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TECHNICAL TRAINING OF THE FEMALE FOIL FENCERS AT THE BASIC SPECIALIZATION STAGE USING BIOMECHANICAL CRITERIA

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INTRODUCTION

Relevance of the topic and importance of the addressed issue. Fencing, a discipline with a long history, has evolved significantly from a combat technique to a refined sport, where innovations such as the introduction of the foil, protective masks, and the electrification of weapons have enhanced both safety and precision in competitions [3, 8, 14, 20].

The application of biomechanical data in fencing enables the personalization of training, optimization of technique and injury prevention. Advanced technologies, such as accelerometers and force platforms, allow for precise monitoring of the performance of athletes, facilitating the adjustment of combat strategies. The integration of visual and kinesthetic feedback in foil fencing training contributes to technical improvement by enhancing proprioception. Understanding and applying current biomechanical criteria, alongside modern technologies, are essential for maximizing performance and reducing injury risk. Furthermore, continuous adaptation to technological innovations emphasizes the efforts of athletes and coaches to maintain a high competitive level in a constantly evolutionary sport [2, 5, 6, 29].

Studies in sports biomechanics are very important for optimizing the performance of athletes, by applying biomechanical principles to improve movements and prevent injuries [26]. The biomechanics of musculoskeletal injuries is analyzed to provide valuable insights into injury prevention during training. A detailed understanding of sport-specific movements contributes to achieving superior performance [15].

A biomechanical perspective on sports techniques allows for their optimization, while the analysis of human movement kinetics is crucial for the proper application of biomechanical principles [12, 29]. Motor control and biomechanics are fundamental for coordinating precise movements, while applying biomechanical principles supports both performance improvement and prevention of injuries [27, 18].

The interactions between the nervous system and human movement highlight the importance of coordination in sports like fencing [10]. Research methods used in biomechanics are highly important for assessing movements in high-performance sports. The integration of qualitative research enriches the understanding of sports movements [14, 21]. The analysis of specific techniques, the use of inertial sensors and the implementation of intelligent algorithms are fundamental for evaluating the efficiency of technical actions and adapting training programs [2, 7].

Moreover, recent studies reveal the importance of personalized physical training that meets the specific biomechanical and physiological requirements of

competitions, contributing to the improvement of athletes' performance [24]. These studies provide a solid foundation for developing more effective training programs tailored to the individual needs of athletes and the specific requirements of high-performance competitions.

In fact, these issues have become the focus of our research. They aim to contribute to the enhancement of the technical training of elite foil fencers through the application of biomechanical criteria.

Description of the research field and identification of research issues. The current state of research on the technical training of foil fencers during the basic specialization stage through the application of biomechanical criteria identifies several relevant aspects and specific issues. Recent studies emphasize the importance of applying biomechanical criteria in the technical training of foil fencers, contributing to performance improvement and injury prevention [4, 5, 16, 23, 28].

Additionally, research in the field of physical training for fencing underscores the need to adapt training loads to the physiological and biomechanical demands of competitions [24, 25]. The use of motion technologies and machine learning approaches to analyze the biomechanical characteristics of foil fencers contributes to assessing their skill level and optimizing training support [2, 3]. Studies on improving the coordination abilities of skilled fencers highlight the importance of specific training for developing these abilities. Furthermore, informational processes and perceptual stimulation in fencing training are essential for enhancing technical performance [5].

Currently, researchers and practitioners in high-performance sports, such as Knudson D. [15] or Whiting W. C. and Zernicke R. F. [26], focus on integrating and applying biomechanical principles in athlete training to optimize movement efficiency, prevent injuries and maximize performance in competitions. These specialists explore ways to refine fundamental techniques, adapt individualized training and incorporate advanced technologies for assessing and improving fencing performance.

In this context, performance optimization can be achieved through a combination of specific training and advanced motion assessment techniques [7], which provide a detailed review of fencing biomechanics. Moreover, advanced physical training techniques, tailored to the biomechanical and physiological requirements of competitions, are essential for achieving a high level of performance [24, 25]. By utilizing technologies such as inertial sensors and intelligent algorithms, it is possible to analyze the efficiency of technical actions [2, 6]. Additionally, mechanical and muscular coordination plays a crucial role in athletic success; the research conducted by Guilhem et al. [11] provides relevant insights in this regard.

Among the research issues identified in studies by authors like Aresta S. et al. [3], Campaniço A. T. [5], Chen T. L. W. et al. [7], Dinţică D. [9], Guilhem G. et al. [11], McGregor S. [19], Roi G. S. and Bianchedi D. [22], Sowerby A. [23], Turner A. [24], Turner A. et al. [25] and Wojciechowski Z. [28], the following stand out:

- The optimization of fundamental foil techniques through biomechanical analysis aimed at improving execution to ensure correctness and efficiency;
- Biomechanical analysis can assess the correct body posture and balance distribution during technical execution, aspects that are essential for movement stability and efficiency in fencing;
- Understanding the dynamics of specific movements, such as advancing and retreating on the piste, can be enhanced through a detailed analysis of biomechanical parameters such as speed, acceleration and deceleration;
- Biomechanics can significantly contribute to evaluating how the blade is used in various offensive and defensive techniques, including attack angles and the application of pressure on the opponent;
- Energy economy is an important factor in fencing performance;
- Injury prevention in fencing is a major concern. Identifying and correcting biomechanical deficiencies can reduce the danger of injuries during training and competitions;
- Individualized training adaptation based on the biomechanical characteristics of athletes is essential for maximizing fencing performance;
- The integration of advanced technologies, such as video analysis and computer simulations, into fencing training can significantly consolidate the understanding and application of biomechanical criteria;
- The effectiveness of training methods consistent with the biomechanical criteria for improving the performance of athletes at the specialization stage can be assessed using a range of specific methods and techniques.

These research aspects reflect the ongoing concern of the scientific community and coaches in refining technical training methods in fencing through the application of advanced biomechanical knowledge. Their systematic approach and the integration of research findings into training practice are essential for continuous progress in this sports field.

The research problem lies in the limited number of scientific and practical-methodological studies on optimizing the technical training process of female foil fencers at the basic specialization stage. The development and implementation of an experimental program focused on planning specific means and action systems based on biomechanical criteria would lead to an improvement in athletic performance in this discipline.

Hypothesis of the study: optimizing the technical training level of female foil fencers at the basic specialization stage, by using biomechanical criteria, will lead to improvements in the key components of execution technique and, consequently, will result in increasing performance levels.

Purpose of the research: the purpose of the research is to investigate the effectiveness of technical training for junior female foil fencers at the basic specialization stage through the use of biomechanical criteria.

Research objectives:

1. Study the conceptual benchmarks regarding the technical training of the female foil fencers at the basic specialization stage.
2. Determine the level of athletic and somato-functional training of junior female foil fencers.
3. Analyze the opinions of specialists regarding the technical training of elite foil fencers through the use of biomechanical criteria.
4. Develop an experimental program focused on using biomechanical criteria for junior female foil fencers.
5. Conduct experimental validation of the effectiveness of the experimental program based on biomechanical criteria in the technical training of foil fencers at the basic specialization stage.

The experimental basis consists of the following training halls: Floreasca Sports Hall- Bucharest, CSTA Băneasa Sports Hall - Bucharest, "Alexandru Csipler" Sports Hall - Satu Mare, the National Sports Complex "Piatra Arsă" Sinaia - Prahova County, and the Olympic Sports Complex "2000" Izvorani - Ilfov County. The sports facilities for the athletes from the Romanian national fencing team (weapon:foil), was well-suited for successfully carrying out the training process at a high level, which allowed us to conduct the research under optimal conditions.

The novelty and scientific originality of the work lie in the advanced integration of biomechanical principles into the technical training of the female foil fencers, an approach that brings innovative perspectives and precise methods for improving sports performance. The main innovative contributions of this research include: the integration of biomechanics into fencing training; evaluation and correction of biomechanical deficiencies; individualized adaptation of training; use of advanced technologies; experimental validation of methods; interdisciplinary contributions. These original inputs demonstrate the potential of using biomechanical criteria in transforming the technical training of fencers, providing a solid foundation for the continuous improvement of sports performance and the development of more effective and safer training methods.

The scientific results experimentally demonstrate the effectiveness of enhancing the technical training level of the female foil fencers through the use of

biomechanical criteria. The implementation of the proposed experimental program will contribute to the improvement of sports performance.

The theoretical significance of the work arises from the fact that, following the analysis of the specialized literature and the opinions of field experts cited throughout the research, methodological benchmarks were established for improving the technical training level of the female foil fencers based on the use of biomechanical criteria. These ones, in turn, contribute to completing existing concepts in the theory and methodology of sports training in fencing, especially at the stage of basic specialization.

The practical value of the work offers the possibility of implementing the experimental program and methodological benchmarks at the stage of basic specialization for junior female foil fencers. The results obtained can serve as a methodological guide for coaches of specialized fencing sports schools (weapon: foil), as well as for students of higher education institutions of physical education and sports specializing in "Fencing."

Implementation of the scientific results. The research results were implemented within the training sessions of junior female foil fencers from various specialized Fencing Sports Clubs in Romania, such as: CS Rapid, Bucharest; C.S.T.A. Bucharest; C.S.A. Steaua, Bucharest; C.S. Corona, Brașov. The results can be used as methodological material in the professional training of students from higher education institutions of physical education and sports, specializing in "Fencing."

Practical application of research results

The proposed experimental methodology has been approved and implemented in the training process of the junior national fencing team. The research results have been presented and published in the form of articles and papers within various national and international scientific conferences and events. Following the conducted research and recorded findings, works have been published at USEFS, the International Congress "Sport. Olympism. Health," Chisinau, 2020, 2021; the International Scientific Conference "Actualities and Perspectives of Physical Education and Sport Sciences," Ecological University of Bucharest, 2022, 2023, 2024. Additionally, the works have been published in specialized journals indexed in international databases (BDI), such as Discobolul – Physical Education, Sport and Kinetotherapy Journal, 2019; Gymnasium – Scientific Journal of Education, Sports and Health, 2020; Ovidius University Annals, Series Physical Education and Sport, Science, Movement, and Health, 2024.

Structure of the thesis: introduction, 3 chapters, general conclusions and recommendations, bibliography with 235 sources, 12 appendices, 140 pages of core text, 26 figures, 44 tables. The results have been published in 8 scientific papers.

Keywords: fencing, female juniors, biomechanics, sports training, physical training, technical training, technical-tactical training, training session, performance.

1. Theoretical and methodological conceptual framework for the training of female foil fencers in the basic specialization stage

In modern fencing, frequent changes in competition regulations and refereeing rules significantly influence the methodology of training the female foil fencers. The development of optimal training programs that focus on developing the key physical qualities is required [13, 20].

In recent years, research on the technical and tactical training of the female foil fencers has highlighted objective changes in their technical-tactical arsenal within the context of competitive activity. Studies have also addressed the physical training of fencers, the pedagogical value of fencing, the theoretical training of fencers and the history of fencing. However, these studies have not approached the improvement of the preparation process for female foil fencers by using technical means and fitness devices during training. Therefore, at the current stage of fencing (foil), achieving a high level of performance is impossible without the use of modern equipment and technical devices [16, 31].

Fencing training, particularly for the foil event, is based on several interdependent components: *physical, technical, tactical, theoretical, psychological* and *biological*.

Technical training of the female foil fencers at the basic specialization stage is a crucial element in shaping a complete and competitive athlete. In this phase, the focus is on developing and refining fundamental techniques, integrating tactical skills and applying biomechanical principles to maximize athletic performance. According to Borysiuk Z. and Waskiewicz Z. [5, p. 64], specific fencing training involves complex informational processes, stimulation and perceptual preparation, all of which contribute to improving reactions and technical execution.

The fundamental techniques in fencing, such as attacks, parries, ripostes and counterattacks, build the foundation of fencer’s skills and are essential for achieving high-level performance. Mastering these techniques requires systematic training, biomechanical precision and a deep understanding of the efficiency of movements.

Biomechanical analysis plays a key role in optimizing fencing techniques (foil), enhancing movement efficiency and preventing injuries. Training at the basic specialization stage includes repetitive exercises, video assessments and personalized adjustments, with continuous evaluation contributing to the correction of techniques through the application of biomechanical criteria [7, 26].

Analyzing the structure of fencing lessons, including *collective, traditional and individual lessons*, emphasizes the importance of each type in different stages of

athlete preparation. This analysis reveals how the lessons contribute to developing the technical-tactical skills and creating a solid foundation for competitive performance.

In our opinion, the most important biomechanical criteria in elite sports and the arguments for their relevance in fencing are: *movement efficiency, force distribution, stability and balance, range of motion, joint kinematics (angular characteristics of segments), movement times and speed, acceleration and deceleration, linear (segmental) impulse and force.*

The methodology for applying biomechanical criteria in the technical training of performance fencers involves the use of specialized tools and techniques for evaluating and optimizing athletes' movements. So, aspects such as muscular strength, speed, acceleration and deceleration, balance, posture and joint kinematics are emphasized. Experts such as Guilhem G. and collaborators [11], Turner A. [24], and Chen T. L. W. and collaborators [7] have demonstrated the importance of detailed biomechanical analysis for improving mechanical and muscular coordination. Studies by Aresta and collaborators [3] highlight the contribution of speed in lunges and advanced technologies for maximizing performance. Turner and collaborators [25] also emphasized the role of customized physical training in achieving maximum performance in fencing competitions.

In the case of the foil fencing, according to this data, feedback can be implemented in the following ways:

a) *real-time feedback:* using advanced technologies, such as video analysis or kinetic sensor systems, to monitor the movements of athletes in real time throughout training or competitions;

b) *post-training detailed analysis*: after training sessions, biomechanical data can be thoroughly analyzed to identify the strengths and weaknesses of each athlete;

c) *development of personalized improvement plans*: starting from individual biomechanical data, coaches can create customized training plans for each athlete;

d) *technical and strategic corrections*: feedback based on biomechanical analysis allows coaches to provide precise corrections and develop strategies for refining athletes' techniques;

e) *monitoring progress and continuous adjustment*: as athletes make progress in training, coaches can use biomechanical data to track development and modify training plans accordingly.

Thus, the primary objective of our research was to investigate the effectiveness of technical training for junior foil female fencers at the basic specialization stage through the use of biomechanical criteria.

2. Research methodology: content of sports training at the basic stage of female foil fencers

The research methods applied in the sports training of female foil fencers at the basic stage are essential for understanding and optimizing their performance. These methods include *general methods* such as: bibliographic study, observation, survey (questionnaire type), testing, experiment (longitudinal with a single group), case study, statistical-mathematical and graphical methods.

Specific methods are consistent with the goals and objectives regarding the evaluation of preparation in training sessions and competitions (specific physical, technical and technical-tactical tests), the biomechanical analysis and progress monitoring through advanced technologies. Thus, a comprehensive and personalized approach to training is ensured [5, 7, 16, 17, 22, 24, 30].

To identify the key components of technical-tactical actions in training, a detailed analysis was performed during the *ascertaining stage*, under different conditions and execution variants. These include: A – with a training dummy, B – with a partner, C – with the coach and D – in competition.

The adaptation of the method of postural orientation of movement (MPOM) in fencing, at the foil event, involves structuring and analyzing the main phases of movement – preparatory, basic and concluding phases – through the integration of modern feedback technologies (video and sensors), aimed at optimizing posture, body alignment and technical efficiency in the execution of specific actions.

In this research, 9 anthropometric tests, 3 motor tests, 3 technical-tactical actions performed in competition and 4 performance level indicators were applied.

Additionally, a series of specific tests were used, including computer-based biomechanical video analysis. Various execution conditions were targeted: with a training dummy (A); with a partner (B); with the coach (C) and in competition (D).

The research for this work was organized within the national fencing team, foil weapon, with a program established and approved by the Romanian Fencing Federation and the Romanian Olympic Committee.

It is important to note that the author attended and participated in several activities (training sessions, camps and competitions) conducted with the female foil fencers, benefiting from the support of the coaching technical staff of the national fencing team, as well as of the Romanian Fencing Federation.

The experiment was carried out over two stages: the ascertaining stage and the formative stage.

The research was conducted in *four stages*, as follows:

Stage I (September 2018 – December 2020), also called the preliminary stage, included the following tasks: approval of the research topic, development of the individual activity plan of the PhD student and the establishment of the literature

review theme. It also involved presenting the scientific project and related reports for the doctoral thesis. At the same time, the training activity of the national fencing team (both men and women) of Romania, in youth and junior categories, was monitored in order to create the experimental research group.

Stage II (January 2021 – December 2021) – *Ascertaining Experiment*: this stage involved observing the preparation process (training and camps) and the participation of the female foil fencers (youth and juniors) in competitions. It also included the administration of a questionnaire addressed to the fencing coaches, the collection of data regarding somato-functional development, physical training, technical-tactical training and performance levels. During this stage, biomechanical analysis was conducted to identify the key components of technical-tactical actions performed during training (with a dummy, with a partner and with the coach) and in competitions. Additionally, an experimental training program for the technical preparation of female foil fencers (2022-2023) was developed, along with the plan for the formative experiment, namely the basic experiment.

Stage III (January 2022 – December 2022) – *Formative Experiment*: this stage included the implementation of the experimental program, focusing on enhancing the technical training of junior female foil fencers, according to the biomechanical criteria and performance levels. Both in the ascertaining and formative experiments, only 8 fencers participated, which led to a longitudinal experiment with a single group. During this period, the final anthropometric and strength tests were conducted, as well as physical training, technical-tactical training and analysis of competition results.

Stage IV (January 2023 – December 2023): development of the post-research experimental program based on the evaluation of the final tests and comparative biomechanical video analysis, including training with the dummy (movement school), with partner and with coach, as well as during competitions.

The sports facilities for the athletes of the Romanian national female foil fencing team was adequate for conducting the training process at a high level, which allowed us to carry out the research under the best conditions. The training halls were: Floreasca Hall– Bucharest; CSTA Hall Băneasa – Bucharest; "Alexandru Csipler" Hall – Satu Mare; National Sports Complex "Piatra Arsă" Sinaia – Prahova County; the Olympic Sports Complex "2000" Izvorani – Ilfov County.

The aim of the study was to identify - by consistently using the questionnaire survey method - the most efficient indicators for consolidating the technical training level of elite female foil fencers, based on the biomechanical criteria.

The study involved 10 teachers-coaches, as follows: 50% aged between 25-30 years, 30% aged between 45-50 years, 10% aged 35-40 years and 10% over 50 years.

Their academic degrees were: full-time professional degree (rank I), coach category (I and III) and coach of the European Women's Foil Team.

The sociological survey highlighted the importance of training factors for the elite foil event at junior level and the variability of training duration and structure depending on training periods. There were also pointed out the need for personalized individual lessons based on the fencers' levels and the role of biomechanical parameters in optimizing the execution of technical-tactical actions, with an emphasis on the efficiency, speed, precision and distance of movements.

The physical training of the junior female foil fencers was assesssed by means of four fitness tests, namely: standing long jump, spring, abdominal strength and lunge after squat. The descriptive analysis of the corresponding results provides a clear picture of their physical capabilities (Table 1, Appendix 3).

Table 1. Results of the physical training of junior female foil fencers

Fitness tests	X	SEM	SD	Cv%	Min	Max	CLM (0.95)
SLL (cm)	194.5	1.76	4.98	2.56	185	200	4.17
D (cm)	29.25	1.29	3,.65	12.5	25	35	3.05
FA (reps no.)	21.6	1.10	3.11	14.4	17	26	2.60
FG (cm)	24.4	0.90	2.56	10.5	21	28	2.14

Notes: SL – Standing long jump; D – Spring; FA – Abdominal strength (reps no./ 1 minute); FG – Lunge after squat (reps no./ 1 minute)

The descriptive analysis of the technical-tactical results obtained from the test conducted on a group of 8 female foil fencers provides a perspective on the execution level of various techniques used in competition (Table 2), specifically during the 2021 Romanian Cup (Appendix 4). A difference of 8.6 can be observed between the number of executions of technical-tactical actions for AD (direct attacks) and AC (compound attacks), with a nearly equal number for PR (parry-riposte) compared to AD.

Table 2. Results of the technical-tactical training for junior foil fencers

Statistical indicators	AD (executions no.)	AC (reps no.)	PR (reps no.)
X	25.4	16.8	25.5
SEM	2.19	1.75	2.57
SD	6.21	4.94	7.27
Cv%	24.5	29.3	28.5
Min	16	9	14
Max	35	23	35
CLM (0.95)	5.19	4.13	6.08

Notes: AD – direct attacks (straight); AC – compound attacks (second intention) , PR – parry riposte;

Competition – Romanian Cup 2021

Table 3. Performance level of the junior female foil fencers

Statistical indicators	V.T.G	T.D. (touches no.)	T.P. (touches)	V.E.D.		R (ranking
				TD (touches)	TP (touches)	
X	3.87	21.75	7.75	38	27.5	15.25
SEM	0.55	1.92	0.62	6.23	1.85	9.03
SD	1.55	5.42	1.75	17.9	5.24	25.5
Cv%	40.1	24.9	22.6	47.1	19.04	67.5
Min	1	9	5	15	21	1
Max	5	25	10	60	34	76
CLM (0.95)	1.29	4.53	1.46	14.9	4.38	21.3

Notes: V.T.G. = group round wins; T.D. = touches hit; T.P. = touches received; V.E.D. = direct eliminations wins; R. = direct result in competitions; C1 = first competition (Romanian Cup 2021)

The descriptive analysis of the performance level of junior female foil fencers at the 2021 Romanian Cup, for a group of 8 athletes, highlights the variability and capabilities in different aspects of the competition, such as wins, touches hit and received, as well as results in direct eliminations (Table 3, Appendix 5).

The analysis of the technical-tactical actions was conducted using the method of postural orientation of movement (MPOM), which we had adapted according to specific requirements. Data were processed by means of biomechanical video analysis software. To segment the positions of the main key components of the phasic structure and measure the angular characteristics of the segments, the Kinovea software was used. The kinematic and dynamic characteristics of the movements were evaluated using the Physics ToolKit program, while the graphical representation of the segmental trajectories was done using KyPlot.

In the research phase, we aimed to analyze the *technical-tactical actions with a training dummy, with a partner, with the coach and during competition, executed on the spot, with steps and with lunges*. In this sense, we present some examples below.

Biomechanical analysis of technical-tactical actions with a training dummy. The temporal characteristics of completing basic motor actions using a training dummy include calibration data in terms of video sequences, guard position, execution time and transfer (transf.), providing insight into the duration and efficiency of the analyzed movements (Figure 1, Appendix 6).

The direct (straight) attack on the spot (m1) shows consistency between the time required to complete the action and the transfer (0.766), indicating a constant temporal control, a key feature in the initial phases of executing the technique.

The direct (straight) attack with step-step (m2) involves two consecutive dynamic phases (step-step). An increase is observed in the total time (1.101 seconds) compared to the static movement. This increase is justified by the greater biomechanical complexity, which requires better coordination and rapid adaptation.

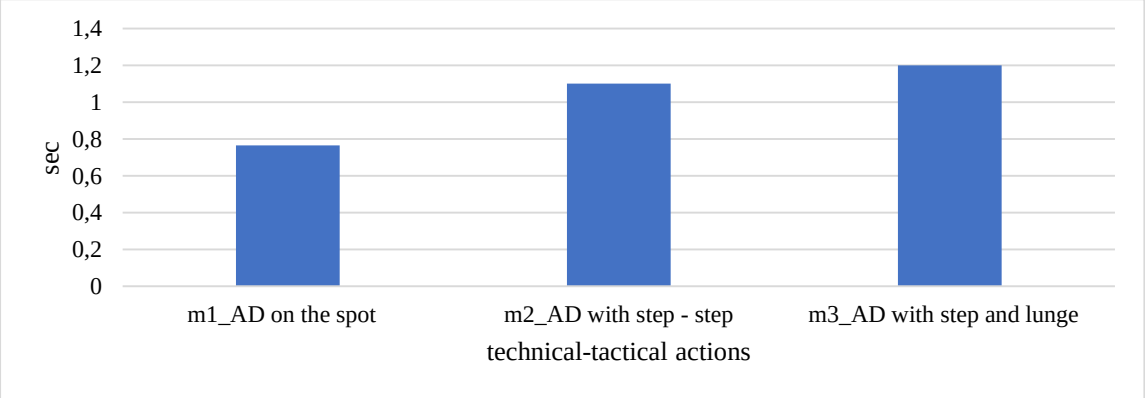

Fig. 1. Temporal characteristics of completing the movement towards the training dummy

The introduction of the lunge into the direct (straight) attack (m3) generates additional technical requirements, resulting in a maximum total duration (1.200 sec) compared to the other actions. This increase in time reflects a balance between stability and execution speed, which is crucial for achieving optimal performance in competitions.

Table 4 describes the body segmental trajectories at the completion of the direct (straight) attack (AD), analyzing both horizontal (X) and vertical (Y) displacements for various body segments. The data reflects the biomechanical complexity of the movement, depending on the type of attack: on the spot, with a step and with a lunge (Appendix 6).

Table 4. Segment trajectory at the completion of the direct(straight) attack on the training dummy

Actions / body segments	AD on the spot		AD with step		AD with lunge	
	X(m)	Y(m)	X(m)	Y(m)	X(m)	Y(m)
GCG	0.078	0.777	-0.539	0.801	-0.672	0.613
Fist	-0.614	1.562	-1.253	1.625	-1.416	1.409
Tip (Foil)	-1.274	1.29	-1.848	1.404	-1.986	1.431
Elbow (Fist)	-0.319	1.453	-0.944	1.459	-0.753	0.734
Knee (PFață)	-0.194	0.513	-0.809	0.500	-0.976	0.512
Front foot (PFață)	-	-	-0.761	0.007	-1.051	0.066
Back foot (PSpate)	-	-	-0.301	0.007	-0.131	0.022

Notes: AD– direct attack; GCG –general center of gravity; PFață – front foot; PSpate – back foot; X - horizontal displacement; Y – vertical displacement

The analysis of the segmental trajectories highlights significant changes in the general center of gravity (GCG) and body segments as the complexity of the movement increases, from the attack on the spot to the one with a lunge. As the attack becomes more complex, the biomechanical requirements also increase, supporting segmental adaptation and body coordination for technical efficiency and stability. These adjustments emphasize the critical role of balance and coordination in sports performance.

Table 5 presents the segmental velocity (horizontal components, Vx, and vertical components, Vy) for different body segments at the completion of the direct(straight) attack (AD), depending on the type of movement: on the spot, with step and with lunge. The analysis highlights significant variations in segmental velocity according to the complexity of the movement (Appendix 6).

Table 5. Segmental velocity at the completion of the direct(straight) attack (AD) on the training dummy

Actions / body segments	AD on the spot		AD with step		AD with lunge	
	Vx(m/s)	Vy(m/s)	Vx(m/s)	Vy(m/s)	Vx(m/s)	Vy(m/s)
GCG	0.00	0.00	-0.24	0.24	0.442	0.332
Fist	-0.00	0.326	-0.481	0.361	0.332	-1.438
Tip (Foil)	0.00	0.00	0.00	0.00	-0.111	0.00
Elbow (Fist)	-0.118	0.235	-0.361	0.00	0.00	-0.634
Knee (PFață)	0.00	0.00	-0.361	-0.12	0.00	0.00
Front foot (PFață)	-	-	0.00	0.00	0.00	0.00
Back foot (PSpate)	-	-	-0.12	0.00	-1.77	-0.111

These biomechanical changes highlight the importance of segmental coordination for maximizing the efficiency of hits, maintaining balance and optimizing sports performance.

Table 6 presents the variations in horizontal (Ax) and vertical (Ay) segmental acceleration based on the type of movement: attack on the spot, with step and with lunge. The data reflect significant biomechanical adaptations aimed at optimizing force and stability during execution (Appendix 6).

Table 6. Segmental acceleration at the completion of the direct(straight) attack (AD) on the training dummy

Actions / body segments	AD on the spot		AD with step		AD with lunge	
	Ax(m/s^2)	Ay(m/s^2)	Ax(m/s^2)	Ay(m/s^2)	Ax(m/s^2)	Ay(m/s^2)
GCG	0.00	0.00	16.387	3.642	40.225	16.76
Fist	3.295	-9.885	16.387	-16.387	62.013	-62.013
Tip (Foil)	0.00	0.00	0.00	0.00	18.436	3.352
Elbow (Fist)	1.784	-12.487	16.387	-20.028	45.889	-18.142
Knee (PFață)	1.784	0.00	12.745	1.821	0.00	0.00
Front foot (PFață)	-	-	0.00	0.00	0.00	0.00
Back foot (PSpate)	-	-	12.745	5.462	13.408	5.028

As the attack evolves from static executions to more complex movements like lunging, segmental accelerations increase significantly, highlighting biomechanical adaptations meant to maximize force and maintain balance. The wrist segment and the center of gravity (GCG) demonstrate an intensification of movement and efficient energy transfer, while the feet and elbow play key roles in stabilization and

coordination. These biomechanical adaptations support optimal performance in the technical execution of the attack.

Table 7. Angular characteristics of the segments at the dummy

Articular angles	Action	Key components of the technique						
		PP			MP	PF		
		c	b	a		a	b	c
Coxofemoral joint(degrees)	AD on the spot	88			70	68		
	AD with step	65	50	59	69	70	58	46
	AD - step & lunge*	67	65	67	123	83	83	-
Joint of front leg knee (degrees)	AD on the spot	131			120	128		
	AD with step	154	130	149	125	152	134	147
	AD - step & lunge*	116	148	124	107	123	162	-
Shoulder joint - arm with weapon (degr)	AD on the spot	21			129	28		
	AD with step	32	22	22	132	30	27	16
	AD - step & lunge*	39	20	20	154	125	33	-
Elbow joint - arm with weapon (degr)	AD on the spot	83			-	106		
	AD with step	108	104	94	-	84	92	84
	AD - step & lunge*	109	98	92	-	-	108	-

*Note: *- retreat of front foot(PFață) with hit*

Table 7 presents the angular characteristics of the key components of the technical actions of the direct(straight) attack (AD) executed in different phases: on the spot, with step and with lunge at the training dummy. The measured joints include the hip joint (°),front knee joint (°), shoulder joint (°) and elbow joint (°) (Appendix 6).

Table 8 presents the values of the segmental linear impulse recorded at the completion of the attack on the dummy for the technical actions of the direct attack (AD) performed in diverse phases: on the spot, with step, with lunge (Appendix 6).

Table 8. Segmental linear impulse at the completion of the attack on the training dummy

Actions / body segments	AD on the spot		AD with step		AD with lunge	
	Px(kgm/s)	Py(kgm/s)	Px(kgm/s)	Py(kgm/s)	Px(kgm/s)	Py(kgm/s)
GCG	0.00	0.00	-16.824	16.824	30.973	23.23
Fist	-7.612	38.058	-33.648	25.236	23.23	-100.663
Tip (Foil)	0.00	0.00	0.00	0.00	-7.743	0.00
Elbow (Fist)	-24.725	41.208	-25.236	0.00	0.00	-44.374
Knee (PFață)	0.00	0.00	-25.236	-8.412	0.00	0.00
Front foot (PFață)	-	-	0.00	0.00	0.00	0.00
Back foot (PSpate)	-	-	-8.412	0.00	-123.893	-7.743

Table 9 presents the values of horizontal (Fx) and vertical (Fy) segmental forces for the technical-tactical actions of the direct attack (AD) on the spot, direct attack with step and direct attack with lunge, highlighting the contribution of body segments (GCG, Fist, Tip – Foil, Elbow – Fist, Knee – Front Foot, Front Foot, Back Foot) in generating the final force (Appendix 6).

The analysis of the biomechanical characteristics of the technical-tactical actions with a partner provides a detailed perspective on how the forces, angles and dynamics of body segments interact in real duel conditions. In such situations, the athlete must quickly adapt their movements to the actions of the partner, involving advanced segmental coordination, precise balance control and efficient force transmission.

Table 9. Segmental force at the completion of the attack on the dummy

Actions / body segments	**AD on the spot**		**AD with step**		**AD with lunge**	
	Fx(N)	**Fy(N)**	**Fx(N)**	**Fy(N)**	**Fx(N)**	**Fy(N)**
GCG	0.00	230.656	1150	254.906	1170	3050
Fist	0.00	-691.97	1150	-1150	-4340	6140
Tip (Foil)	0.00	0.00	0.00	0.00	234.644	1310
Elbow (Fist)	124.873	-874.1	1150	-1400	3210	-1270
Knee (PFață)	124.873	0.00	892.173	127.453	0.00	0.00
Front foot (PFață)	-	-	0.00	0.00	0.00	0.00
Back foot (PSpate)	-	-	892.173	382.359	938.582	351.968

Analysis of the biomechanical characteristics of technical-tactical actions with the coach. The temporal characteristics of the completion of basic motor actions in the context of training with the coach are presented. Calibration data in terms of video sequences, guard position, execution time and transformation (transf.) are included, providing an insight into the duration and efficiency of the analyzed movements (Appendix 8).

Analysis of the biomechanical characteristics of technical-tactical actions in competition. Competitive activity represents an essential component in the technical training of fencers, providing the opportunity to apply and perfect technical-tactical actions in real confrontation conditions. Thus, it contributes to developing the skills of adaptation, precision and efficiency of the execution.

The methodological benchmarks for developing the experimental program in the training of junior female foil fencers was based on a detailed planning of the 2022-2024 Olympic cycle, focusing on 2022 for the experimental phase and 2023 for the post-experimental evaluation (Appendix 10).

The experimental program was structured based on the identification and determination of key technical components, using the biomechanical parameters analyzed with the dummy, a training partner and in competitive contexts. In this framework, methods and tools were established to achieve the technical-tactical training objectives, including technical training with movement, individual lessons

for short and medium distances and technical exercises for distance, disengagement attack, feint attack and long-distance hit. These approaches were directed towards improving technique and adaptability in various competitive situations.

Table 1 in Appendix 10 of the thesis presents the planning and content of the fencers' training for the 2022-2024 Olympic cycle, structured on an annual cycle (2022-2023), detailing the stages of general training, specific training, pre-competition, competition and transition. Each period is defined by specific performance objectives and training content, including non-specific training, general physical and technical training, performance evaluations, recovery and psychological preparation, to ensure the peaking for various international competitions and championships.

General structure of the experimental program

The annual plan includes 5 mesocycles (MZC), 52 weekly microcycles (MiC), and 20 training stages, divided as follows:

Experimental period (35%): 7 stages, including general training (1), specific training (2), pre-competition (2), competition (2) and transition (1);

Post-experimental period (65%): 13 stages, with a focus on pre-competition (6), competition (5) and transition (3).

Content and implementation

The program concentrates on:

- General training: development of basic physical skills and reinforcement of techniques;
- Specific training: biomechanical and tactical adaptations;
- Pre-competition: simulations and integration of technical-tactical skills under high-intensity conditions;
- Competition: application of strategies and performance evaluation;
- Transition: active recovery and recalibration for the next cycle.

Practical implementation. The program was applied during the specific and pre-competition stages through:

- Biomechanical analysis-based training;
- Competition simulations for adaptation to combat under pressure;
- Individualized feedback for technique improvement.

This progressive structure ensures balanced development and optimization of athletic performance.

Technical exercises 1 (ETh 1):

a) Distance exercises. These exercises will focus on adjusting the position and step length based on the distance from the opponent, optimizing stability and attack power.

Biomechanics: the transfer of weight from a static position to a dynamic one will be efficiently performed through proper use of ground reaction forces and posture control during fast movements.

b) Attack with disengagement exercises. Disengagements are essential to avoid counterattacks and regain control of the piste. The exercises will focus on the correct synchronization of defense and attack movements, with an emphasis on the biomechanics of the arm disengagement and on maintaining the body stability.

Biomechanics: during disengagement, the female fencer will apply force through the full extension of the arm and will control the torso position to avoid imbalance.

c) **Exercises – Attack with feint and hit.**

Long distance. Feints are used to induce a reaction from the opponent, and the final hit must be precise and effective. The exercises will involve quick feints followed by the attacking hit.

Biomechanics: emphasis will be placed on synchronizing the feint with arm movements and positioning the feet to provide more stability and quick reaction.

Long-distance attacks require a correct assessment of angles and distance from the opponent. In this phase, the athlete will learn to recognize the right moment to launch the attack while maintaining control of posture and body balance.

Biomechanics. Control and coordination of arm movements with feints and long-distance attacks are essential to maximize hit efficiency and reduce the risk of counterattacks.

In conclusion, each technical exercise will be adapted to maximize the use of efficient biomechanics, focusing on fast and precise movements, body weight control and steady balance during attacks and defenses. The training will help the athlete understand and apply biomechanical principles in fencing technique, improving long-term performance.

This training plan for fencing throughout 2022 provides a clear and detailed structure for developing the effort capacity, technical-tactical and psychological skills necessary to achieve the performance objectives. The structure of the stages allows for a comprehensive and balanced training, with special attention given to recovery and maintaining the good shape over long term.

3. Experimental validation of junior female foil fencers' technical training by means of biomechanical criteria

The evolution of physical and technical-tactical training in junior female foil fencers highlights the importance of an integrated approach that combines individual lessons, personalized methods, advanced technology and customization of the

training process. This approach contributes to optimizing performance and adapting to competitive requirements [6, 7, 16].

Table 10 shows the changes in physical training parameters in junior fencers between the initial and final testing, including the mean and standard deviation, mean differences, standard error of the mean difference and t-test and p values (Appendix 3).

Table 10. Dynamics of physical training indicators in junior female foil fencers

Parameters	X ±SD		DM	ESDM	t- test	Pvalue
	Initial testing	Final testing				
SLL (cm)	180.87 ±6.46	186.87 ±7.52	6.00	1.61	3.71**	0.007
Spring (cm)	30.75 ±4.20	33.87 ±3.13	3.12	0.64	4.88**	0.0017
FA (reps no.)	23.00 ±2.62	24.00 ±2.62	1.00	0.38	2.65*	0.033
FG (reps no.)	21.25 ±1.91	22.87 ±1.88	1.62	0.42	3.87**	0.006

Notes: SLL – standing long jump (cm); D – spring (cm); FA –abdominal strength (30 sec) FG – squat to lunge (1 min); DM - Mean Difference; ESDM - Standard Error of the Mean Difference; t(0.05) = 2.364; - p <0.05; **- p< 0.01.*

Table 11 presents the dynamics of results for three crucial technical-tactical parameters in junior female foil fencers: direct attacks (DA), compound attacks (CA) and parry-riposte (PR). The analysis is performed for two consecutive tests: the initial testing (March 2021) and the final testing 1 (January 2022) (Appendix 4).

Direct attacks (DA): the number of executions slightly decreased in the group phase (P=0.172, not significant), but a significant reduction was observed in the elimination rounds (P=0.028) and overall (P=0.019), revealing a general decrease in the effectiveness of direct attacks.

Table 11. Dynamics of technical-tactical training indices in junior foil fencers

Parameters	Indices	X ±SD		DM	ESDM	t- test	Pvalue
		Initial testing	Final testing				
AD (no. of executions)	group	6.62 ±3.16	5.25 ±2.55	1.37	0.91	1.52	0.172
	elim.	8.12 ±3.18	5.62 ±3.20	2.50	0.91	2.76*	0.028
	total	16.5 ±4.03	10.87 ±5.46	5.62	1.86	3.02*	0.019
AC (no. of executions)	group	8.25 ±3.19	7.25 ±4.27	1.00	1.15	0.87	0.413
	elim.	9.12 ±3.72	9.12 ±4.70	0.00	1.46	0.00	1.00
	total	17.37 ±6.76	15.75 ±8.51	1.62	2.24	0.72	0.492
PR (no. of executions)	group	2.62 ±1.99	1.62 ±0.74	1.00	0.65	1.53	0.170
	elim.	3.75 ±2.31	4.00 ±3.42	0.25	1.01	0.25	0.812
	total	6.37 ±4.17	5.62 ±3.88	0.75	1.21	0.62	0.553

*Notes. Actions performed during competitions: Competition 1, Junior National Championship 2021, March 11,2021; Competition 2, Junior National Championship 2022, January 9, 2022; AD– direct attacks; AC – compound attacks ; PR – parry riposte; AD and AC - successful offensive actions (touches made /valid); PR - defensive actions(touches made /valid); the study of the Group Table (actions performed) shows us the character (,,spirit") of each athlete as a "shooter"(fencer): offensive / defensive; DM - Mean Difference; ESDM - Standard Error of the Mean Difference; t(0.05) = 2.364; *p<0.05*

Compound attacks (CA): a non-significant decrease in the group stage (P=0.413), maintained performance in the elimination rounds (P=1.00) and an overall decrease without statistical relevance (P=0.492), suggesting stability in executions.

Parry-Riposte (PR): a slight decrease in defensive executions in the group stage (P=0.170) and a minimal increase in the elimination rounds (P=0.812), with no significant changes overall (P=0.553), indicating consistency in defensive performance.

Table 12 shows the dynamics of the results regarding the performance indices for different categories of junior female foil fencers. The indices were measured between two tests (initial testing and final testing) (Appendix 5).

Table 12. Dynamics of performance index results in junior foil fencers

Indices	X ±SD		DM	ESDM	t- test	Pvalue
	Initial testing	Final testing				
VTG (touches no.)	3.50 ±1.41	3.50 ±1.31	0.00	0.267	0.00	1.00
VED touches no.)	3.25 ±1.28	2.87 ±1.24	0.37	0.18	2.04	0.079
TD (touches no.)	62.0 ±23.80	63.62 ±23.13	1.62	2.11	0.76	0.467
TP touches no.)	45.75 ±10.80	44.25 ±11.48	1.50	1.10	1.36	0.215
R (ranking position)	10.37 ±7.48	9.37 ±6.90	1.00	0.68	1.46	0.185

Notes: Romanian National Junior/Cadet Championship - March 11, 2021; Junior National Championship, January 9, 2022; VTG – Group round wins (assault of the type „whoever achieves 5 winning touches the first is declared the winner"); VED – Wins in direct eliminations (assault of the type „whoever achieves 15 winning touches the first is declared the winner"); TD – Touches made; TP – Touches received; R –Final result (position in the ranking); DM - Mean Difference; ESDM - Standard Error of the Mean Difference; t(0.05) = 2.364

VTG (Wins in group stage): the average remains constant (P=1.00), indicating stability in the technical and tactical skills of the female foil fencers during this stage of the competition.

VED (Wins in direct eliminations): a slight decrease in wins (P=0.079, not significant), possibly influenced by the difficult opponents and competition pressure, but without a consistent pattern among the fencers.

TD (Touches made): a minor increase in points scored (P=0.467, not significant), reflecting individual variations and highlighting the need for personalized interventions.

TP (Touches received): a slight diminution in touches received (P=0.215, not significant), suggesting a possible defensive improvement, but without a clear general trend.

R (Final result, ranking position): a moderate improvement in ranking position (P=0.185, not significant), but the high variability among the fencers indicates uneven progress within the group.

Table 13 presents the kinematic characteristics of the direct attack with lunge on the dummy, analyzing the differences between the initial and final testing for junior female fencers practicing the foil. The comparison was made using indices such as the mean (X), standard deviation (SD), mean difference (DM), standard error of the mean difference ($ESDM$), t-test, and P-value (Appendix 11).

Table 13. Analysis of kinematic characteristics indices in the final execution phase of the right-hand attack with lunge at the dummy in junior fencers

Characte-ristics	Indices		X ±SD		DM	ESDM	t- test	Pvalue
			Initial testing	Final testing				
Temporal	t(sec)		0.412 ±0.07	0.416 ±0.06	0.004	0.028	0.15	0.882
Trajectory (m)	GCG	X	-0.685 ±0.11	-0.682 ±0.09	0.003	0.025	0.12	0.908
		Y	0.388 ±0.07	0.378 ±0.08	0.009	0.018	0.51	0.625
	Fist	X	-1.539 ±0.13	-1.564 ±0.18	0.025	0.028	0.87	0.411
		Y	1.109 ±0.09	1.114 ±0.08	0.005	0.008	0.59	0.569
	PFață	X	-0.895 ±0.10	-0.929 ±0.14	0.035	0.031	1.13	0.293
		Y	-0.065 ±0.09	-0.08 ±0.09	0.014	0.009	1.59	0.156
Speed (m/s)	CGG	X	-0.202 ±0.68	0.041 ±0.25	0.243	0.297	0.82	0.440
		Y	-0.124 ±0.56	0.223 ±0.37	0.347	0.213	1.63	0.146
	Pumn	X	-0.186 ±0.13	-0.117 ±0.15	0.069	0.080	0.86	0.418
		Y	0.056 ±0.37	0.134 ±0.32	0.078	0.077	1.02	0.343
Acceleration (m/s^2)	GCG	X	26.76 ±11.94	28.57 ±6.02	1.809	3.989	0.45	0.664
		Y	15.51 ±13.82	17.84 ±8.67	2.338	4.963	0.47	0.652
	Fist	X	13.38 ±6,08	14.35 ±10.10	0.967	2.647	0.36	0.725
		Y	-0.621 ±10.07	3.445 ±8.42	4.065	3.52	1.15	0.286

Notes: DM - Mean Difference; ESDM - Standard Error of the Mean Difference; t(0.05) = 2.364

Table 14 shows the analysis of the dynamic characteristics indices in the final execution phase of the direct attack with lunge to the dummy, focusing on segmental impulse and the force applied along the X and Y directions, both at the general center of gravity (GCG) and at the fist. These parameters highlight the biomechanical efficiency of the movements, providing insights into force distribution and segmental coordination during the technical execution (Appendix 11).

Kinematic characteristics, such as trajectory, velocity and acceleration, remained stable between tests, suggesting a consistent level of execution in the junior fencers. Significant improvements in segmental impulse and force indicate biomechanical progress, though limited during the training period.

Table 14. Analysis of the dynamic characteristics indices in the final execution phase of the direct attack with lunge to the dummy in junior fencers

Characte-ristics	Indices		X ±SD		DM	ESDM	t-test	Pvalue
			Initial testing	Final testing				
Segmental impulse (kgm/s)	GCG	X	-12.027 ±37.04	2.381 ±14.04	14.408	15.756	0.91	0.391
		Y	-7.458 ±30.50	12.308 ±20.80	19.766	11.315	1.75	0.124
	Fist	X	-10.253 ±6.97	-6.616 ±8.86	3.637	4.437	0.82	0.439
		Y	3.367 ±20.42	7.813 ±17.69	4.446	4.480	0.99	0.354
Force (N)	GCG	X	1500.5 ±829.7	1571.25 ±267.2	70.75	250.4	0.28	0.785
		Y	741.66 ±808.3	994.04 ±484.1	252.4	285.04	0.88	0.405
	Fist	X	690.4 ±379.4	786.4 ±546.3	95.98	180.9	0.53	0.612
		Y	-61.3 ±626.8	191.2 ±477.03	252.5	206.5	1.22	0.261

Notes: DM - Mean Difference; ESDM - Standard Error of the Mean Difference); t(0.05) = 2,364

The increase in impulse and force along the vertical direction, particularly for the fist, reflects potential for further progress. However, the large variations between athletes highlight the need for more individualized training programs, aimed at optimizing force and impulse along the horizontal direction to enhance the efficiency of movements in attacks.

The evaluation of the relationships between anthropometric parameters, muscle strength, technical-tactical abilities and biomechanical characteristics is crucial for optimizing the training of junior female foil fencers. Research shows that integrating biomechanical analysis and advanced technologies, such as machine learning and mechanical models, can support the adjustment of training programs to improve performance and the efficiency of technical movements [2, 7, 11, 24, 25].

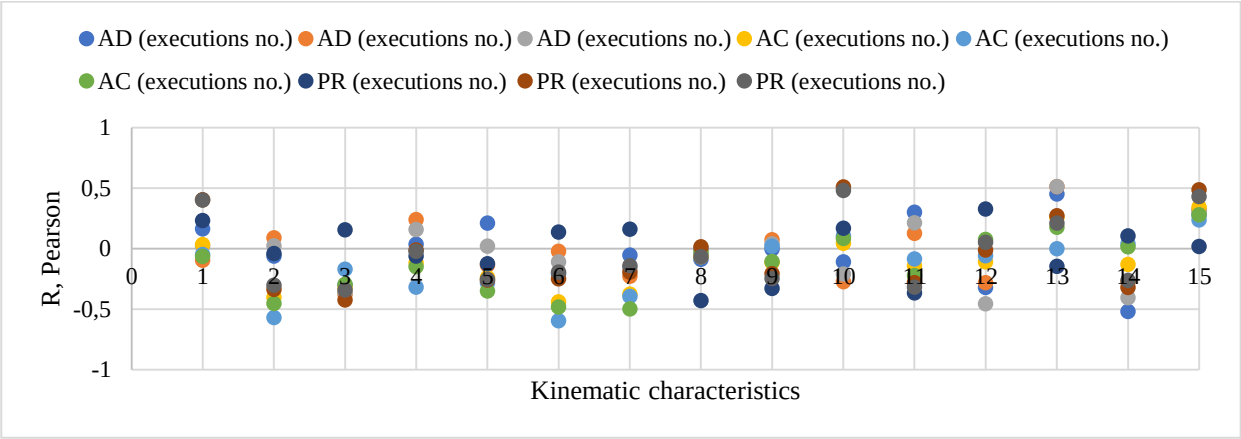

Fig. 2. Results of the correlation analysis (r) between the kinematic characteristics indices and the technical-tactical training indices after the application of the experimental program

Notes. Kinematic characteristics: 1- t(s); 2,3 –GCG (x, y); 4,5 – Fist (x, y), 6, 7 – Pfață(Front foot) (x, y); 8, 9 –GCG (m/s; x, y); 10,11 - Fist (m/s; x, y); 12, 13 –GCG (m/s²; x, y); 14, 15 - Fist (m/s²; x, y)

Figure 2 analyzes the correlations between kinematic characteristics (temporal parameters, trajectory, speed and acceleration of movements) (Appendix 11, Tables 6-8) and technical-tactical training indices (number of successful executions for direct attacks - AD, compound attacks - AC and parry-riposte - PR) after the application of the experimental program (Appendix 4). The analysis includes both results by groups (successful executions), eliminations (elim.) and the total number of executions. After the correlation analysis, 135 correlations were recorded, of which 61.5% are negative and 38.5% are positive. Regarding the degree of association between the indices, insignificant correlations were observed at P>0.05.

Correlations for temporal characteristics (t sec) are weak in all cases, indicating a limited influence of execution time on technical-tactical performance. The reduced positive correlations between execution time and PR (groups: R=0.231; eliminations: R=0.403; total: R=0.399) show a slight trend for athletes with longer times to perform more parry-riposte actions, but the relationship is not significant.

Figure 3 highlights the correlations between dynamic characteristics (segmental impulse and force) (Appendix 11, Tables 9 and 10) and technical-tactical training indices (number of executions for AD, AC and PR, by groups, eliminations and total) after the implementation of the experimental program (Appendix 4).

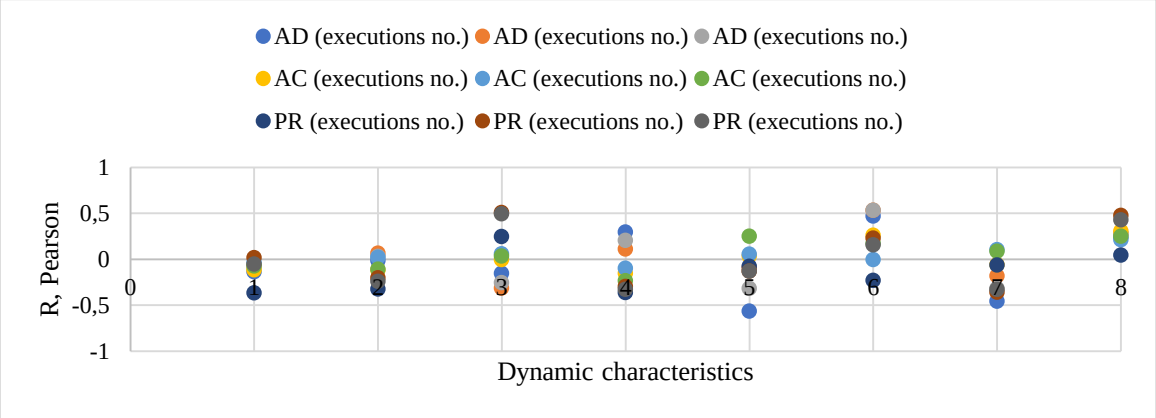

Fig. 3. Results of the correlation analysis (R) between dynamic characteristics indices and technical-tactical training indices after the application of the experimental program

Notes. Dynamic characteristics: 1, 2- GCG (kgm/s; x, y); 3, 4 – Fist (kgm/s; x, y); 5, 6 –GCG (N, x, y); 7, 8 – Fist (N, x, y)

The correlation analysis identified 72 correlations, of which 54.2% were negative and 35.8% were positive. Regarding the degree of connection between indices, insignificant correlations were observed with P>0.05. The linear correlation analysis between kinematic and dynamic characteristics indices and anthropometric, strength, technical-tactical and performance indices in junior female foil fencers, after using the experimental program, highlighted 552 correlations. These ones are divided as follows: 360 were negative, with 2.78% strong significant links (P<0.05 and P<0.01), and 192 were positive with 3.12% strong significant links (P<0.05 and P<0.01).

These strong correlations emphasize the connections between biomechanical indices and other investigated indices, specifying what are the training recommendations that could be achieved.

Training recommendations include exercises for vertical strength, control of horizontal strength, plyometric and explosive methods for horizontal and vertical impulses, training for impulse control in complex movements and the use of sensors for real-time feedback to optimize technique and performance.

Significant contributions from post-experimental programs aimed at improving performance through specific strategies and techniques are presented, supported by recent research in biomechanics and sensor technologies applied to the foil [3, 6].

Table 15 presents the results of the technical-tactical analysis of junior fencers, following the application of a post-experimental program, using One-Way Repeated Measures ANOVA to evaluate the effects of training on various performance parameters (AD - number of executions, AC - number of executions, PR - number of executions). The analysis is done at three moments: final testing C2 (T.F.C2), post-experimental testing C1 (T.P-E.C1) and post-experimental testing C2 (T.P-E.C2) (Appendix 4).

Table 15. Analysis of technical-tactical performance indices in junior female foil fencers after post-experimental testing

Th-Ta actions	Indices	X ±SD			One-Way Repeated Measures ANOVA					
		T.F.	T.P-E.		Fct.	SS	MS	F_{ratio}	$P_{valoare}$	η^2
		C2	C1	C2						
AD (no. of executions)	groups	4.62 ±1.50	7.12 ±3.68	9.00 ±3.50	A	77.08	38.54	9.946*	0.0205	0.235
					B	196.75	9.37			
					Err.	54.25	9.369			
	elim.	6.62 ±2.61	13.62 ±6.84	14.62 ±5.09	A	304	152	21.67***	0.0005	0.316
					B	557.62	26.55			
					Err.	98.67	7.04			
	total	11.25 ±3.77	20.75 ±10.18	23.75 ±7.97	A	681.33	340.67	23.45***	0.0003	0.316
					B	1270.5	60.5			
					Err.	203.33	14.52			
AC (no. of executions)	groups	9.00 ±1.77	10.25 ±5.34	12.75 ±5.47	A	58.33	29.17	7.704**	0.0055	0.178
					B	215.0	10.24			
					Err.	53.0	3.78			
	elim.	10.5 ±4.37	15.5 ±4.24	15.25 ±5.47	A	127.0	63.5	23.19***	0.0004	0.200
					B	469.5	22.36			
					Err.	38.33	2.74			
	total	19.5 ±5.34	24.5 ±7.44	28.0 ±8.60	A	292.0	146.0	11.028**	0.0013	0.184
					B	1106.0	52.67			
					Err.	185.3	13.24			
PR (no. of executions)	groups	8.87 ±1.35	13.0 ±3.42	8.62 ±2.92	A	96.58	48.29	11.508**	0.0011	0.311
					B	154.75	7.37			
					Err.	58.75	4.19			
	elim.	12.12 ±3.27	14.25 ±3.32	11.25 ±4.65	A	38.08	19.04	4.711*	0.0272	0.096
					B	303.87	14.47			
					Err.	56.58	4.04			
	total	21.0 ±3.50	27.25 ±6.22	19.87 ±7.47	A	252.58	126.29	12.62***	0.0007	0.221
					B	748.37	35.64			
					Err.	140.08	10.01			

*Notes: T.F. –final testing; T.P-E. – post-experimental testing, AD – direct attacks; AC –compound attacks ; PR – parry riposte; AD and AC - successful offensive actions (touches made/valid); PR – defensive actions (touches made/valid); One-Way Repeated Measures ANOVA, Fct. – factors, A – between groups, B – inside the group; SS – sum of squares; Err. – error; MS – mean square of variances; F_{ratio} - statistical; η^2 – effect size; Critical values F at df $_{(2,14)}$: * – p<0.05, F_{crit} = 3,74; ** - p<0.01, F_{crit} = 6,51 și *** - p<0.001, F_{crit} = 10.21*

The post-experimental program had a positive impact on the development of technical-tactical skills in junior female foil fencers, with significant improvements in offensive executions, such as direct and compound attacks, and defensive actions, particularly parry-ripostes. However, the effects on the number of touches received were limited and the small effect size suggests the need for further adjustments in training to strengthen defensive performance and ensure continued progress in competitions.

The experimental intervention had a significant impact only on the number of touches received, and the small effect size indicates that additional adjustments in

training are required to achieve more substantial improvements in the performance of junior female foil fencers.

GENERAL CONCLUSIONS AND RECOMMENDATIONS

In conclusion, this scientific endeavor regarding the technical training of junior female foil fencers based on the use of biomechanical criteria, consistent with the set objectives, has led to the following conclusions:

1. The review of specialized literature on the training of female foil fencers during the basic specialization phase highlights the importance of integrating theoretical and methodological approaches grounded in scientific principles and adapting them to the individual needs of athletes. The basic specialization phase is essential for establishing a solid foundation in sports training, with the goal of developing fundamental techniques, improving physical fitness and acquiring the tactical skills necessary for high-performance competitions.

2. The results of the sociological survey addressed to specialists underscored the importance of training factors in performance fencing at the junior level, the variability in training duration and structure depending on preparation periods, the need for personalized individual lessons based on athletes' levels and the role of biomechanical parameters in optimizing the execution of technical-tactical actions, with a focus on efficiency, speed, precision and movement distance.

3. Based on the research conducted during the ascertaining experiment, the results of somato-functional development and sports training prove good adaptability and cardiovascular capacity in junior female foil fencers, with emphasis on physical diversity and healthy physiological responses. There are also opportunities for improvement in areas such as flexibility and abdominal strength. Furthermore, variability in technical-tactical execution indicates the need for personalized training programs to optimize sports training and reduce competitive inequalities, thus enabling continuous progress and superior performance.

4. The monitoring of the technical training of junior female foil fencers during the experimental research was carried out through the biomechanical analysis of the kinematic and dynamic characteristics of technical-tactical actions performed in training with a dummy, with a partner, with the coach and in competitions. The detailed analysis and systematization of the results allowed for the identification of key components in execution techniques, detection of execution errors and the finding of the most effective training methods based on the biomechanical criteria used, which led to the development of the experimental program.

5. The analysis of somatic indices, strength parameters and cardiovascular parameters in junior female foil fencers shows a positive adaptation to intense

training, with a significant reduction in body weight, significant increases in strength in critical areas, and stable heart rate and blood pressure, highlighting good physical condition and an effective ability to regulate physiological functions.

6. The results obtained reveal significant improvements in the specific physical abilities of junior female foil fencers, with notable increases in explosive strength, vertical jump, abdominal strength and lower limb muscular endurance. These progressions reflect effective adaptations to training programs, contributing to the development of optimal physical fitness necessary for performance in fencing, characterized by speed, agility and precision in execution.

7. The analysis of technical-tactical actions and performance levels of junior female foil fencers shows a decrease in the effectiveness of direct attacks during the elimination phases, emphasizing the need for adjustments in technical-tactical preparation through personalized training. The improvement of performance under competitive pressure is also necessary, considering individual differences and the need for special attention during critical stages of competition.

8. Despite significant improvements in segmental impulse and strength, kinematic characteristics did not undergo notable changes, confirming optimal performance. To maximize results, a more individualized training program would be necessary, focused on improving strength and impulse, particularly in the horizontal direction, to optimize the efficiency of attacking movements.

9. The results of the correlation analysis highlight the strong correlation between the kinematic and dynamic characteristics of junior fencers and the anthropometric, strength, technical-tactical and performance indices. This validates the effectiveness of the experimental program and suggests that integrating biomechanical criteria into technical training can significantly enhance the development and performance of athletes.

10. The post-experimental program had a significant positive impact on the technical-tactical actions of junior female foil fencers, with notable improvements in offensive and defensive actions, especially in parry-riposte techniques. However, performance in defensive techniques showed variability and the results suggest the need to continue and adapt the program for the ongoing development of these techniques. The experimental intervention had a smaller impact on the number of touches received, and the small effect size indicates the need for further adjustments to training in order to achieve significant improvements in this area, leaving some aspects unresolved in the overall enhancement of performance.

11. By recording the performances related to the sports training of junior female foil fencers, it was addressed the scientific issue concerning the limited number of scientific and practical-methodological studies analyzing the optimization of the junior fencers' technical training process in the basic specialization phase. The

development and implementation of an experimental program concentrated on planning specific means and action systems based on biomechanical criteria led to an increase in sports performance in this area.

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Starting from the research conducted with junior female foil fencers, several practical-methodological recommendations have been formulated, grounded in biomechanical analysis. These recommendations aim to optimize technique through improving strength, speed and precision of movements, adapting them to the specific conditions of training and competition. A continuous feedback system is implemented for correcting technical errors, in order to enhance performance and efficiency at every stage of training and competition.

1) *Recommendations for training on a dummy*. Focusing on proper execution of technique is essential, ensuring each attack is executed with precision and efficiency. It is recommended to practice adjusting strength and speed based on the type of action, such as direct attacks, ripostes or defense. Training should include exercises for correcting posture and balance control, utilizing equipment that allows to evaluate and adjust body positioning throughout the action.

2) *Recommendations for training with a partner*. Developing the ability to adapt to tactical changes of the partner: in training with a partner, it is important to simulate variable scenarios with unpredictable attacks and quick reactions. Exercises that stimulate reaction speed and anticipation of the opponent’s movements are recommended, such as duel exercises, active defense and executing quick ripostes. The fencer should be able to respond quickly to the opponent's tactical changes, adjusting the force and direction of the attacks.

3) *Recommendations for training with the coach*. The use of movement capture technologies, such as video or biomechanical sensors, can help the coach monitor the execution of technique in real time and provide immediate feedback for correcting technical errors. The coach can guide the athlete in adjusting the trajectory of the attacks so that the force applied is effective and well-distributed along the correct direction, minimizing the risks of premature fatigue and enhancing competition efficiency.

4) *Recommendations for biomechanical analysis during competition*. Fencers need to apply force and speed efficiently during competitions without compromising precision. Exercises that simulate real competition conditions, including moments of fatigue and under pressure, will help the athlete improve decision-making performance. Anticipation and synchronization with the opponent: it is recommended to develop exercises that focus on anticipating the opponent's movements and synchronizing attacks with key moments of the confrontation.

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List of the author's publications on the topic of the thesis

1. **PAVEL, L.,** PAVEL, A., KRIVENTSOVA, I., POTOP, V., JURAT, V. Characteristics of the technical-tactical and physical training of ėpėe fencers aged 8 to 10 years. Discobolul – Physical Education, Sport and Kinetotherapy Journal, 2019, Year XV Vol. 58 no. 4, p. 80-84. ISSN (online) 2286 – 3702, ISSN–L 1454 – 3907.

2. **PAVEL, L. P.,** PAVEL, A. V., BRATU, I., GHERMAN, S. Studiu privind influența mijloacelor specifice asupra nivelului pregătirii tehnico-tactice şi fizice la scrimerii spadasini de 10–12 ani. In: Sport. Olimpism. Sănătate, 10-12 septembrie 2020, Chişinău. Chișinău, Republica Moldova: Editura USEFS, 2020, Ediția 5, pp. 351-359. ISBN 978-9975-131-98-8.

3. **PAVEL, L. P.,** POTOP, V., JURAT, V. Individualizarea în antrenamentul de scrimă (arma floretă). In: Sport. Olimpism. Sănătate, Ed. 6, 16-18 septembrie 2021, Chişinău. Chișinău, Republica Moldova: Editura USEFS, 2021, Ediția 6, pp. 169-175. ISBN 978-9975-131-99-5.

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5. **PAVEL, L. P.,** JURAT, V., DORGAN, V., TRIBOI, V., POPA, S. G., POTOP, V. Study on the importance of using biomechanical criteria in the technical training of junior fencers. In Actualities and Perspectives of Physical Education and Sport Sciences, 2023, p. 130-137. ISSN 2734-8512, ISSN-L 2734-8512.

6. **PAVEL, L. P.** Importance of the individual lesson in the technical-tactical improvement of fencing athlete. Ovidius University Annals, Series Physical Education and Sport, Science, Movement and Health, 2024; 24 (2): p. 167- 172. ISSN-L 2285-777X, ISSN online 2285-7788.

7. **PAVEL, L. P.** The somatic characteristics of junior fencers. International scientific conference "Actualities and perspectives of physical education and sport sciences", 5th edition, 4.04.2024. Printech, Ecological University of Bucharest (p. 131-137). ISSN 2734-8512, ISSN-L 2734-8512.

8. POTOP, V., PAVEL, A. V., **PAVEL, L. P.** Practical-Methodical Aspects Regarding the Training of the Fencers Aged 8 to 10 Years. Gymnasium. 2020, 21(1 Suppl), pp. 18-28. ISSN 2344-5645.

ADNOTARE

Pavel Liviu Paul: *„Pregătirea tehnică a floretistelor la etapa specializării de bază prin utilizarea criteriilor biomecanice”.* Teză de doctor în științe ale educației, specialitatea 533.04. Educație fizică, sport, kinetoterapie și recreație. Chișinău, 2025.

Structura tezei: introducere, 3 capitole, concluzii generale şi recomandări, bibliografie 235 surse, 12 anexe, 140 pagini text de bază, 26 figuri, 44 tabele. Rezultatele au fost publicate în 8 lucrări științifice.

Cuvinte - cheie: scrimă, junioare, biomecanică, pregătirea sportivă, pregătirea fizică, pregătirea tehnică, pregătirea tehnico-tactică, lecția de antrenament, performanța.

Scopul cercetării constă în cercetarea eficienței pregătirii tehnice a floretistelor junioare la etapa specializării de bază prin utilizarea criteriilor biomecanice.

Obiectivele cercetării: 1. Studierea reperelor conceptuale privind pregătirea tehnică a floretistelor la etapa specializării de bază. 2. Determinarea nivelului pregătirii sportive și somato-funcționale a floretistelor junioare. 3. Analiza opiniilor specialiștilor privind pregătirea tehnică a floretistelor de performanță prin utilizarea criteriilor biomecanice. 4. Elaborarea programului experimental axat pe utilizarea criteriilor biomecanice la floretistele junioare. 5. Validarea experimentală a eficienței aplicării programului experimental axat pe utilizarea criteriilor biomecanice în pregătirea tehnică a floretistelor la etapa specializării de bază.

Noutatea şi originalitatea științifică a cercetării constă în elaborarea și validarea experimentală a programului de pregătire tehnică la floretistele junioare pe baza utilizării criteriilor biomecanice. Au fost identificați, măsurați, determinați și analizați indicii caracteristicilor cinematice și dinamice a componentelor cheie ale execuției tehnice în antrenament și concurs. Aplicarea practică a programului dat va contribui la optimizarea nivelului pregătirii tehnice a floretistelor junioare și, în consecință, va duce la îmbunătățirea capacității performanțiale în competiții.

Problema științifică importantă soluționată în domeniu este reprezentată de numărul redus de cercetări științifice și practico-metodice privind optimizarea procesului de pregătire tehnică a floretistelor la etapa specializării de bază. Elaborarea și implementarea unui program experimental, axat pe planificarea mijloacelor specifice și a sistemelor de acționare pe baza criteriilor biomecanice, ar conduce la sporirea performanței sportive la proba dată.

Semnificația teoretică a lucrării se desprinde din faptul că, în urma analizei literaturii de specialitate și a opiniilor specialiștilor din domeniu citați pe parcursul cercetării, au fost stabilite reperele metodologice privind creșterea nivelului pregătirii tehnice a floretistelor pe baza utilizării criteriilor biomecanice. Acestea, la rândul lor, contribuie la completarea concepțiilor existente în domeniul teoriei și metodicii antrenamentului sportiv la scrimă, în special la etapa specializării de bază.

Valoarea aplicativă a lucrării oferă posibilitatea implementării programului experimental şi a reperelor metodologice la etapa specializării de bază, elaborate pe baza indicilor criteriilor biomecanice la floretistele junioare. Rezultatele obținute pot fi folosite în calitate de ghid metodologic de către antrenorii școlilor sportive specializate în scrimă (arma floretă), precum şi de către studenții instituțiilor de învățământ superior de educație fizică şi sport cu specializarea ”Scrimă”.

Implementarea rezultatelor științifice. Rezultatele cercetării au fost integrate în procesul de antrenament al floretistelor junioare de la diverse Cluburi Sportive specializate în scrimă din România: CS Rapid, București; C.S.T.A. București; C.S.A. Steaua, București; C.S. Corona, Brașov. Sportivele se aflau în pregătire centralizată la Lotul Național de Floretă junioare și tineret al României. Rezultatele pot fi utilizate ca material metodologic în cadrul pregătirii profesionale a studenților din instituțiile de învățământ superior de educație fizică și sport, specializați în „Scrimă”.

АННОТАЦИЯ

Павел Ливиу-Паул: «Техническая подготовка рапиристок на этапе базовой специализиции с применением биомеханическим критериям». Диссертация на соискание степени доктора педагогических наук, специальность 533.04 – Физическое воспитание, спорт, кинетотерапия и рекреация. Кишинёв, 2025.

Структура диссертации: введение, 3 главы, выводы и рекомендации, библиография, 235 источников, 12 приложения, 140 страниц основного текста, 26 фигуры, 44 таблиц. Результаты опубликованы в 8 работах.

Ключевые слова: фехтование, юниорки, биомеханика, спортивная подготовка, физическая подготовка, техническая подготовка, технико-тактическая подготовка, тренировочное занятие, производительность.

Цель исследования состоит в исследовании ефективность технической подготовки рапиристок на этапе базовой специализированной подготовки с применением биомеханическим критериям.

Задачи исследования: 1. Изучение концептуальных ориентиров в подготовке рапиристок на этапе базовой специализации. 2. Определение уровня спортивной и соматофункциональной подготовки рапиристок молодежного возраста. 3. Анализ мнений специалистов относительно технической подготовки фехтовальщиков высокого уровня с использованием биомеханических критериев. 4. Разработка экспериментальной программы, ориентированной на использование биомеханических критериев для рапиристок молодежного возраста. 5. Экспериментальная валидация эффективности применения экспериментальной программы, ориентированной на использование биомеханических критериев в технической подготовке рапиристок на этапе базовой специализации.

Научная новизна и оригинальность исследований заключаются в разработке и экспериментальной проверке программы технической подготовки среди юниорок-фехтовальщиц на основе использования биомеханических критериев. Были выявлены, измерены, определены и проанализированы индексы кинематических и динамических характеристик компонентов технического выполнения в тренировке и соревнованиях. Практическое применение данной программы поспособствует оптимизации уровня технической подготовки юниорок- рапиристок и, соответственно, приведет к улучшению их функциональных способностей на соревнованиях.

Важная научная проблема исследования решенная в этой области, является недостаточное количество научных и практико-методических исследований, направленных на оптимизацию процесса технической подготовки фехтовальщиц на этапе базовой специализации. Разработка и внедрение экспериментальной программы, основанной на планировании специфических средств и систем действий на основе биомеханических критериев, приведет к повышению спортивной результативности в данном виде соревнований.

Теоретическая значимость работы заключается в том, что в результате анализа специальной литературы и мнений специалистов, приведенных в ходе исследования, были установлены методологические ориентиры для повышения уровня технической подготовки фехтовальщиков на основе использования биомеханических критериев. Это, в свою очередь, способствует дополнению существующих концепций в области теории и методики спортивной подготовки в фехтовании, особенно на этапе базовой специализации.

Практическая значимость работы работы заключается в возможности внедрения экспериментальной программы и методологических ориентиров на этапе базовой специализации, разработанных на основе индексов биомеханических критериев для юниорок-фехтовальщиц. Полученные результаты могут быть использованы в качестве методического пособия тренерами специализированных спортивных школ фехтования, а также студентами вузов физической культуры и спорта, обучающимися по специальности "фехтование".

Внедрение научных результатов. Результаты исследования были интегрированы в процесс тренировки юниорок-фехтовальщиц в различных специализированных спортивных клубах фехтования в Румынии: СК «Рапид», Бухарест; С.К.Т.А. Бухарест; С.К.А. «Стяуа», Бухарест; С.К. «Корона», Брашов, которые находятся на централизованной подготовке в составе Национальной сборной Румынии по фехтованию на рапирах среди юниоров и молодежи. Эти результаты могут быть использованы как методический материал в процессе профессиональной подготовки студентов в учреждениях высшего образования в области физической культуры и спорта, специализирующихся на «фехтовании».

ANNOTATION

Pavel Liviu-Paul: ”Technical training of the female foil fencers at the basic specialization stage using biomechanical criteria”. Doctoral thesis in educational sciences, specialty 533.04. Physical education, sport, kinesiology and recreation. Chișinău, 2025.

Thesis structure: introduction, three chapters, general conclusions and recommendations, bibliography sources (235), appendices (12), basic text (140 pages), figures (26), tables (44), research results published in 8 scientific papers.

Keywords: fencing, junior female foil fencers, biomechanics, sports training, physical training, technical training, technical-tactical training, training session, performance.

The purpose of research is to investigate the effectiveness of the technical training of junior female foil fencers during the basic specialization stage through the use of biomechanical criteria.

Objectives: 1. Studying the conceptual frameworks regarding the technical training of female foil fencers at the basic specialization stage. 2. Determining the level of sports and somato-functional training of junior female foil fencers. 3. Analyzing the opinions of experts regarding the technical training of elite female foil fencers by means of biomechanical criteria. 4. Developing the experimental program focused on the use of biomechanical criteria in junior female foil fencers. 5. Experimental validation of the effectiveness of applying the experimental program concentrated on the use of biomechanical criteria in the technical training of female fencers at the specialization stage.

The scientific novelty and originality of the paper consists in the development and experimental validation of the technical training program for junior female foil fencers based on the use of biomechanical criteria. Kinematic and dynamic characteristics of the key components of technical execution in training and competition were identified, measured, determined and analyzed. The practical application of this program will contribute to optimizing the technical training level of junior female foil fencers and, consequently, lead to improved performance capabilities in competitions.

The important scientific problem resolved in this field is the limited number of scientific and practical-methodological studies on optimizing the technical training process of female foil fencers at the basic specialization stage. The development and implementation of an experimental program focused on planning specific means and action systems based on biomechanical criteria would lead to an increase in sports performance in this sports event.

The theoretical significance of the paper is derived from the fact that, after analyzing the specialized literature and the opinions of experts in the field cited throughout the research, methodological benchmarks were established. These ones are meant to increase the technical training level of the female fencers based on using biomechanical criteria. In their turn, these criteria contribute to the enhancement of the existing concepts in the field of theory and methodology of sports training in fencing, particularly at the stage of basic specialization.

The applicative value of the work offers the possibility of implementing the experimental program and the methodological benchmarks at the stage of basic specialization, developed according to biomechanical criteria for junior female foil fencers. The results obtained can be used as a methodological guide by coaches of specialized fencing sports schools(weapon:foil), as well as by students of higher education institutions in physical education and sports with a specialization in "Fencing."

Implementation of scientific results. The results of the research have been integrated into the training process of junior female foil fencers at various specialized fencing sports clubs in Romania: CS Rapid, Bucharest; C.S.T.A. Bucharest; C.S.A. Steaua, Bucharest; C.S. Corona, Brașov, which are part of the centralized training program of the Romanian National Junior and Youth Foil Team. These results can be used as a methodological resource in the professional training of students in higher education institutions of physical education and sports, specializing in "Fencing."

PAVEL Liviu – Paul

TECHNICAL TRAINING OF THE FEMALE FOIL FENCERS AT THE BASIC SPECIALIZATION STAGE USING BIOMECHANICAL CRITERIA

Specialty 533.04. Physical education, sport, kinesiology and recreation

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