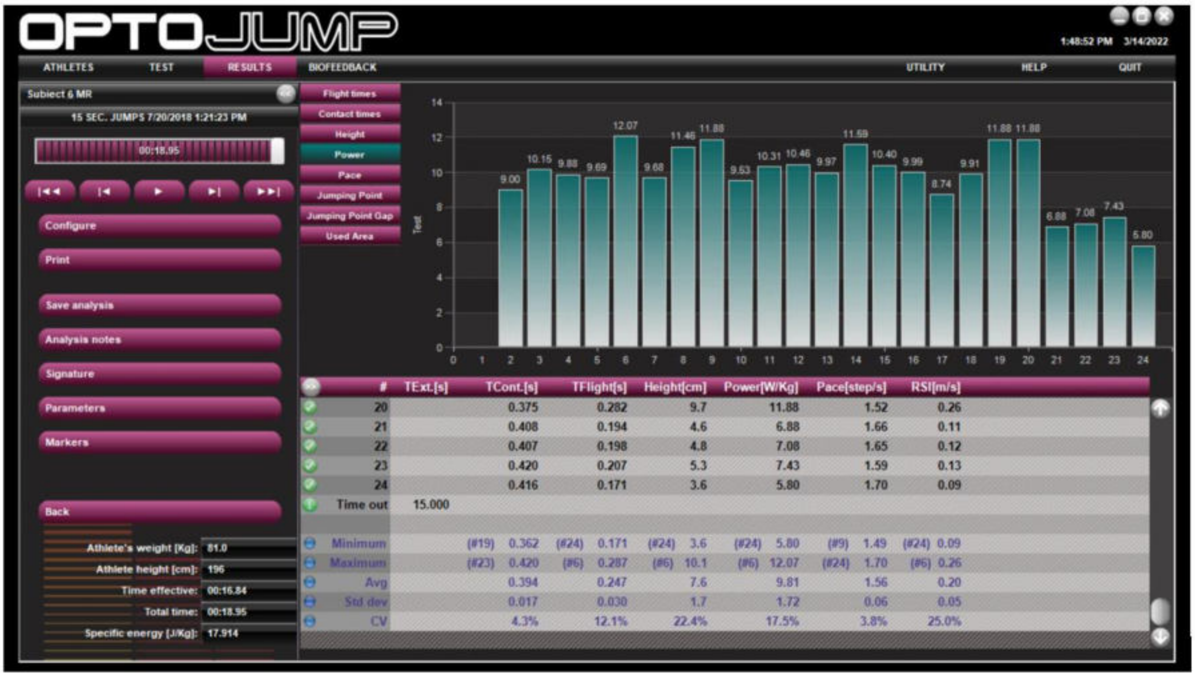


Fig. 82 – OptoJump test results for subject 6 exercise 5 – power 20.07.2018

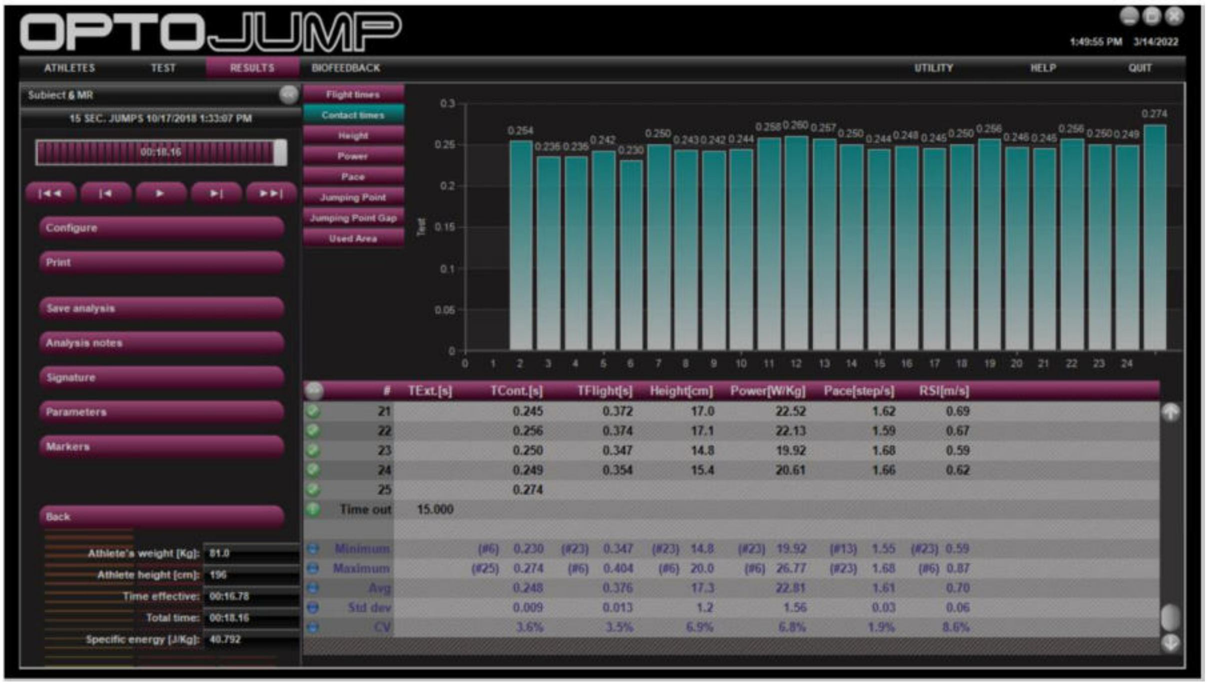


Fig. 83 – OptoJump test results for subject 6 exercise 5 – contact times 17.10.2018

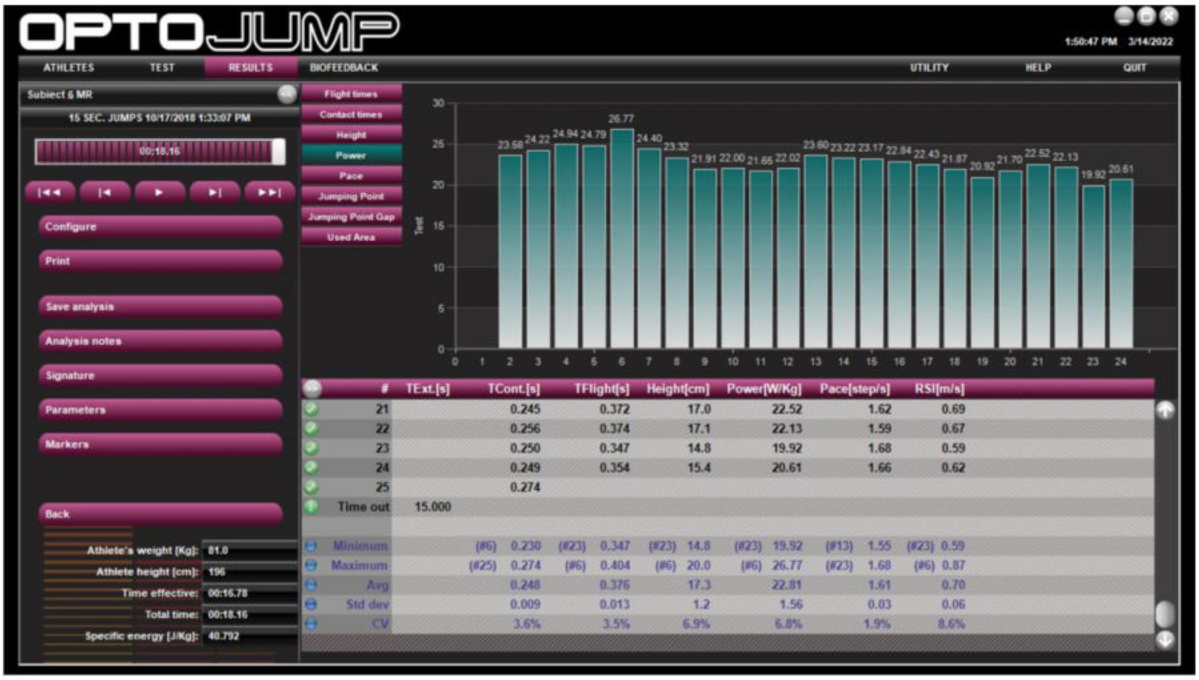


Fig. 84 – OptoJump test results for subject 6 exercise 5 – power 17.10.2018

Next we will present a comparison between the average values calculated by the OptoJump software for the three rows of tests, for each of the two exercises.

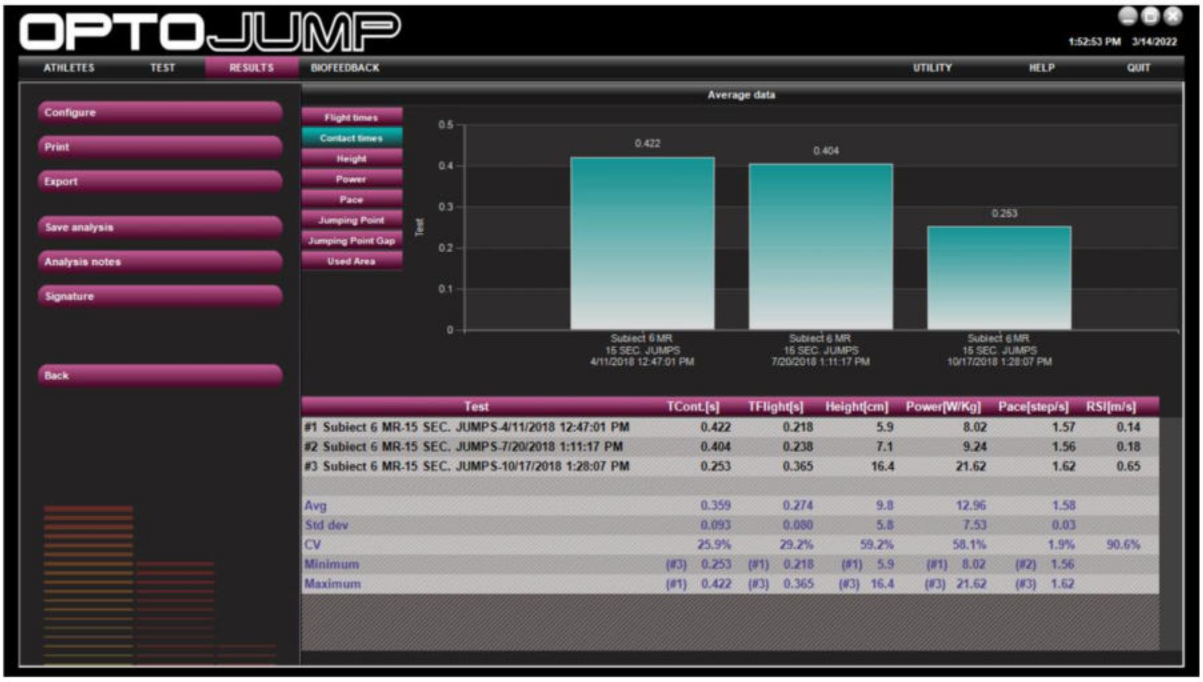


Fig. 85 – Average results for subject 6 exercise 4 – contact times

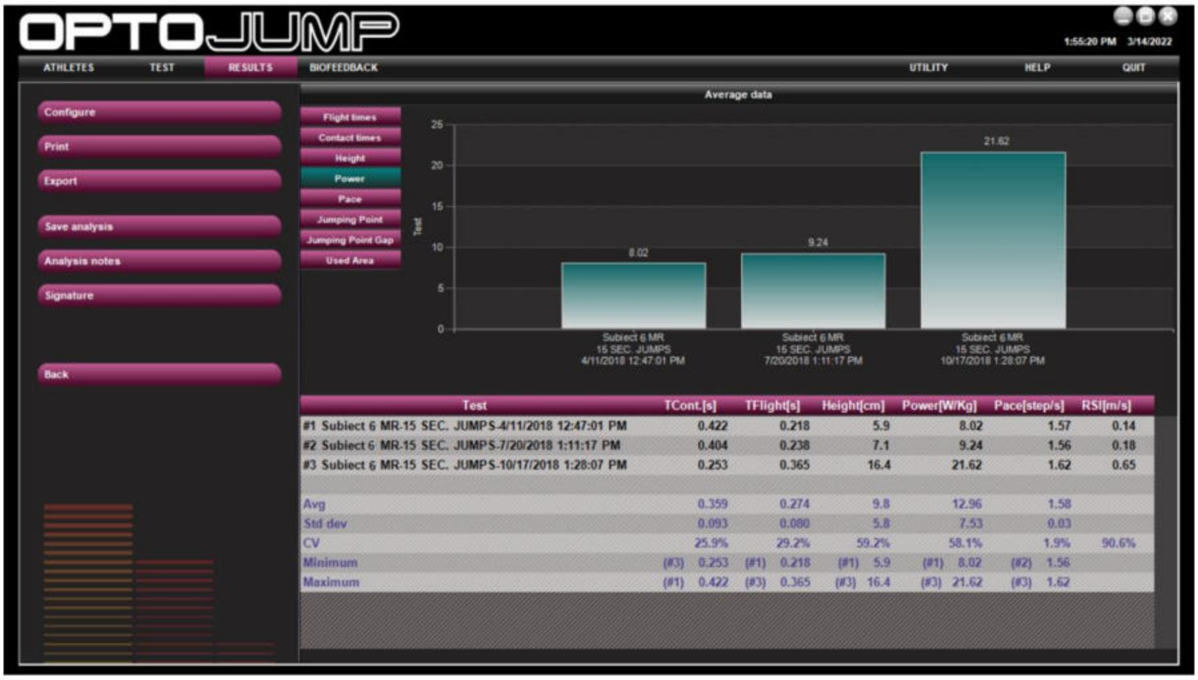


Fig. 86 – Average results for subject 6 exercise 4 – power

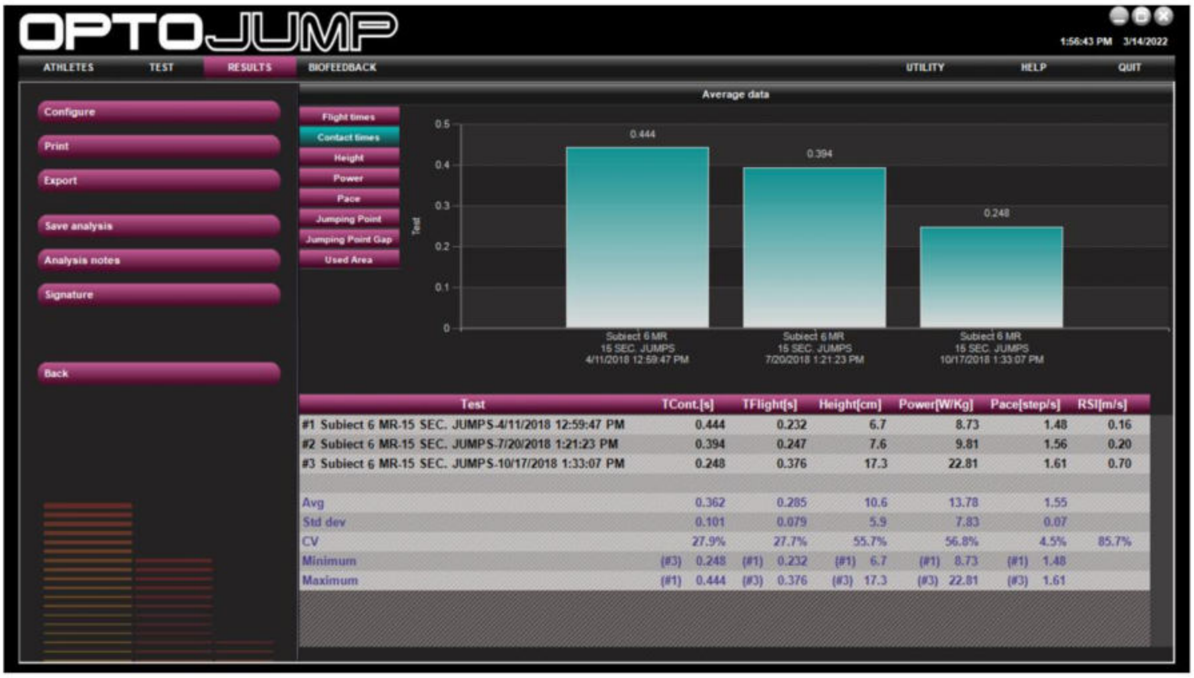


Fig. 87 – Average results for subject 6 exercise 5 – contact times

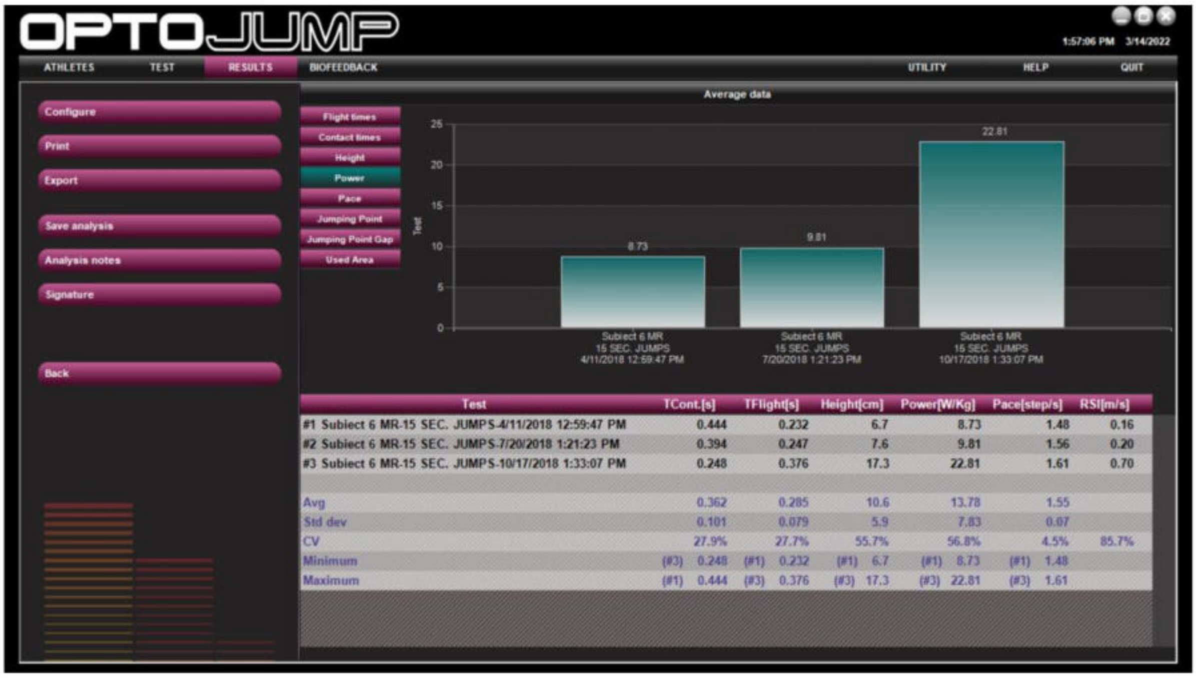


Fig. 88 – Average results for subject 6 exercise 5 – power

From the statistics above we can note that in the case of the measurements of both exercises included in the monitoring tests following the individualized proprioceptive training program, the values constantly improve as the subject athlete no. 6 advances and perfects their proprioceptive skills, impulse contact times decreasing and impulse strength increasing considerably in the 9th month of the program.

The other measured data for subjects 1 – 5 can be found in appendix no. 9.

In the following, we present the centralization of the results for exercises 5 and 6 where we used the OptoJump platform as a means of training in the optimization of the hurdle runner step technique in the 6 junior subjects.

Table 66 – Centralization of the results obtained with the OptoJump platform

No.	Subjects		Exercise 5		Exercise 6	
			T.cont	Putere	T.cont	Putere
1.	S1	A	0.504	2.74	0.480	3.18
		I	0.369	7.35	0.447	5.49
		O	0.480	3.18	0.362	8.19
2.	S2	A	0.439	3.29	0.466	3.76
		I	0.464	2.77	0.470	4.88

		O	0.390	6.76	0.389	6.78
3.	S3	A	0.402	4.33	0.463	3.99
		I	0.497	2.94	0.460	4.41
		O	0.348	10.02	0.347	9.97
4.	S4	A	0.465	5.64	0.540	4.42
		I	0.469	4.25	0.466	4.94
		O	0.360	9.05	0.380	8.03
5.	S5	A	0.436	4.43	0.524	3.71
		I	0.451	5.11	0.423	5.91
		O	0.376	9.10	0.373	9.34
6.	S6	A	0.421	4.39	0.496	5.40
		I	0.454	4.47	0.395	8.18
		O	0.278	14.87	0.285	12.56

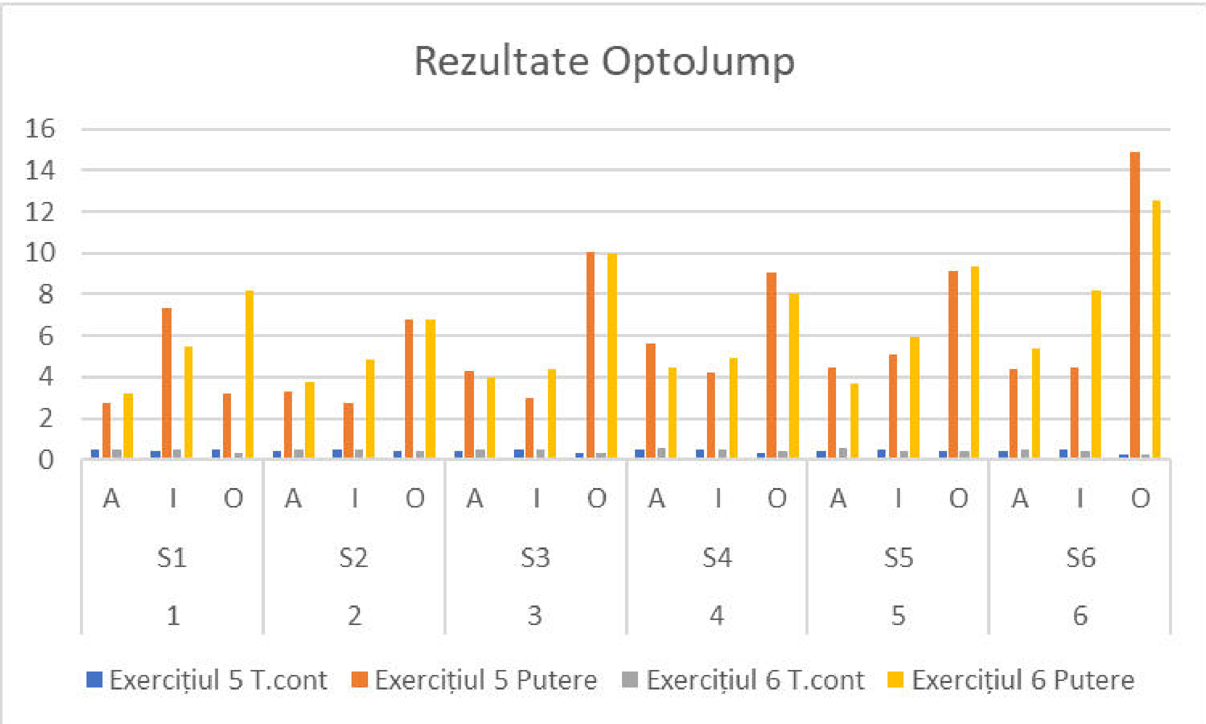


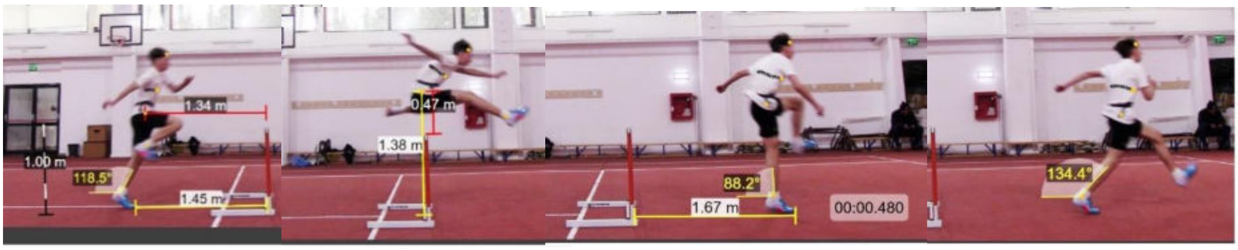
Fig. 89 – Centering the results using OptoJump for the 6 subjects

3.7 Kinematic recordings used to optimize the technique of hurdles running

In the longitudinal experimental research, kinematic parameters were recorded using modern video camera technology, analyzed through the Dartfish program (appendix 11), on the four phases of the hurdle running step, provided for the purpose of the preliminary research, which contribute to the optimization of the hurdle crossing technique .

Recordings were made from the side plane to capture as faithfully as possible the angles and distances during the phases of going over the hurdle. The camera was placed at a distance of 7 m from the hurdle and at a height of 1.20 m, leaving the plane on the left 4.55 m and on the right 5.05 m to be able to capture as much as possible much more faithful from the phases of going over the hurdle.

3.7.1 Kinematic recordings, comparative interpretation of parameter values for subject no. 1



F1 F2 F3 F4

Fig. 90 – Vector representation of distance and angular parameters of subject 1 – initial testing

Subject 1, junior cat. III, records the value of 1.45 m from the place of detachment to the hurdle, the proximity to the hurdle being quite large and 1.67 m from the hurdle to the place of landing after it and reaches a ratio of approximately 55 - 45, compared to the proportion of the absolute model chosen (about 60 – 40).

The technical errors of crossing and running the hurdles continue with the CGM approach to the hurdle which is 1.10m due to the approach to the hurdle and the angle between the ground and the breakaway leg is 118.5 degrees, too open compared to that of the chosen model, but in proportion to the other parameters, since the horizontal distance to the hurdle would have to be greater.

Over the hurdle we will notice that the CGM rises to a value of 1.38 m. from the ground, and 0.47 m. from the hurdle post. Due to the height of the crossing over the hurdle, the landing will be 1.67m from the hurdle, far too long for a balanced landing, as we can see in the next phase, and unsuitable for a safe and correct continuation of the run between the hurdles.

The landing leg is at an angle of 88.2 degrees at first contact with the ground, an angle denoting the advanced position achieved due to the prolonged flight over the hurdle in the second phase of the flight, partially determining a more advanced position than that of the reference model, but obtained by a wrong proportion of the distances.

The continuation of the impulse of the landing leg is made at an angle of 134.4 degrees due to an unbalanced landing and the need to compensate for the position to continue running, under the influence of an incorrect posture of the body segments and the trunk at the time of landing.

F1 F2 F3 F4

Fig. 91 – Vector representation of distance and angular parameters of subject 1 – final test

Following the individualized proprioceptive training program, in the final testing, better results were obtained as follows:

The impulse before the hurdle was performed at a horizontal distance from it of 1.88 m and at an angle of 121.3 degrees, the angle remaining unchanged from the initial test, allowing the runner to pass the CGM at a height of 1 .25 m from the ground and 0.34 m from the hurdle post.

The pass became more grouped and balanced, the landing could be made 1.03 m from the hurdle and at an angle of 84.1 degrees, all parameters being improved and highlighting an improvement in the coordination capabilities and the automation of movements compared to spatio-temporal dimensions. Flight time has also improved due to better technique and better controlled flight.

The continuation of the run was achieved with an angle of impulse between the landing leg and the ground of 136.6 degrees, allowing the subject to continue in a compensatory regime of the parameters towards the next hurdle. There is no progress, the angle needs to be more open, but it retains its characteristics according to the proportions and training level of the subject.

We also note that the level of coordination is better, more appropriate, which indicates that the coordination aspects as well as the balance have improved following the proprioceptive training program, and the technique of the hurdle runner's step has registered a substantial progress.

Table 67 – Kinematic parameters recorded for subject 1 – comparison between initial and final testing

No.	**Kinematic parameters 110 m. hurdles**	**It**	**Ft**	It – Fr	**Progress rate* %**
1	Raising the C.G.M. ground level (m.)	1,38	1,25	0.13	9,42
2	Maximum elevation of C.G.M. over the hurdle (m.)	0,47	0,34	0.13	27,66
3	Size of angle of attack (degrees)	118,5	121,3	-2.8	-2,36
4	Size of landing angle (degrees)	88,2	84,1	4.1	4,65
5	Flight time (sec.)	0,48	0,46	0.02	4,17
6	The horizontal distance from which the attack starts from the hurdle (m.)	1,45	1,88	-0.43	29,66
7	Horizontal distance of the landing from the hurdle (m.)	1,67	1,03	0.64	38,32

* The progress rate is expressed as a percentage (%) and is calculated according to the formula: [(Ti-Tf)x100]/Ti

3.7.7 Centralization and interpretation of kinematic parameters obtained by the 6 subjects

Table no. 73 – Centralization of kinematic parameters results for the 6 subjects – initial testing and final testing

	Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)	
	I.t.	F.t.	I.t.	F.t.	I.t.	F.t.	I.t.	F.t.	I.t.	F.t.	I.t.	F.t.	I.t.	F.t.
Subject 1	1,38	1,25	0,47	0,34	118,5	121,3	88,2	84,1	0,48	0,46	1,45	1,88	1,67	1,03
Subject 2	1,42	1,38	0,43	0,40	116,1	119,2	86,2	95,5	0,40	0,39	1,89	1,98	1,55	1,33
Subject 3	1,46	1,48	0,47	0,49	118,2	115,1	91,5	90,4	0,40	0,41	2,45	2,24	1,69	1,71
Subject 4	1,29	1,27	0,30	0,28	112,6	121,8	91,0	85,7	0,36	0,36	1,36	1,95	0,93	1,23
Subject 5	1,44	1,36	0,45	0,37	120,2	121	78,5	81,9	0,43	0,43	1,99	2,06	1,76	1,64
Subject 6	1,43	1,34	0,38	0,28	118	120	81,3	82,4	0,36	0,34	2,21	2,28	1,54	1,20

3.8 Testing the balance of subjects in the hurdles running step using Xsens sensors.

During the initial and final tests, the kinematic recordings were supplemented by recordings of the balance parameters (Roll, Pitch and Yaw) [15], using the high-precision Xsens sensors. [16]

Xsens offers cutting-edge technology that intelligently merges sensor data streams, combining them with precise, application-related mathematical models, providing accurate, high-fidelity motion tracking data ready for integration.

Fig. 109 – Xsens sensor used for parameter records of the 6 subjects

An Xsens sensor was mounted with the help of Prof. Zamfira Sorin from the mechatronics department of the "Transylvania" University in Brașov, and with the help of the special Matlab software, individually recorded data strings were generated. Approximately 100,000 values were generated for each recording, and following the selection of the tracked interval, namely the phases of passing over the hurdle, sequences of approximately 9,000 values resulted. These were represented in a graphical system and interpreted.

The three relevant parameters in the initial and final tests and which can provide us with information about the level of improvement in coordination capacities and balance following the individualized proprioceptive training program are: Roll, Pitch and Yaw. The three parameters show us, as in the case of all objects in nature that move on the 3 axes in the three-dimensional system, the direction of the rotation and the angle in which it occurs.

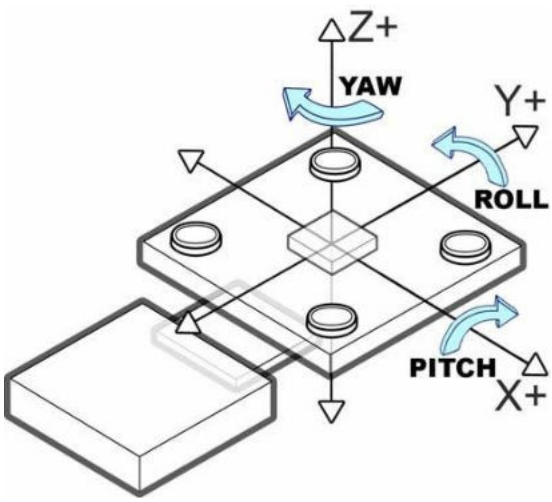


Fig. 110 – Motion parameters in the 3 3D axes

In the figure above we can see the three parameters represented by the 3 axes (X, Y and Z), representing the 3 planes (length, width and height), around which an object can move.

In the measurements made on the 6 subjects, we placed the Xsens sensor near the center of gravity because we thought it was the most relevant to provide us with information about the balance of the athletes during the crossing of the hurdle.

Fig. 111 – Placement of the Xsens sensor on the subject

All the data of the 3 parameters analyzed are in the form of angular values and show us the degree of inclination of the CG in the 3 planes. In other words, we will be able to analyze how much the athlete's torso bends, bends or twists together with the center of gravity during the passage over the hurdle.

By segmenting the string of records, we kept data highlighting the approximate time of the last running step before the hurdle to the next running steps after landing behind the hurdle. We took into account the two extreme values of the oscillations at the moment of landing behind the hurdle, values that allowed us to measure how balanced the landing of the 6 subjects is according to the 3 parameters measured by the Xsens sensor for the center of gravity.

3.8.1 Recording and interpretation Xsens values for the subject no. 1

In the initial testing, subject 1 recorded the reference values of the Roll parameter, according to the following graph:

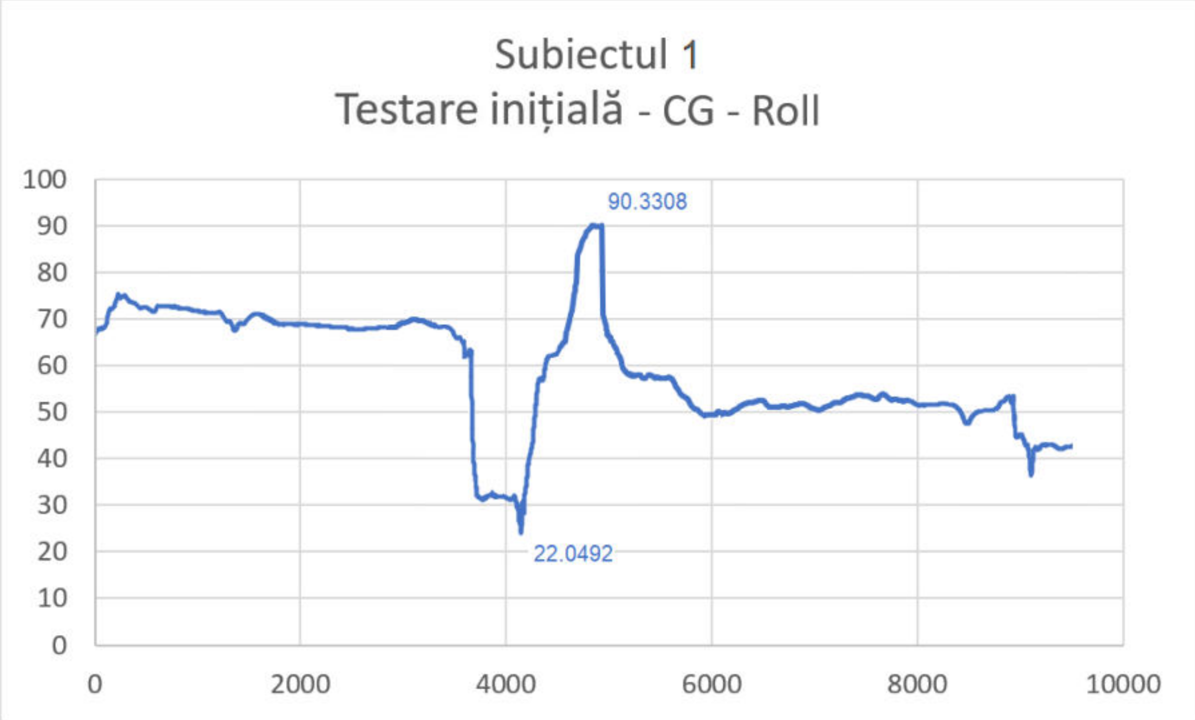


Fig. 112 – Xsens values for subject 1 C.M. during initial testing – Roll

When the subject lands behind the hurdle, the left-right inclination of the center of gravity registers the value of 22.0492 degrees, immediately after straightening, on the next step, it registers the angular value of 90.3308 degrees, after which, on the following steps, it returns to the initial values.

In order to obtain an absolute value to interpret in case of initial testing, we calculated the difference between the two angular values of the Roll parameter and obtained a value of 68.2816 degrees, the interval in which the center of gravity of the subject during the landing phase after the hurdle oscillates left – right on the horizontal axis.

For the final testing of the subject, the Roll parameter, values were obtained according to the following graph:

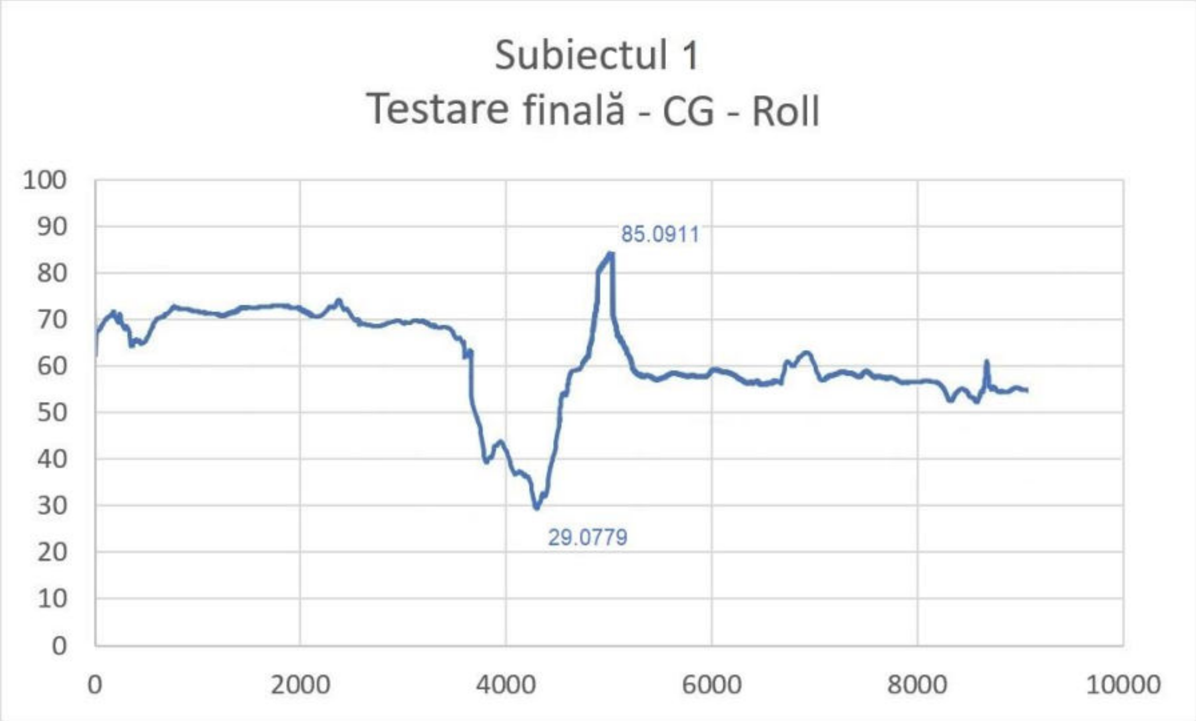


Fig. 113 – Xsens values for subject 1 C.M. during final testing – Roll

When the subject lands behind the hurdle, the left-right inclination of the center of gravity registers the value of 29.0779 degrees, immediately after straightening, on the next step, it registers the angular value of 85.0911 degrees, after which, on the following steps, it returns to the initial value.

After calculating the difference between the two angular values of the Roll parameter, we obtained an interval of 56.0132 degrees, in which the center of gravity of the subject in the landing phase after the hurdle oscillates left - right on the horizontal axis.

It can be seen that in the case of the final testing, the left-right inclination of the subject's center of gravity is lower than in the case of the initial testing by 12.2684 degrees. This indicates that the landing from the point of view of the Roll parameter (tilt left - right on the horizontal axis) was more balanced.

The angular values of the Pitch parameter for subject 1 in the initial testing were as follows:

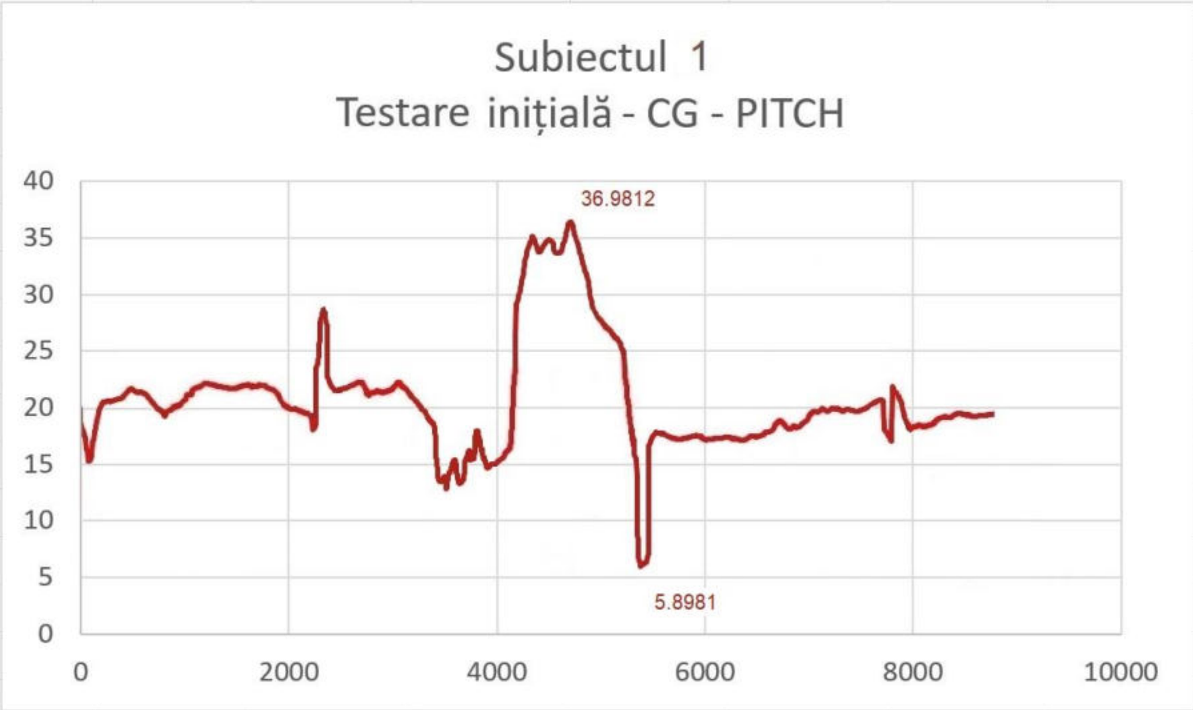


Fig. 114 – Xsens values for subject 1 C.M. during initial testing - Pitch

When the subject lands behind the hurdle, the front-back inclination of the center of gravity registers the value of 36.9812 degrees, immediately after straightening, on the next step, it registers the angular value of 5.8981 degrees, after which, on the following steps, it returns to the initial values.

By calculating the difference between the two angular values of the Pitch parameter, we obtained an interval of 31.0831 degrees in which the center of gravity of the subject in the landing phase after the hurdle oscillates front - back.

For the final testing of the subject, the Pitch parameter, values were obtained according to the following graph:

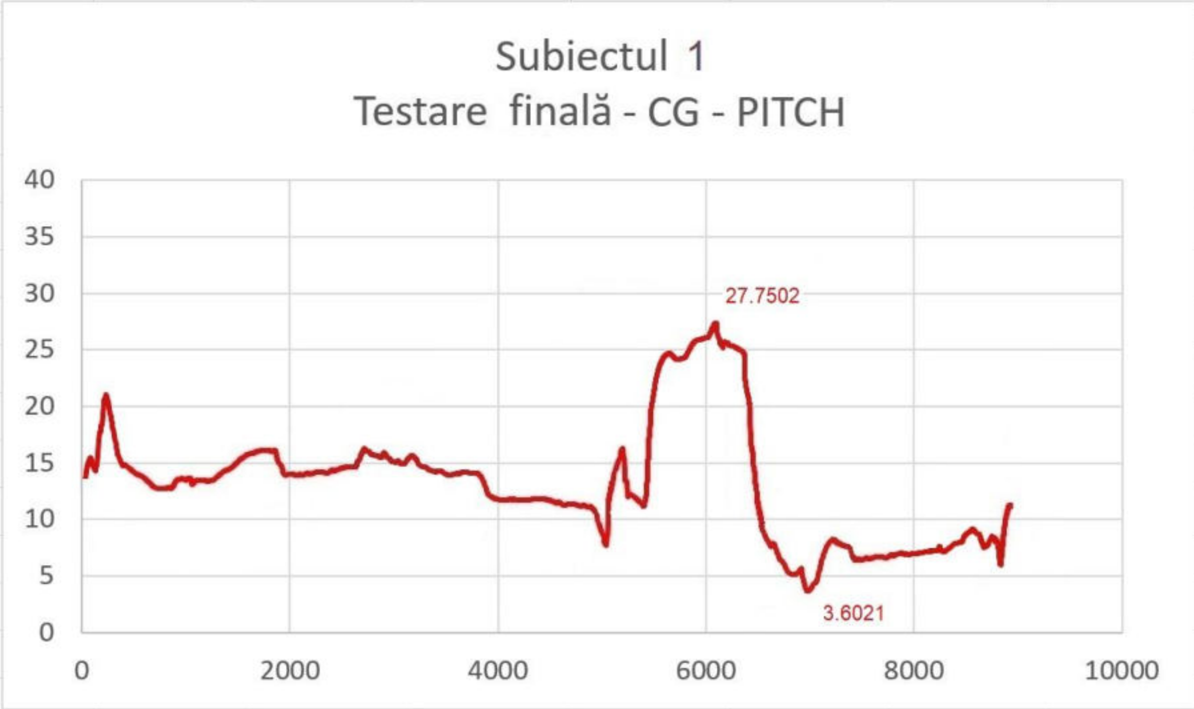


Fig. 115 – Xsens values for subject 1 C.M. during final testing – Pitch

At the moment of landing after the hurdle, the front-back inclination of the center of gravity registers the value of 27.7502 degrees, immediately after righting, on the next step, it registers the angular value of 3.6021 degrees, after which, on the following steps, it returns to the starting value, the average of the values from which the sensor was placed.

By calculating the difference between the two angular values of the Pitch parameter, we obtained an interval of 24.1481 degrees, in which the center of gravity of the subject oscillates front - back.

It can be seen that in the case of the final testing, the front-back oscillation of the center of gravity (Pitch) of the subject, as in the case of the Roll parameter, is less than in the case of the initial testing by 6.935 degrees. This indicates that the landing from the point of view of the Pitch parameter (front-back oscillation) was more balanced, with less amplitude oscillations.

The angular values of the subject's Yaw parameter in the initial testing were as follows:

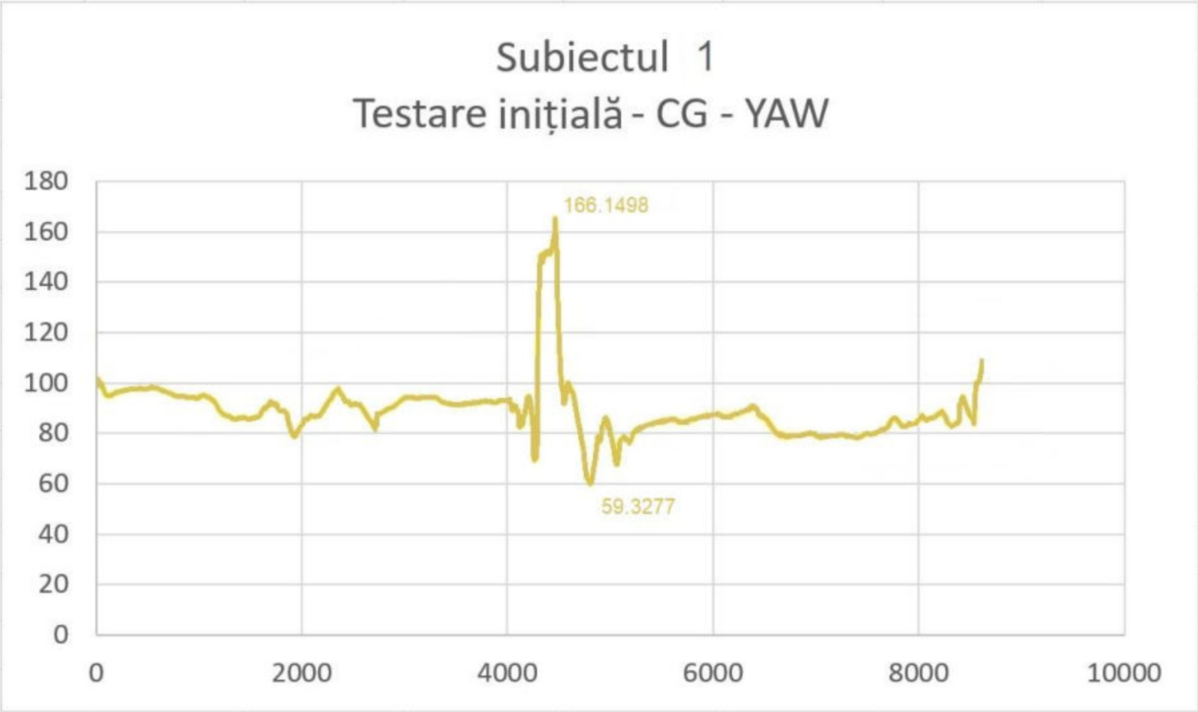


Fig. 116 – Xsens values for subject 1 C.M. during initial testing – Yaw

When the subject lands behind the hurdle, the left-right oscillation on the vertical axis of the center of gravity registers the value of 166.1498 degrees, immediately after the recovery, on the next step, it registers the angular value of 59.3277 degrees, after which, on the following steps , it returns to the initial start-up values.

By calculating the difference between the two angular values of the Yaw parameter, we obtained an interval of 106.8221 degrees in which the center of gravity of the subject oscillates left – right on the horizontal axis.

For the final testing of the subject, the Yaw parameter, values were obtained according to the following graph:

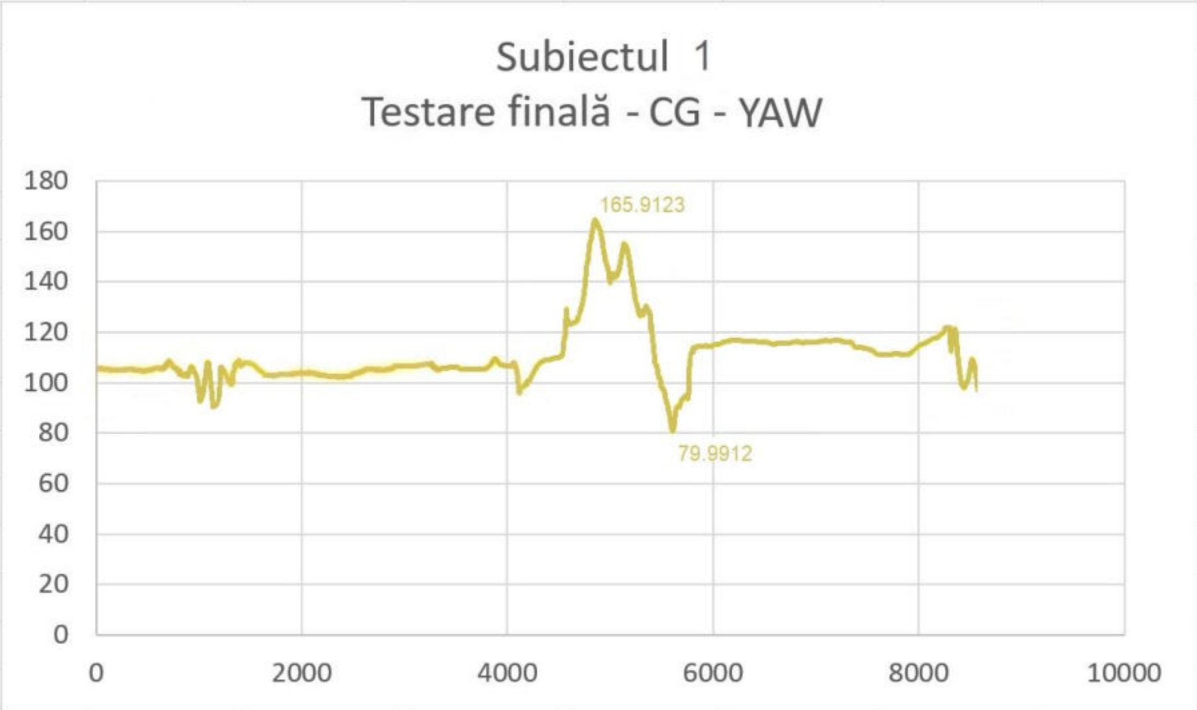


Fig. 117 – Xsens values for subject 1 C.M. during final testing – Yaw

When the subject lands behind the hurdle, the left-right oscillation on the vertical axis of the center of gravity registers the value of 165.9123 degrees, immediately after the recovery, on the next step, it registers the angular value of 79.9912 degrees.

Calculating the difference between the two angular values of the Yaw parameter, we obtained a value of 85.9211 degrees, where the center of gravity of the subject oscillates left - right on the vertical axis.

It can be seen that in the case of the final testing, the left-right twist of the center of gravity of the subject is less than in the case of the initial testing by 20.901 degrees. This denotes the fact that the landing from the point of view of the Yaw parameter (turning left - right) was more balanced, with less amplitude oscillations.

3.8.7 Centralization of the results obtained with the Xsens sensor

Following the recordings made on the center of gravity of the body mass for the 6 subjects using the Xsens sensor and as we could see above in the graphs and previous interpretations, we will consider the eloquent differences between the angular values obtained for the 3 analyzed parameters and centralize subject results as follows:

Table 74 – Difference between tests for the 3 Xsens parameters (angular values)

	Roll	Pitch	Yaw
S1	12.2684	6.935	20.901
S2	11.1369	3.865	11.3424
S3	12.4739	7.7679	22.0543
S4	0.438	5.7334	16.3181
S5	17.8078	0.3119	7.9045
S6	5.5084	1.7971	20.51

Except for subject 4, the Roll parameter, and subject 5, the Pitch parameter, where there is a stagnation in landing stability after the hurdle, otherwise, in all other cases, the 6 subjects show considerable progress in landing balance behind the hurdle

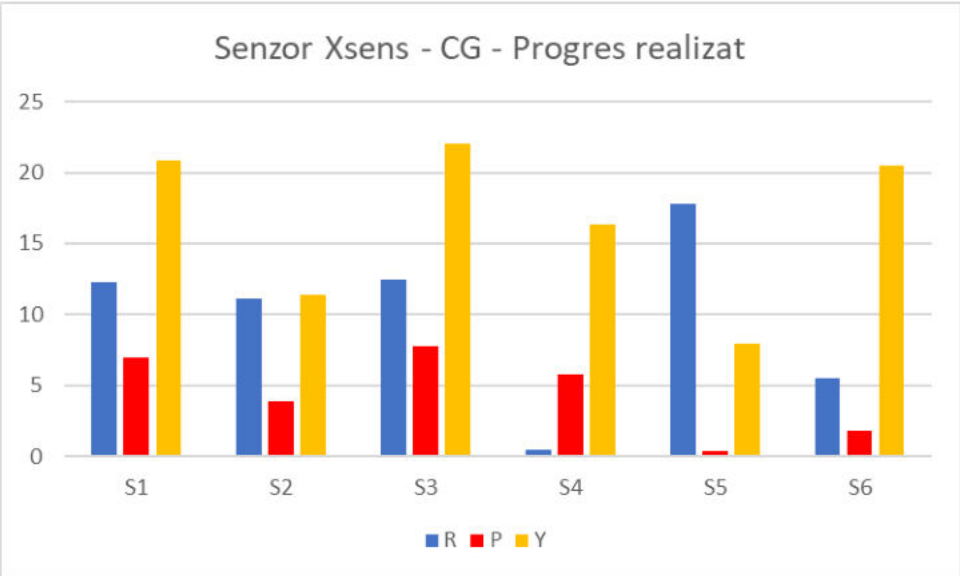


Fig. 148 – Xsens testing – Progress after the two tests

3.9 Centralization and interpretation of results

Table nr. 75 – Centralization of the results of the 6 subjects – initial test and final test non-specific samples

	Standing long jump (cm)		Sprint 50m (sec)		Pull-ups (reps)		Abdominals in 30 sec. (rep)	
	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.
Subject 1	182	183	8,0	7,9	7	8	28	31
Subject 2	189	195	7,5	7,2	10	12	25	28
Subject 3	195	193	6,8	6,9	9	9	30	30
Subject 4	192	208	7,5	6,9	8	11	34	35
Subject 5	186	193	7,1	6,7	10	12	27	32
Subject 6	248	255	5,8	5,7	12	14	35	38

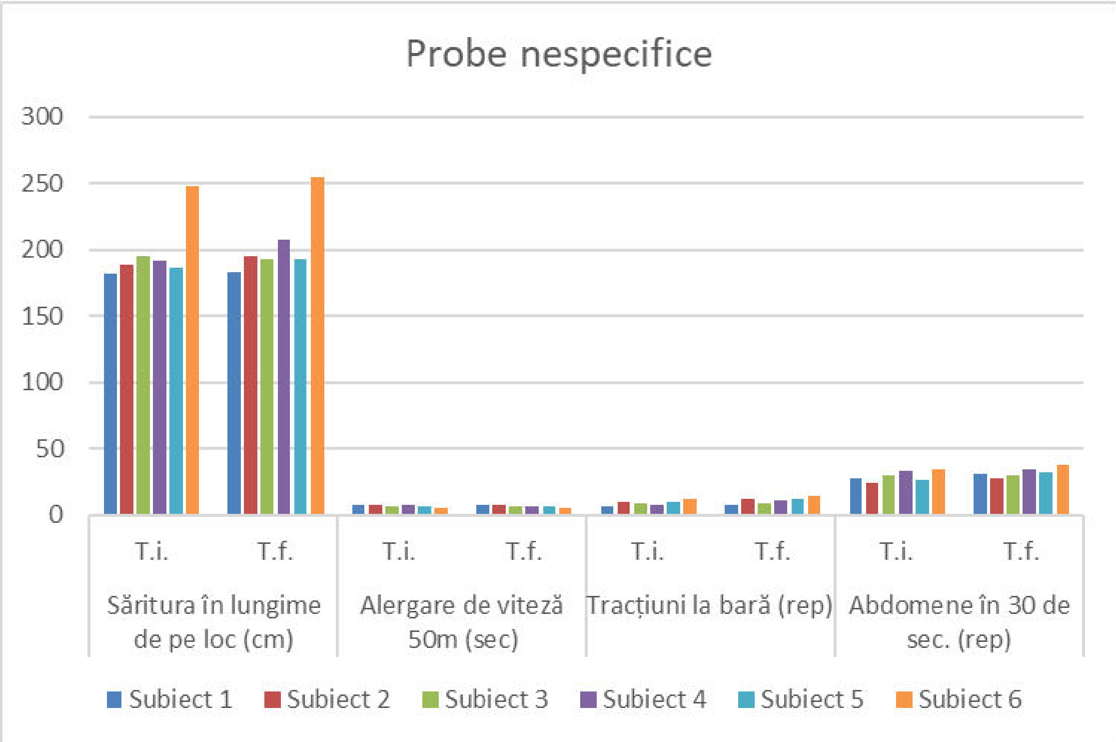


Fig. 149 – Centralization of non-specific test results of the 6 subjects

Table nr. 76 – Centralization of the results of the 6 subjects – initial test and final test specific samples

	60 m hurdles		Start with crossing 1 hurdle (sec)		Start with crossing 2 hurdles (sec)		Start with crossing 3 hurdles (sec)		Start with crossing 5 hurdles (sec)		Best result 110 mg (sec)	
	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.
S1	10,83	10,44	3,54	3,51	5,65	5,42	7,76	7,43	11,12	11,01	19,47	17,73
S2	9,34	9,06	2,61	2,55	4,07	3,95	5,75	5,54	8,88	8,24	18,45	17,67
S3	8,76	8,91	2,22	2,44	3,73	3,92	5,15	5,55	8,03	8,35	16,68	17,15
S4	8,72	8,65	2,37	2,13	3,71	3,55	5,34	4,99	7,78	7,42	15,84	15,53
S5	8,52	8,35	2,21	2,06	3,42	3,31	4,93	4,62	7,88	7,53	16,15	15,83
S6	8,84	8,42	2,15	2,05	3,44	3,25	4,88	4,66	7.75	7,47	14,67	14,28

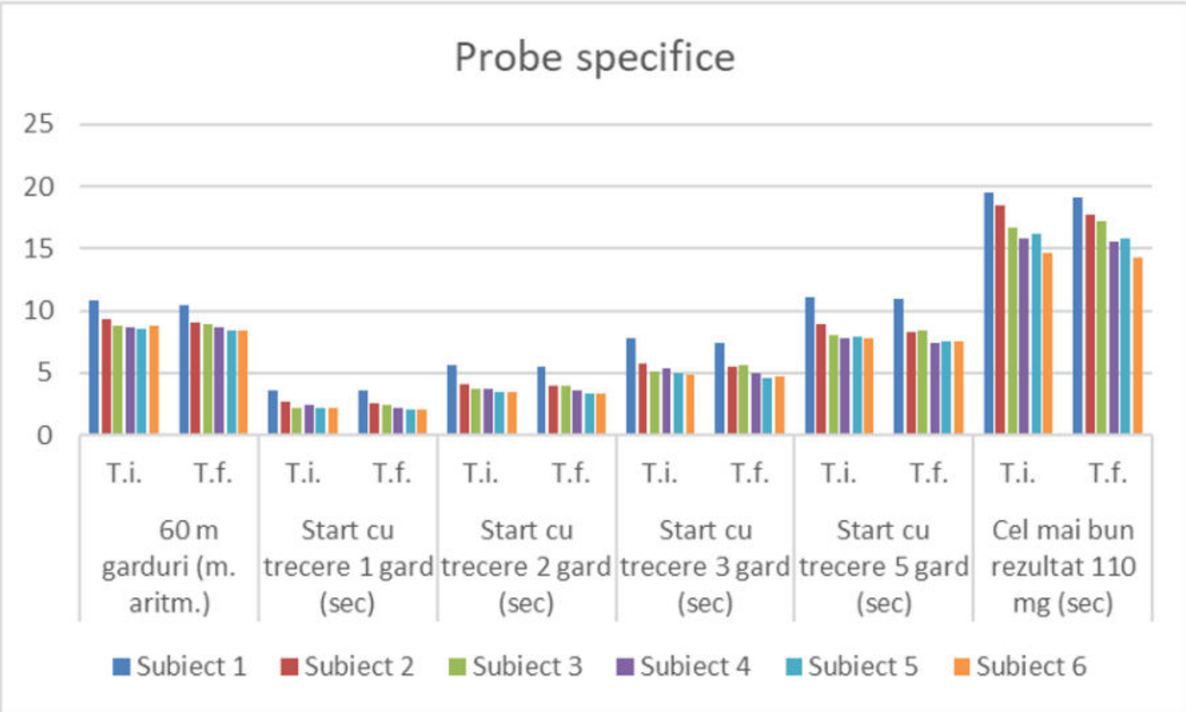


Fig. 150 – Centralization of the results of the specific tests of the 6 subjects

Table nr. 77 – Centralization of kinematic parameters results for the 6 subjects – initial testing and final testing

	Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)		Raising the C.G.M. ground level (m.)	
	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.	T.i.	T.f.
Subject 1	1,38	1,25	0,47	0,34	118,5	121,3	88,2	84,1	0,48	0,46	1,45	1,88	1,67	1,03
Subject 2	1,42	1,38	0,43	0,40	116,1	119,2	86,2	95,5	0,40	0,39	1,89	1,98	1,55	1,33
Subject 3	1,46	1,48	0,47	0,49	118,2	115,1	91,5	90,4	0,40	0,41	2,45	2,24	1,69	1,71
Subject 4	1,29	1,27	0,30	0,28	112,6	121,8	91,0	85,7	0,36	0,36	1,36	1,95	0,93	1,23
Subject 5	1,44	1,36	0,45	0,37	120,2	121	78,5	81,9	0,43	0,43	1,99	2,06	1,76	1,64
Subject 6	1,43	1,34	0,38	0,28	118	120	81,3	82,4	0,36	0,34	2,21	2,28	1,54	1,20

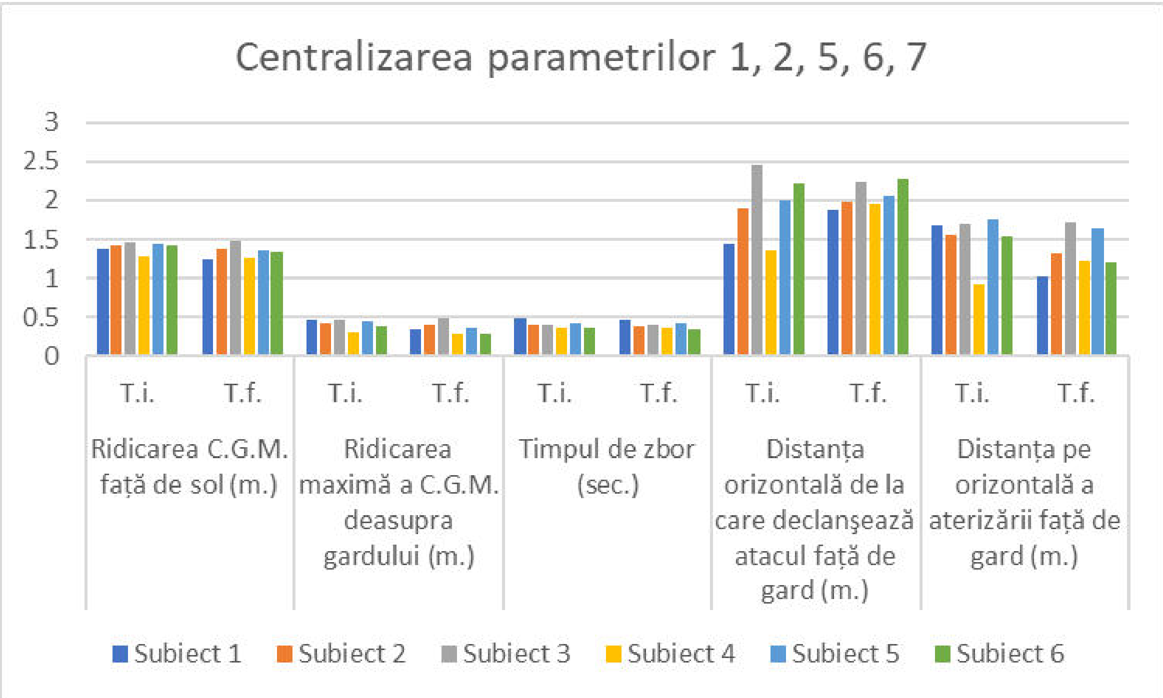


Fig. 151 – Centralization of kinematic parameters 1, 2, 5, 6, 7

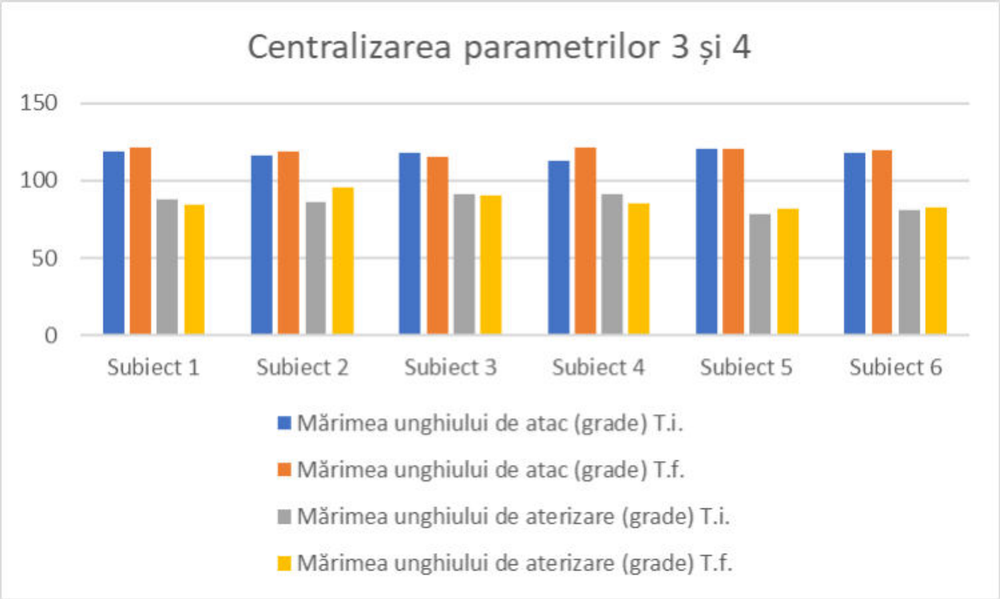


Fig. 152 – Centralization of kinematic parameters 3 and 4

Table 78 – Centralization of the results obtained with Gyko sensor

Nr	Subjects		Exercise 1			Exercise 2			Exercise 3			Exercise 4		
			Lenght	Dist.	Speed	Lenght	Dist.	Speed	Lenght	Dist.	Speed	Lenght	Dist.	Speed
1.	S1	A	1361	11.9	216.8	1138	19	189.9	1011	12.5	161.7	357	3.11	59.4
		I	1161	27.7	185	796	16.9	138.5	439.3	7.48	69.7	159.4	4.3	26
		O	487.5	30.1	77.6	677	16.7	114.7	466.7	12	78.8	137.4	3.5	23.4
2.	S2	A	1147	17.4	189.7	1146	16.1	189.2	727	6.9	120.4	381.4	3.3	63.6
		I	737.4	11.8	121.2	739	10.8	114.9	411.2	7.9	67.6	176.4	5.7	28.1
		O	673.4	11.3	113	818.9	12.1	130.9	653.5	11.1	108.5	169.3	3.5	27.8
3.	S3	A	989.7	9.5	166.5	946.2	15.9	156.2	582	8.7	95.1	359.2	3.5	59.7
		I	653.3	11.5	108.7	754.8	14.2	126.7	529	10.5	86.8	176.2	5.8	29
		O	610.6	8.8	100.8	768.8	12.9	128.5	439	10	73.4	148.1	4.2	25.2
4.	S4	A	808.4	8.4	133.1	1081	15.2	170.2	633.4	9.8	103.3	203.5	2.5	32.6
		I	685.3	11.1	113.1	696.3	20.4	117.7	343.9	5.8	57.5	179.2	3.6	30.1
		O	633.9	8.1	109.1	830.5	14.4	136.1	506.9	8.3	85.7	169.9	4.5	29.5
5.	S5	A	978.2	10.6	160.9	784.2	13.7	132.6	530.3	6.2	89.6	295.5	2.7	49.5
		I	576.1	8.3	97.6	676.6	14.8	113.7	479.1	7.2	80	253.3	6.5	42.4
		O	518.9	7.6	86.5	427.9	10.7	69.9	399.1	5.2	66.9	136.2	5.3	23.4
6.	S6	A	595.6	8.6	103.2	810.6	16.9	132	498	6.8	82.4	164	2.9	26.9
		I	542.6	7.3	92.6	685.4	17.1	113.7	376.3	8.5	63.9	149.7	7.1	24.6
		O	239.7	6.6	41.2	384	11.8	65.2	271.9	5.8	45.2	96.5	5.4	15.9

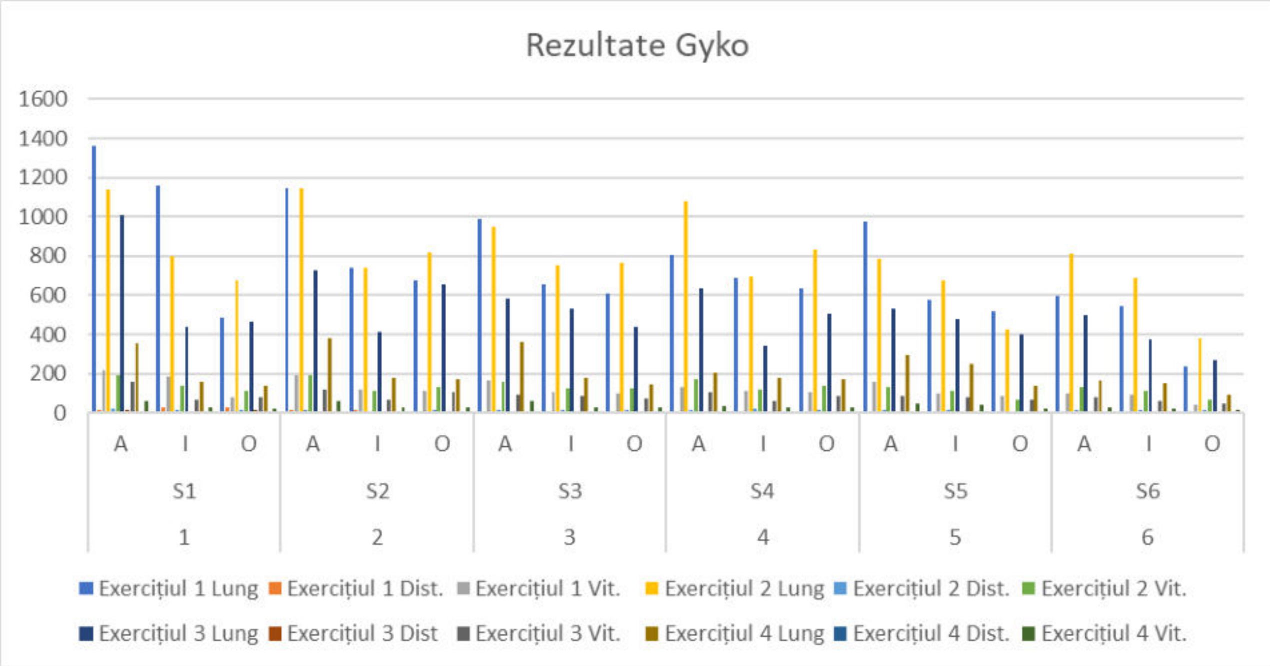


Fig. 153 – Centralization of results using Gyko for the 6 subjects

Table 79 – Centralization of the results obtained with the OptoJump platform

Nr. crt.	Subjects		Exercise 5		Exercise 6	
			Cont. T.	Power	Cont. T.	Power
1.	S1	A	0.504	2.74	0.480	3.18
		I	0.369	7.35	0.447	5.49
		O	0.480	3.18	0.362	8.19
2.	S2	A	0.439	3.29	0.466	3.76
		I	0.464	2.77	0.470	4.88
		O	0.390	6.76	0.389	6.78
3.	S3	A	0.402	4.33	0.463	3.99
		I	0.497	2.94	0.460	4.41
		O	0.348	10.02	0.347	9.97
4.	S4	A	0.465	5.64	0.540	4.42
		I	0.469	4.25	0.466	4.94
		O	0.360	9.05	0.380	8.03
5.	S5	A	0.436	4.43	0.524	3.71
		I	0.451	5.11	0.423	5.91
		O	0.376	9.10	0.373	9.34
6.	S6	A	0.421	4.39	0.496	5.40
		I	0.454	4.47	0.395	8.18
		O	0.278	14.87	0.285	12.56

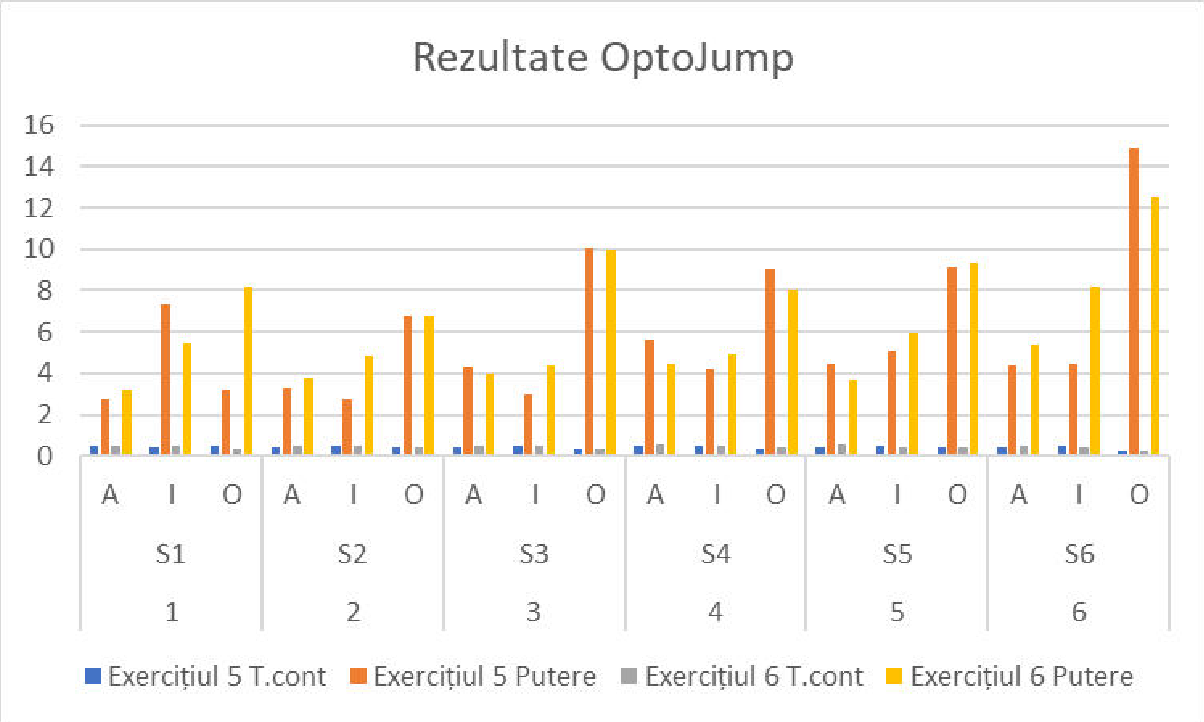


Fig. 154 – Centralization of results using the OptoJump platform for the 6 subjects

Table 80 – Centralization of the results obtained with the Xsens sensor

Nr. crt.	Subiecți		Testare inițială		Testare finală	
			Min.	Max.	Min.	Max.
1.	S1	R	22.0492	90.3308	29.0779	85.0911
		P	5.8981	36.9812	3.6021	27.7502
		Y	59.3277	166.1498	79.9912	165.9123
2.	S2	R	19.1158	82.5833	30.4508	82.7814
		P	4.8781	33.1268	2.4915	26.8752
		Y	49.2276	151.1343	79.9845	170.5488
3.	S3	R	8.2298	77.8019	21.7791	78.8773
		P	6.2291	34.7139	7.7679	28.4492
		Y	49.9932	151.8221	64.9803	144.7549
4.	S4	R	30.6223	80.2194	30.0144	80.0495
		P	8.0193	33.7519	7.3309	27.3301
		Y	89.7739	162.5452	61.8338	150.9232
5.	S5	R	25.8803	93.2865	35.0225	84.6209
		P	6.9205	34.1393	7.4845	34.3914
		Y	82.3991	140.7792	85.8344	152.1190
6.	S6	R	40.0023	90.0552	45.2289	89.7734
		P	8.2209	29.2208	10.8301	30.0329
		Y	70.9338	170.3208	79.3431	158.2201

3.10 Statistical-mathematical interpretation of research results

We use the method of arithmetic percentage calculation of the progress rate for each subject: Ft -It all divided by Ft, and the result multiplied by 100, used in order to obtain the forecast of the rate of progress in performance.

Table nr. 81 - Average progress rate of the sample of subjects researched in the experimental research

	Non-specific physical training	Specific physical training	Recorded kinematic parameters	TOTAL
S1	6,7%	2,64%	16,6%	(6,7+2,64+16,6):3 = 8,64%
S2	9,79%	3,88%	6,38%	(9,79+3,88+6,38):3 = 6,68%
S3	-6,23%	- 5,21%	0,45%	(-6,23+(-5,21)+0,45):3 = - 3,66%
S4	14,19%	4,53%	13,97%	(14,19+4,53+13,97):3 = 10,89%
S5	11,97%	4,11%	5,51%	(11,97+4,11+5,51):3 = 7,19%
S6	7,44%	4,28%	9,48%	(7,44+4,28+9,48):3 = 7,06%

IBM SPSS Statistics for Windows software, Version 26.0, was used for statistical processing of the study data. Armonk, NY: IBM Corp.

Continuous variables were expressed by mean value, standard deviation, minimum and maximum.

As the sample studied was very small, the Wilcoxon test was used for paired observations. For multiple comparisons we used the Friedman test.

Although the sample of subjects in the experiment is small, which means a low statistical power, some test results are statistically significant being below the significance threshold of 0.05, and most being statistically marginal, at the threshold. For this reason we can say, without error, that the hypotheses related to the data recorded using modern technologies are confirmed.

CONCLUSIONS FOLLOWING THE BASIC RESEARCH

- All the modern means of recording and measuring used in the training of junior hurdle runners in the study proved to be extremely useful by analyzing and interpreting the data provided by them and the significant influence they had in improving the step technique. hurdle runner, confirming the first hypothesis formulated in the thesis.

- The software through which we analyzed the 7 parameters monitored in the kinematic recordings made on the 6 subjects of the study, and the interpretation of the results obtained by comparing the values of the parameters in the initial and final tests, highlighted the confirmation of hypothesis II, most errors technique registering a good and very good evolution in the sense of correction, which led to the improvement of the hurdle running technique.

- We found that the introduction of the proprioceptive training program in the specific training of hurdles for the 6 athletes considerably influenced the development of coordination skills, ground impulse power, ground contact time and balance, aspects that led us to confirm the third hypothesis formulated in the paper.

- The working hypotheses that were established can be said to have been met, which is confirmed by the results of basic research, and we can see the objectification of the technique in the 110 m hurdle in the junior category in the case of 5 of the 6 subjects of the study.

- The more modern technologies are used to record and monitor the relevant parameters for the hurdle running technique, the more can influence the training in sports training for junior hurdle runners.

Technical-methodical conclusions:

- Following the implementation of the proprioceptive training program for junior hurdle runners, the athletes improved, among other things, their speed of execution, balance, mobility and postural control in the hurdle running step.

- Correction of technical errors observed in the final test by analyzing the images with the parameters of the run of the hurdle led to a decrease in flight time in 3 subjects and its stagnation in 2 subjects, which led to better performance in competitions at over half of the subjects of the basic research.

- If it is possible to improve the running of the hurdles and especially the landing phase after the hurdle, the running between the hurdles will be faster due to the firmer impulse and the more balanced position, which determines the decrease of execution times within the passage phases of all 10 hurdles, and in the end, better results in the races of 110 m. Hurdles.

- The use of modern technological means of recording and analysis of aspects of technical finesse provides technicians with essential support in establishing individualized training programs among runners in the 110 m hurdles. They have at their disposal a multitude of variants of modern means that can provide them with data and analysis about every detail of the technical process or motor action that they want to correct and optimize.

- Following the study, 5 out of 6 subjects improved their results in the 2018 - 2019 - 2020 competition seasons, subject 6 progressing from 14.67 to 14.28 sec performance. in the test of 110 m hurdles, an aspect that confirms again the hypotheses from which we started the research. The follow-up of the subsequent competitive results of the subjects can be analyzed in Annex 17.

DISSEMINATION OF RESULTS

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RESEARCH LIMITS AND FUTURE RESEARCH DIRECTIONS

The proposal of this paper to contribute to the improvement of the technique of running hurdles by modern means of registration and testing, and individualized proprioceptive training has some limitations. These, together with the results obtained in the study and the objectives achieved, offer the possibility to orient the research approach towards new and challenging directions.

The first limitation of the paper is that regarding the number of subjects, only 6 case studies being investigated, but if their number had been higher, the study could have been more relevant, the subsequent directions could be more precise and the conclusions with a higher degree. great generalization.

Another limitation is the number of modern technological means with which the recordings and measurements were made. Thus, if they had been more numerous (more high-speed cameras, more inertial sensors, more OptoJump platforms), the data obtained would have been more, their interpretation would have issued more relevant conclusions.

Because the athletic event of 110 m hurdles is extremely technical, and the training of athletes at the age of junior becomes difficult in the absence of the necessary material equipment.

The present research meets the limits described above but we consider that the proposed objectives have been met, and the aspects studied can be further developed for new training programs that use the processing and analysis of kinematic recordings through modern software. Also, the use of test equipment with sensors and infrared cell can be used in modeling the training of athletes and optimizing the performance of athletes running hurdles.

RECOMMENDATION

- After obtaining all the results of the research, we recommend emphasizing the training of junior athletes in the 110 m hurdles on encouraging the self-correction of technical errors following the analysis of images with the coach and his explanations.

- We recommend emphasizing the means of proprioceptive training in hurdle training, especially the landing phase after the hurdle within the hurdle run, because the level of its balance depends on the optimal chaining of phases and stages of the hurdle race, and finally competitive performance in the test of 110 m. hurdles.

- We recommend the application of an individualized proprioceptive training program from the beginning of the junior period because it will be possible to improve the technical execution in the hurdle running step based on the capacity of coupling and segmental coordination.

- We recommend the use of high-performance, quality modern means, because their poor quality can alter the training objectives and the expected results may be small compared to expectations.

- It is also recommended to introduce at least two modern technologies for measuring, recording and monitoring the technical parameters in the sports training of junior athletes for a greater relevance of the measurements, but the more such means will be used, the more the technical, biomechanical aspects will be analyzed in more detail and the running of the hurdles will be corrected in more detail, with much improved results.

ABSTRACT

The study carried out in this paper aimed to highlight the importance and usefulness of introducing and using modern means of recording, measuring, testing, as well as introducing a proprioceptive training program and analyzing and correcting technique using kinematic recordings processed and analyzed using a modern software in sports training in the 110 m. hurdles for junior athletes.

In part I of this paper we addressed the defining concepts of hurdles sports training and international approaches to improving the technique of hurdle clearance using kinematic recordings processed using high-performance software. In part II we elaborated the preliminary study in which we analyzed the kinematic recordings of the phases of the hurdles running step on a junior subject national champion of the test. The obtained results highlighted the usefulness of the images and parameters analyzed in correcting the technique in the 110 m hurdles. Part III includes concrete intervention methods such as a proprioceptive training program and modern means of recording and monitoring 6 junior runners.

The conclusions of the study confirm all the hypotheses that we initially established, as well as the fact that we can continue the research in other studies but also the progress of the subjects in the official competitions in which they participated.

Keywords: hurdles running step, proprioception, modern technology, technique

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