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The contribution of biomechanical analysis to improving the execution of balance beam technical elements, the category of juniors

DOCTORAL THESIS ABSTRACT

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Keywords: Artistic Gymnastics; biomechanical analysis; individualised programs; "balance beam" event; technical training; physical training; psychomotor conducts; psychological evaluation.

INTRODUCTION

AG is a sports discipline that has garnered the admiration of the public (specialised and more) through its spectacular valences, meant to combine harmoniously beauty and force, spontaneity and precision, improvisation, and technical rigour. Besides the characteristics of AG performance sports, it comprises a series of traits getting it closer to theatre and dance; music also plays a decisive role, insofar as it instils a specific rhythm to the exercises performed by athletes.

Consequently, AG may also be seen as a sports activity with a strong emotional impact, thus contributing decisively to modelling the taste and sensitivity of the public. It explains why the athletes, just like actors, are so motivated to perform as well as possible and to win the admiration of both spectators and specialists, able to assess their work in a competent and detailed manner.

In Romania, the first mention of the constitution of an AG team dates from 1911, when participating in the contest organised by IGF (the International Gymnastics Federation), but the moment of the international affirmation of Romanian gymnastics would represent the participation in the 1976 Olympic Games of Montreal when Nadia Comăneci obtained the first 10 (ten) grade in the history of the competition. In the following lines, I will list the most notable performances of the Romanian gymnastics team in the “balance beam” event.

The AG’s popularity determined increased exigences from the public, which had direct repercussions on the technical training of the athletes, permanently improved using increasingly demanding training methods and practices. The researchers of this sports phenomenon have elaborated a series of working tools and programmes adjusting to the new realities, to improve the performance of gymnasts. The technological revolution of the last years has also marked the methods of projecting and organising practices, using special intervention and planning procedures. As such, by combining technical, biomechanical, and psychological knowledge, specialists have elaborated ever more efficient methodologies, meant to contribute to a permanent improvement of sports performance.

The motivation of the topic

I have decided to focus on this topic because I wanted to investigate the influence of biomechanical research within performance sports. The reason for choosing this topic was the experience acquired as a performance athlete during my years of study at the

Sports High-school "Nadia Comăneci Onești". My goal was to complete an optimising experimental research study concerning the elaboration and implementation of intervention possibilities using training routines to improve the execution of the technical elements in the "balance beam" event, among junior gymnasts (10 -12 years old), by introducing new elements characteristic to modern technology, in the training process. Hence, I start from the premise that the training routines may bring efficient contributions and solutions for an optimal training process. I highlight that I chose the "balance beam" event because I see it as the weak link within AG. Furthermore, the progress of gymnastics and the performances currently recorded by female gymnasts in this event (with few exceptions) are quite modest for a country like Romania.

I chose this doctoral topic based on both my experience as an athlete during my years at the Sports High-school "Nadia Comăneci Onești", and my intention of studying the impact of biomechanical analysis in performance sports. Hence, in this doctoral thesis, I proposed an experimental study aiming to improve the performance of balance beam exercises among junior gymnasts (10-12 years old) through training routines adapted to modern technology. My own experience has proven that the optimisation of training routines contributes to an improvement in performance. They are even more desirable, as the current training level of the Romanian athletes is relatively modest; the option for the "balance beam" event is justified by its importance within Artistic Gymnastics.

This research topic is at the crossroads between theory and practice in the field of Sports and Physical Education Science, and it aims to enforce an instruction model meant to elaborate complex training routines adapted to modern technology.

Thus, by applying conventional and nonconventional techniques and means, connecting tradition to actuality, and using biomechanical and various other types of knowledge, I believe we may reach the optimisation of sports performance in AG and the execution of technical elements in the "balance beam" event (particularly among juniors) through a comparative assessment of the results (mostly, the gymnasts' performances) following the implementation of training routines.

PART I

THEORETICAL BACKGROUND OF THE RESEARCH TOPIC

Chapter 1 - Actuality, relevance, and reflection of the topic in the scientific literature

1.1 Synthesis of the scientific literature data regarding the execution technique of the technical elements in the "balance beam" event

Biomechanics is an important science in the world of sports. It analyses and corrects technical errors. AG is more related to biomechanics than other sports, and this science contributes to the analysis, illustration, understanding, and improvement of sports techniques (Amneen et al., 2016).

The endeavours to improve technical executions in AG have always been a top priority for researchers in the field. The biomechanical video analysis can provide relevant information related to the kinematic and spatial-temporal characteristics regarding the trajectory of body segments involved in the movement, important components of sports technique, regarding the characteristics of movements of translation with rotation around the body axis (barycentre), the characteristics of the angular speed of the body segments related to the barycentre, and the dynamic characteristics of the barycentre of AG elements. Such information may be processed and analysed using the specialised program to this end, Physics Toolkit (Potop et al., Timnea, 2013).

1.2 Defining, methodological, and systematising elements regarding Artistic Gymnastics and the "balance beam" event

An event requiring special attention in AG is the *Balance beam*. It is one of the four events in women's AG that gymnasts execute elements within different groups during an exercise taking up to one minute and 30 seconds. Each exercise comprises the incipient element - mounting and it ends with a dismount. Each exercise comprises the incipient element - mounting and it ends with a dismount. Concerning the composition of the exercise, throughout the balance beam routine, the gymnast performs jumps, leaps, gymnastics-specific twists and turns, acrobatic elements with/without flight phases, with/without handstands. The evaluation of the routine starts as the gymnast mounts the balance beam, and ends with the dismount. Whereas the difficulty score represents the

maximum sum of the eight elements with the highest difficulty score (dismounts included), usually, gymnasts compete with more than 8 elements in the balance beam routine. The Code of Points defines the difficulty score as comprising eight elements with the highest difficulty score (five acrobatic elements at most and three artistic elements at least) (Kalinski et al., 2014; Pajek et al., 2018).

1.3 Aspects of the movements within Artistic Gymnastics from a biomechanical perspective

AG is more related to biomechanics than other sports, and this science contributes to the analysis, illustration, understanding, and improvement of sports techniques. The biomechanical analysis in AG has evolved. The most accessible method of analysis is the video analysis of movement. The use of movement video analysis to analyse the execution technique and find the best methods to increase efficiency and improve performance is useful for both coaches and athletes. The identification of the significant parameters of execution contributes to successful performance in AG (Ameen et al., 2016; Mkaouer, 2012; Pimental et al., 2012; Neptune et al., 2009).

1.4 Artistic Gymnastics through the lens of psychomotricity

Psychomotor education and re-education through movement have the role of modelling the personality of gymnasts by associating an action with environment discovery for knowledge purposes. The specialists in the field (Benes, et al. (1972) and Judite, et al. (1985) apud Abalaşei (2014) have convened on the fact that the entire body, muscular and nervous systems included, need psychomotor education (Abalaşei, 2014).

1.5 Competition schedule requirements

Artistic Gymnastics has recorded remarkable progress, through its development in conformity with the trends of performance sports but keeping some particularities. Researchers refer here to an increased virtuosity and difficulty of the elements performed in women's AG (Vieru, 1997, apud Potop et al., 2014; Scharer et al., 2019).

AG is at a new level of development because the modifications within the Code of Points have entailed significations alteration to the content and structure of routines and

compositional requirements. At the same time, gymnastics has made remarkable progress and has proven to have developed in conformity with high-performance sports trends (Potop et al., 2018; Vieru, 1997, apud Potop et al., 2014; Scarborough et al., 2019).

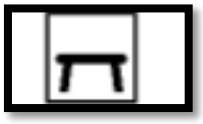
1.6 The requirements of the Code of Points

There are separate grades for each type of apparatus (nota D - difficulty + grade E - execution), the two cumulated constituting the Final Grade. One may increase the difficulty of the elements if we keep the groups of elements required in the Classification Syllabus for the Romanian Federation of Gymnastics.

(examples: *Lateral Danilova* instead of *Side cartwheel*, *Forward Danilova* instead of *Slow forward roll*, *Handspring bwd (Flic - Flac) - Leap* instead of 2 *Consecutive Handspring bwds (Flic – Flac)*, *Salto forward with a 360^0 turn* instead of *Salto forward*, etc.). The difficulty score of the elements is constituted as per the table of elements within the CdP (The Code of Points). Penalties are applied in conformity with the CdP, with a few exceptions concerning some apparatus. For the floor routine, grade D comprises 10.00 p, from which execution penalties are subtracted. In individual performances (for levels 2, 3, and 4), they consider the fifth event, namely the mandatory floor routine (F.R.G.).

1.7 The "balance beam" event - The standards of apparatus in Artistic Gymnastics

Standards and technical content

a. Symbol: 

b. Dimensions: *b.1* Length: 500 cm (±1cm); b.1.2 Cross-section; *b.1.2.1* upper surface: 10 cm (±0.5 cm); *b.1.2.2* horizontal axis: 13 cm (±0.5 cm); *b.1.2.3* vertical axis: 16 cm (±0.5 cm); *b.1.2.4* lower surface: 10 cm (±0.5 cm); *b.1.3* Height of the upper part measured from the floor: 125 cm (±1 cm); *b.2* Metal rods of the platform; *b.2.1* Maximum distance: 500 cm; *b.2.2* Maximum width: 125 cm; *b.3* Supports' buffer; *b.3.1* Thickness: min. 15 mm; *b.3.2* Width of supports – buffer material included: max 125 cm; *b.4* Supports' buffer; *b.4.1* Thickness: minimum 15 mm; *b.5* Width of supports – buffer material included maximum 125. cm. Buffering of front parts: Thickness: minimum 15 mm; *b.6* The balance

beam must comprise a height-adjusting system, which may be continuous or may feature a 5-cm adjustment.

c. Colours: the colour of the balance beam must be different from the colour of the mats (F.R.G)

Chapter 2 - Sports practice and its reflection in the training of gymnasts

2.1 Methodical priorities of current sports training

A coach is much invested in the training of athletes by monitoring the practices rigorously, while athletes improve their motor skills until they become automatic (regardless of their complexity). As such, methodological strategy plays an essential role in the training of gymnasts until they reach an artistry level in their execution. It must be stated that the training methodology in gymnastics relies on practical methods, resulting from the years of experience in teamwork and the good collaboration between coaches and female gymnasts. On the other hand, the methodology of learning relies on rigorous scientific research, meant to select and inventory essential information regarding the relevant parameters in performance for each element (Dragnea & Teodorescu, 2002).

2.2 Characteristics of sports training

Physical and motor development represent the basic condition for performance by athletes endowed with skills and talent. The training (involving increased intensity of physical effort) requires great planning that encompasses many particular aspects. The training relies on the bilateral relationship between the coach and the athlete; it is also worth noting that the training of one athlete alone requires a great number of technicians and specialists (Cojocariu, 2010).

2.3 Content of sports training

The evolution of sports performances has led to a modification in the content of training: it became more complex, which meant the enforcement of a proper working methodology. Specialists have pointed out the necessity of clear rules to systematise the content of the training. A central role is played by physical exercises adapted to various sports branches, depending on their specifics and addressability, by focalising on the essential elements of instruction, from technique and exercise capacity to the psychosomatic, artistic, or theoretical sphere. The targeted fields would be mental, theoretical, artistic, biological, technical, tactical, as well as exercise capacity (Dragnea, 1996).

2.4 Training components

The polyvalent training of athletes (physical and technical and tactical, as well as theoretical-artistic, and mental), essential for attaining the desired performance, takes place gradually. Each component has a particular weighting in the various stages of training (Dumitru, 2015).

2.4.1 Physical training

A crucial part of physical training is represented by improving the athletes' capacity of implementing their motor skills during both practices and competitions. From this perspective, one must ensure the specific level of physical training, the interdependent relation between resistance and physical training, the activity of the nervous system and the development of the other motor skills. Optimal physical training is the first step toward great performance, and the coach must insist on developing the biomotor qualities and the physiological potential of the athlete through practical tests and control trials in various combinations of versions and measurements. A type of training targeting the improvement of physical training is the education of motor qualities for an athlete, for a correct acquisition of the elements, connections, and combinations within AG routines (Potop et al., 2018; Kochanowicz et al., 2009).

2.4.2 Technical training

Experts have pointed out that the technique of a sports branch encompasses all the motor actions executed ideally from the perspective of their effectiveness. In gymnastics, technical training must be adapted to the particularities of the sports technique specific to this discipline. The technical elements with a high degree of coordination in gymnastics are executed using harmony, beauty, easiness, and elegance, without showing the great physical effort necessary for such a routine. Athletes must focus on the correct execution of the movement. A secondary role in the technique of gymnastics routines is the perception of outside particularities, objects, and apparatus (Potop et al., 2019).

2.4.3 Artistic training

AG includes *artistic training* as a special and complex component of sports training. Through it, we ensure the physical and mental support necessary to perform a movement in a personal manner, using technicity, plasticity, and expressivity indicators specific to the particularity of the sport (Grigore, 2002, apud Moraru, 2010).

2.4.4 Psychological training

Anxiety is a very important aspect of AG, especially in execution in balance beam, where elements of great difficulty are executed on a piece of apparatus measuring 10 cm in width and 125 cm in height. The effect of competitive anxiety on performance has also been analysed by specialists. It has always been assumed that anxiety throughout competitions (i.e., a negative emotional state characterised by feelings of agitation, worry, and restlessness) has beneficial or harmful effects on sports performance (Cottyn et al., 2006).

2.4.5 Biological training

Training for competition and *recovery of exercise capacity* represent the two different directions followed within the current biological training of gymnasts. The purpose of both is to protect the health and capacity of the body enduring training stress for contests, with the goal of obtaining sports performance (Dumitru, 2015).

Effort and recovery do not use the same channels, but various ones, depending on the characteristics of the effort made by athletes, mostly given the specific effort within AG. From this perspective, gymnastics involves a neuromuscular effort based on immense endocrine-metabolic and mental loading, at least according to sports experts (Avramoff, 1982, apud Dumitru, 2015).

2.4.6 Tactical training

Tactical training is not as relevant in AG tactical training compared to other sports branches, but it refers to aspects such as the following: “the tactics of elaborating the technical training: in what concerns music selection, it should be adequate to the female gymnast and correlated with composition requirements; the motor content should follow the regulation demands and insert in the competition routine that the gymnast knows best;

competition routine composition tactics; elaborating execution versions to execute in unpredictable situations; the tactics of making up the team and participating in the competition; determining the competition order of gymnasts; tactics during the contest. (Moraru, 2010).

2.4.7 Theoretical training

An athlete becomes more independent by acquiring this element, being able to enforce a permanent attitude of self-observation and self-control in what concerns training methodology. Theoretical training comprises the following elements of content: "the notions concerning the social implications of the sports phenomenon; the identification of special moments in the historical evolution of the sports branch; minimal theoretical notions in the field of physiology, hygiene, and biomechanics, related to the sports discipline studied; actions related to sports tactics; notions of educational psychology able to provide the premises of efficient self-education; getting to know competition regulations and the consequences of failing to observe them; notions related to equipment and competition material maintenance" (Moraru, 2010).

2.5 The importance of individualising training routines in the "balance beam" event

Sports training is a complex, intensive, and long-term process, manifested under various forms, modalities, and solutions, leading to approximately the same results, but with different efficiency. Consequently, one may use several methods with the same purpose. Performance depends very much on the paths used, the coaches' skills, the organisational and material conditions, and the value of the human material (Bibire & Dumitru, 2010; Potop et al., 2015; Potop & Crețu, 2010).

The coach, through his expert skills in the field, may turn a child into an athlete. To this end, the training process should have well-determined objectives, thus implementing specific means and methods (Cornici, 2013; Coppola et al., 2015; Potop & Crețu, 2018).

The conclusions of the first parte

By inventorying and generalising the information provided by the studies concerning the assessment of technical training, several relevant conclusions may be extracted:

- by using the specific tools and didactic materials, specialists have identified a real necessity to improve the sports activity of gymnasts through the means and methods of optimisation of the technical elements in AG, adapted to the specifics of the discipline
- the coach plays an essential role in the identification of specific technical and mental features, to improve the performance of each female gymnast; he also has to implement effective working methods, targeting several educative-corrective objectives that are precise and easy to apply
- specialists have pointed out the existence of various ways to assess the technical and tactical training of the athletes, such as classic and modern recordings, using the latest educational software programs, as well as numerous didactic materials – determining a coach to use a multitude of activities meant to optimise the technical elements in the training of junior gymnasts
- from the 210 articles analysed, 56% of the studies highlight the importance of gymnastics and approaching the "balance beam" event, physical education, and sports training; the optimisation of the technical elements using various devices, tools, accompanied by biomechanical analysis, video analysis, data processing. Hence, it is worth mentioning the following: *the biomechanical analysis (software) (2D):* Physics ToolKit; Kinovea; Skill Spectator; Qualisys Qqus; Smart Capture; Smart Trackera, and Smart Analyzer. *Video recording*: Panasonic NV - MX500EG; Panasonic NV - MS1 HQ - VHS, hpeak, etc; *data processing*: ANOVA, APAS, The KyPlot Statistical Method; d-Cohen, T-Test, the Biological Variation Coefficient (BVC); Microsoft Office Excel 2003; the graphical representation method. Tests: Kruskal – Wallis
- within the research, I focused on the "balance beam" event in AG and analysed most technical elements related to this event. The fundamental elements are as follows: *dismounts through double salto backward*; *lateral Danilova*; *Handspring bwd (FF); slow back walkover*; *salto backward*; *salto forward*; *rondad*; salto

backward / backward with a 360^0 turn. *Miscellaneous:* leap phases; flight phases; dismount; teaching the elements in various cycles; technical training; technical elements

- 20% of the papers highlight the role played by the components of sports training (technical, physical, artistic, psychological training). All of them, it has been concluded, are very useful in technical training. Concerning physical training, research studies have used the following tools: Alpha – Fit and Ergo Strength Meter; the Strength plate, and the EMGs system
- 11% of the works highlight the role of gymnastics from the perspective of psychomotricity (the relevance of balance, coordination, and mobility in the "balance beam" event)
- 13% of the works analyse various aspects characteristic of this discipline and event (the importance of body stance and anthropometrical measurements in AG; the importance of recovery following various injuries and the role of statistics within the research work)
- regarding technical training, it is worth noting that these notions concerning the assessment of technical training support the coaches, helping them estimate the potential of each athlete and/or to direct the training on less ideal aspects
- research also underlines that technical elements may be influenced by the composition of the apparatus
- studies show that insufficient physical training among gymnasts leads to inadequate and faulty technique, and failure in competitions, eventually. Furthermore, faulty technical training based on proper physical training leads to modest performances.
- the research in the scientific literature highlights that the assessment of sensorimotor coordination in agreement with the biomechanical analysis of the fundamental elements of sports technique has an impact on the technical training and performances obtained during competitions
- research findings show that the development of sensorimotor coordination in relation to spatial and temporal orientation, balance, and coordination, physical training and basic technique, kinematic and dynamic analysis of the key-elements of sports technique, could translate into performances in competitions, such as the D, E scores, and the final score in the competition per apparatus

- furthermore, research states the need to have algorithm-based programs to acquire gymnastics routines by relying on an optimal relation between sensorimotor development, physical training, and the biomechanical video analysis of the key-elements of sports technique. All of them have influenced the sports training level during the fundamental specialisation phase in women's AG.

By studying the scientific literature, I have noticed that the effective use of learning transfer in the gymnastics routines on various apparatus, based on the biomechanical analysis of the primary components of sports techniques may contribute to increasing the difficulty of routines, to improved technical executions, and to obtaining better performances during competitions.

Through all the aspects investigated and analysed, my theoretical research has facilitated the road to the preliminary study and, eventually, to the experimental study.

PART II

PERSONAL CONTRIBUTIONS

Chapter 3. Preliminary study regarding the contribution of biomechanical analysis on the balance beam technical elements, the category of juniors - Handspring bwd (Flic – Flac) (RÎP (FF) and Dismount by salto bwd tucked (CSG))

3.1 Research premise

The premise from which I started this study is that we are in a favourable moment to use new intervention methods for improved execution of the balance beam technical elements, through software programmes and modern technological devices which, along with new training means, may have positive influences on sports performances.

3.2 Purpose, objectives, tasks, hypotheses

3.2.1 Research goal

Considering the rigidity of the CdP and the fact that competitive performances are conditioned by the results in technical and execution scores, the purpose of this study was to observe possible errors of execution in the performing of the technical elements in AG in balance beam - RÎP (FF) and CSG. At the same time, this research endeavour aims at identifying specific methods to improve optimally the execution technique through the biomechanical analysis and the calculation of particular parameters, meant to increase performance in competitions and optimise the training means.

3.2.2 Research objectives

For the preliminary research, I determined the following objectives:

- identifying and applying the most effective training means and methods, as well as highlighting the beneficial effects of these means
- associating these efficient training means and methods with classic means and methods, to optimise technical execution in the balance beam
- determining the intervention programs to obtain qualitative transformations in what concerns the execution technique of such balance beam technical elements

- processing and interpreting the data obtained
- justifying the roles of the software programs Kinovea and Physic ToolKit in this field.

3.2.3 Research tasks

In the preliminary research, I sought to accomplish the following tasks:

- elaborating the working hypotheses
- selecting the research and actuation means
- constituting the group of investigated subjects
- recording the balance beam technical elements RÎP (FF) and CSG
- processing the data using the software programs Kinovea and Physics ToolKit
- applying the technical training and physical training trials to the group of investigated subjects as TI
- processing, interpreting the data recorded by the group of investigated subjects after TI
- designing and implementing the practical intervention program (training means, planning sessions per days/weeks/months; assessing the quality and efficiency of the programs applied by recording and processing the data, their analysis and interpretation)
- implementing and directing the training routine in the "balance beam" event
- applying the technical training and physical training trials to the group of investigated subjects as TF
- processing, interpreting the data recorded by the group of investigated subjects after TF
- elaborating a training model specific to the "balance beam" event for junior gymnasts
- elaborating the general and applicative conclusions specific to the preliminary research and determining the subsequent endeavour.

3.2.4 Research hypotheses

In the preliminary research, I started with the following hypotheses:

General hypothesis 1:

I believe that the optimisation of the key-components within the phasic structure (the start position (the position before the dismount (PP), the body position multiplication (the

maximum flight height (MP) and the final position (dismount) (PF) of specific elements in balance beam, depends on the biomechanical analysis and the personalised working means and methods.

Specific hypothesis 1:

The correct execution of technical elements in the "balance beam" event is influenced positively by the start position (PP).

Specific hypothesis 2:

The biomechanical analysis identifies influences of the multiplication of the body position (MP) in the correct execution of the technical elements.

Specific hypothesis 3:

I assume that the final position (PF) upon dismount influences the accuracy of the execution of technical elements.

Specific hypothesis 4:

Personalised means and methods improve the execution technique of elements in the "balance beam" event: Handspring bwd (RÎP (FF) and Dismount by salto bwd tucked (CSG).

3.3 Research methods and techniques

Bibliographical research technique; Observation technique; Videographic technique; Biomechanical analysis technique; Experimental method; Statistical-mathematical method; Computerised graphical representation method.

3.3.1. Events used in the research

The subjects comprised in the research were subjected to assessments aiming at the following:

Technical trials: Technical element 1: RÎP (FF) and Technical element 2: CSG.

3.4 Research organisation and unfolding

3.4.1 Research place

The preliminary study was carried out in the Gymnastics Hall "Andreea Răducan" Bârlad, a club with a gymnasium endowed with equipment and the didactic material

necessary for the unfolding of the training process in gymnastics. Gymnasts participating in the research are athletes legitimated at this club. In what concerns the unfolding of the activity, I requested and obtained the consent of the sports club and the parents of gymnasts included in the research group.

The research aimed at identifying the possible execution errors in the technical elements in the "balance beam" event - RÎP (FF) and CSG of junior gymnasts and optimising this execution technique by elaborating specific programs individualised with new means, to increase their performances and exploitation in competitions.

The research was conducted in the period 29. 07. 2020 - 29. 10. 2020, in the Gymnasium "Andreea Răducan" Bârlad, on a 14-week duration.

3.4.2 Research variables

Dependent variables:

- anthropometrical and biomechanical parameters specific to the characteristics of movements of the technical elements analysed - RÎP (FF) and CSG
- spatial characteristics of the body segments in the execution of the technical elements (PP - the position before the dismount - the angle between the horizontal of the balance beam and the shoulder, the angle between the thigh and the torso, and the angle between the torso and the arms; MP - the multiplication of the position (the maximum flight height CGG) - the angle between the thigh and the torso, the angle between the thigh and the calf, and the angle between the arms and the torso; PF - the final position (dismount).

Independent variables:

- operational models for optimisation of the technical element RÎP (FF)
- operational models for the optimisation of the technical element CSG
- routines for the development of back muscles
- routines for the development of lower limb muscles
- routines for the development of mobility
- means to educate the coordination capacity and psychomotor aptitude.

3.4.3 Research phases

Concerning the research phases, I planned the tasks, as they have an essential role in determining the order of preliminary research phases, as follows:

- reviewing and analysing the scientific literature
- determining the group of investigated subjects
- TI of the group of investigated subjects comprised in the research (video analysis)
- formulating and applying personalised intervention programs for the group of investigated subjects
- TF of the group of investigated subjects comprised in the research
- the statistical-mathematical interpretation of the data obtained
- formulating final conclusions and recommendations.

3.4.4 The group of investigated subjects

The group of subjects who took part in the preliminary research (Table 3.1.2.) comprised five female gymnasts, aged between 10 and 12, determined by the following inclusion criteria:

- female athletes practising performance AG
- female gymnasts aged between 10 and 12
- clinically healthy / medically fit, as per the medical file of each female gymnast
- written consent obtained from the parents / tutors, of coaches and club management to include the minors in the preliminary research study
- capable of executing the technical elements studied here: RÎP (FF) and CSG.

3.5 The training routine in the "balance beam" event applied in the preliminary research

The exercises used in the training and practice of gymnasts in the balance beam concerned the attainment of the following objectives proposed:

- influencing the motor and psychomotor aptitudes involved in the execution of the technical elements
- correcting the execution errors identified
- optimising the execution technique of various technical elements in the "balance beam" event by rationalising and standardising the training means

- optimising the execution technique of various technical elements in the “balance beam” event by carrying out the physical training with new means, to improve the technical training of the elements in the balance beam.

3.6 Results and discussions

Table 3.1. Anthropometrical and biomechanical parameters specific to the movement characteristics of the technical element RÎP (FF) - Physics toolKit

Subject code/ Technical element symbol	Weight (kg)		Height (m)		Rotation inertia ½(kg·m²)		Segmental movement radius (m)							
							Leg				Shoulder		Hand	
							Front		Back					
TESTARE	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**
S1_L1	37	37,6	1,45	1,46	9,805	9,964	0,782	0,84	0,781	0,887	0,448	0,446	0,917	0,987
S2_L1	26	26,5	1,38	1,39	6,188	6,399	0,774	0,733	0,789	0,76	0,416	0,387	0,843	0,816
S3_L1	31,3	31,7	1,38	1,39	7,449	7,656	0,744	0,822	0,701	0,828	0,422	0,473	0,872	0,994
S4_L1	33,0	33,6	1,39	1,40	7,969	8,232	0,834	0,848	0,85	0,864	0,488	0,489	1,015	1,036
S5_L1	33,4	34,0	1,40	1,41	8,183	8,449	0,818	0,803	0,798	0,794	0,433	0,446	0,856	0,903
X	**32,14**	**32,68**	**1,4**	**1,41**	**7,919**	**8,14**	**0,790**	**0,809**	**0,784**	**0,827**	**0,441**	**0,448**	**0,901**	**0,947**
SD	**4,01**	**4,06**	**0,03**	**0,03**	**1,31**	**1,29**	**0,04**	**0,05**	**0,05**	**0,05**	**0,03**	**0,04**	**0,07**	**0,09**

Note: S1-5_L1 - side view, subject 1 - 5, exercise 1 (RÎP (FF) ;< x- arithmetic mean - mean error; TI - initial testing; TF - final testing, x - arithmetic mean, SD - standard deviation

Table 3.2. Anthropometrical and biomechanical parameters specific to the movement characteristics of the technical element CSG - Physics toolKit

Subject code/ Technical element symbol	Weight (kg)		Height (m)		Rotation inertia ½(kg·m²)		Segmental movement radius (m)							
							Leg				Shoulder		Hand	
							Front		Back					
TESTARE	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**	**TI**	**TF**
S1_L2	37	37,6	1,45	1,46	9,805	9,964	0.515	0.509	0.511	0.503	0.297	0.309	0.426	0.443
S2_L2	26	26,5	1,38	1,39	6,188	6,399	0.446	0.464	0.453	0.473	0.251	0.269	0.353	0.389
S3_L2	31,3	31,7	1,38	1,39	7,449	7,656	0.635	0.674	0.635	0.667	0.378	0.379	0.588	0.628
S4_L2	33,0	33,6	1,39	1,40	7,969	8,232	0.621	0.654	0.632	0.651	0.383	0.405	0.654	0.634
S5_L2	33,4	34,0	1,40	1,41	8,183	8,449	0.558	0.601	0.533	0.598	0.345	0.366	0.506	0.532
X	**32,14**	**32,68**	**1,4**	**1,41**	**7,919**	**8,14**	**0.555**	**0.5804**	**0.553**	**0.578**	**0,331**	**0,346**	**0.505**	**0.525**
SD	**4,01**	**4,06**	**0,03**	**0,03**	**1,31**	**1,29**	**0,08**	**0,09**	**0,08**	**0,09**	**0,06**	**0,06**	**0,12**	**0,11**

Note: S1-5_L2 - side view, subject 1 - 5, exercise 1 (CSG) ;< x- arithmetic mean - mean error; TI - initial testing; TF - final testing

Concerning the technical element *RÎP (FF)*, the results of the calculations *of the anthropometrical and biomechanical parameters* underline differences between TI and TF as follows: in *body weight*: 0.54 kg; in *rotation inertia*: 0,221 kg·m^2; in *body movement radius*: *front leg*: 0,109 m; *rear leg*: 0,043 m; in *shoulder*: 0,007 m and in *hand*: 0,046 m. These significant differences in the TF *of the anthropometrical and biomechanical parameters* show the improved execution of the phasic structure in the technical element *RÎP (FF)*. Therefore, the values *of rotation inertia* influence movement, the higher the height and weight values of the female gymnast, the higher the rotation inertia. Concerning *segmental movement radius* (front leg and rear leg), the higher values recorded in the TF involve an improved trajectory. In this respect, the range of motion improved in the legs, shoulder, and hand (Table 3.5.).

Concerning the technical element *CGS*, the results of the calculations *of the anthropometrical and biomechanical parameters* underline differences between TI and TF as follows: in *body weight*: 0.54 kg; in *rotation inertia*: 0,221 kg·m^2; in *segmental movement radius*: *front leg*: 0,025 m; *rear leg*: 0,025 m; in *shoulder*: 0,015 m, and in *hand:* 0,02 m. These significant differences in the TF *of the anthropometrical and biomechanical parameters* prove improved execution of the phasic structure in the technical element *CGS*. Therefore, the values *of rotation inertia* influence movement, the taller and heavier the female gymnast, the higher the rotation inertia. Therefore, the values *of rotation inertia* influence movement, the higher the height and weight values of the female gymnast, the higher the rotation inertia. Concerning *segmental movement radius* (front leg and rear leg), the higher values recorded in the TF involve an improved trajectory. In this respect, range of motion improved in the legs, shoulder, and hand (Table 3.6.).

Table 3.3. Spatial characteristics of the body segments in the execution of the technical element RÎP (FF) - Kinovea

Element symbol	PP (grade)				MP, ÎMZ (grade)						PP2		PF 1(grade)						PF 2 (grade)					
	a		b		a		b		c		a		a		b		c		a		b		c	
TESTING MOMENT	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF
S1_L1	233	234	173	175	272	281	195	206	207	203	123	122	56	53	150	153	150	158	-	114	-	163	-	97
S2_L1	216	225	182	183	281	270	186	187	221	224	150	140	63	59	167	136	155	161	93	102	134	147	114	125
S3_L1	233	231	206	185	278	278	218	247	212	216	107	100	58	53	141	187	158	160	75	91	108	145	131	121
S4_L1	218	215	182	190	282	287	236	237	214	212	90	100	50	64	179	170	147	134	118	122	152	153	107	116
S5_L1	218	238	182	197	274	281	228	221	205	207	125	164	52	67	186	177	133	131	123	119	154	152	64	104
X	**223,60**	**228,60**	**185,00**	**186,00**	**277,40**	**279,40**	**212,60**	**219,60**	**211,80**	**212,40**	**119,00**	**125,20**	**55,80**	**59,20**	**164,60**	**164,60**	**148,60**	**148,80**	**102,25**	**109,60**	**137,00**	**152,00**	**104,00**	**112,60**
SD	**8,62**	**8,96**	**12,37**	**8,19**	**4,34**	**6,19**	**21,40**	**24,00**	**6,30**	**8,14**	**22,35**	**27,41**	**5,12**	**6,34**	**18,98**	**20,23**	**9,71**	**14,96**	**22,41**	**12,90**	**21,32**	**7,00**	**28,51**	**11,76**

Note: PP - the start position (before dismounting); PPa - the angle between the rear leg and the torso; PPb - the angle between the arms and the torso; MP - the multiplication of the position (the flight phase), Mpa - the angle between the rear leg and the torso; MPb - the angle between the front leg and the torso; MPc - the angle between the arms and the torso PP2 - handstand; PF - the final position (dismount); (flic-flac); PF1 - the final position (support on the front leg), PF2 – support on the rear leg (finish); Pfa - the angle between front leg and the torso; PFb - the angle between rear leg and the torso; PFc - the angle between the arms and the torso; ” - ” fall (values outside the plane of movement

X - arithmetic mean, SD – standard deviation

Table 3.4. Spatial characteristics of the body segments in the execution of the technical element CSG - Kinovea

ID/ Technical element symbol	PP (grade)						MP, ÎMZ (grade)						PF (grade)					
	a		b		c		a		b		c		a		b		c	
TESTING MOMENT	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF	TI	TF
S1_L2	108	103	197	194	125	136	93	109	77	77	31	28	99	98	118	112	151	118
S2_L2	107	107	187	195	164	193	72	95	63	71	36	37	110	110	115	128	68	77
S3_L2	95	96	181	186	165	163	91	93	89	84	29	35	161	153	165	163	157	152
S4_L2	90	93	189	182	190	198	87	83	95	87	29	31	136	142	132	134	151	140
S5_L2	104	103	193	195	174	185	97	85	85	75	41	41	82	138	86	132	59	112
X	**100,8**	**100,4**	**189,4**	**190,4**	**163,6**	**175,0**	**88,0**	**93,0**	**81,8**	**78,8**	**33,2**	**34,4**	**117,6**	**128,2**	**123,2**	**133,8**	**117,2**	**119,8**
SD	**7,92**	**5,73**	**6,07**	**6,02**	**23,9**	**25,6**	**9,64**	**10,3**	**12,4**	**6,57**	**5,21**	**5,08**	**31,2**	**23,2**	**28,7**	**18,5**	**49,2**	**28,9**

Note: PP - the start position (before dismounting from the balance beam), a) the angle between the horizontal of the balance beam and the shoulder. b) the angle between the thigh and the torso, c) the angle between the torso and the arms ; MP - the multiplication of the position (the maximum flight height CGG), a) the angle between the thigh and the torso, b) the angle between the thigh and the calf, c) the angle between the arms and the torso; PF - the final position (dismount), a) the angle between the thigh and the torso, b) the angle between the thigh and the calf, c) the angle between the torso and the arms

Concerning the technical element *RÎP (FF),* the results of the calculations *for the spatial characteristics of the body segments in the execution of the element* underline differences between TI and TF, as follows: in PP: a: 5^0; b: 1^0; in MPZ, ÎMZ: a: 2^0; b: 7^0; c: $0,6^0$; and in PF: a: $3,4^0$; b: - ; c: $0,2^0$ and in PF2: a: $7,35^0$; b: 15^0; c: $8,6^0$. These significant differences in the TF of the spatial characteristics (PP, MPZ and PF) prove an improved execution the technical element *RÎP (FF)* (Table 3.7.).

Concerning the technical element *CGS*, the results of the calculations *for the spatial characteristics of the body segments in the execution of the element* underline differences between TI and TF as follows: in PP: a: - ; b: 1^0 ; c: $11,4^0$; in MPZ,ÎMZ: 0 a: 5^0; b: - ; c: $1,2,^0$; and in PF: a: $10,6^0$; b: $10,6^0$; c: $2,6^0$. These significant differences in the TF of the spatial characteristics (PP, MPZ and PF) prove an improved execution the technical element *CGS* (Table 3.8.).

In the following lines, I feature the results of biomechanical analysis for subject 1: B.E., 11 years old, 37 kg, 145 cm, in the technical element 1, RÎP.

Figure 5.1 features *the spatial characteristics* of the body segments in the key-elements PP, MP, and PF. In the *TI*, in the key-element *PI*, it may be noted that S1 records the following values: 0,01 X1 (m) and 0,696 Y(m), while in *TF* - 0,01 X1(m) and 0,762 Y(m). In the key-element *PP*, the following values are recoded: 0,072 X1(m) and 0,912 Y1(m) in the *TI* and 0,125 X1(m) and 1,054 Y1(m) la *TF*. Regarding *MP*, the following values are noted: - 0,154 X1(m) and 1,116 Y1(m) in the *TI* and -0,136 X1(m) and 1,232 Y1(m) in the *TF*. *PP2* records the following values: -0,492 X1(m) and 0,952 Y1(m) in the TI and - 0,397 X1(m) and 1,033 Y1(m) in the *TF*. PF1, - 0,799 X1(m) and 0,86 Y1(m) in the *TI* and - 0,689 X1(m) and 0,929 Y1(m)) in the *TF*. PF2, - 1,219 X1(m) and - 0,02 Y1 (m) in the *TI* and - 1,002 X1(m) and 0,825 Y1(m)) in the *TF*. In additional, the PF, - 1,301 X1(m) and - 0,256 Y1(m) in the *TI* and - 1,013 X1(m) and 0,856 Y1 (m) la *TF* (Appendix 2, Table 2.1.).

Figure 5.2. shows *the values of special speeds* of the segments analysed in the *TI*. Regarding *PP*, the following values were found: 0,609 rad/s in the *front leg*, 3,79 rad/s in *the rear leg*, 21,927 rad/s in *the shoulder* and 28,161 rad/s in *the hand*. In what concerns the *MP*, the following values were obtained: 27,691 rad/s in *the front leg*, 11,152 rad/s in *the rear leg*, rad/s in *the shoulder* 17,192 and 15,839 rad/s in *the hand*. Regarding *PP2*, the following values were recorded: 30,578 rad/s in *the front leg*, 12,378 rad/s in *the rear leg*, 5,352 rad/s in *the shoulder* and 3,079 rad/s in *the hand*. Concerning *PF1*, the following values were found: 5,844 rad/s in *the front leg*, 25,401 rad/s in *the rear leg*, 9,595 rad/s in

the shoulder and 4,195 rad/s in *the hand*. Regarding *PF2*, the following values were found: 3,311 rad/s in *the front leg*, 2,152 rad/s in *the rear leg*, 13,119 rad/s in *the shoulder* and 19,886 rad/s in *the hand*. Regarding *PF*, the following values were found: 2,124 rad/s in *the front leg*, 2,225 rad/s in *the rear leg*, 1,365 rad/s in *the shoulder* and 5,115 rad/s in *the hand* (Appendix 2, Table 2.2.).

Figure 5.3. illustrates *the values of the spatial speed* of segments analysed in the *TF*. In what regards *PP*, the following values were found: 2,19 rad/s in *the front leg*, 4,275 rad/s in *the rear leg*, 22,627 rad/s in *the shoulder* and 16,35 rad/s in *the hand*. Regarding *MP*, the following values were found: 26,995 rad/s in *the front leg*, 14,352 rad/s in *the rear leg*, 14,816 rad/s in *the shoulder* and 16,35 rad/s in *the hand*. Regarding *PP2*, the following values were found: 35,597 rad/s in *the front leg*, 10,248 rad/s in *the rear leg*, 5,134 rad/s in *the shoulder* și 2,581 rad/s in *the hand*. Concerning *PF1*, the following values were found: 5,527 rad/s in *the front leg*, 27,591 rad/s in *the rear leg*, 8,12 rad/s in *the shoulder* and 3,24 rad/s in *the hand*. Regarding *PF2*, the following values were found: 1,034 rad/s in *the front leg*, 0,723 rad/s in *the rear leg*, 11,639 rad/s in *the shoulder* and 21,922 rad/s in *the hand*. Regarding *PF*, the following values were found: 0,111 rad/s in *the front leg*, 0,265 rad/s in *the rear leg*, 3,49 rad/s in *the shoulder* and 9,501 rad/s in *the hand* (Appendix 2, Table 2.3.).

It may be stated that in the *PP*, before dismounting the balance beam, the arm movement is not performed by the shoulders, S1 starts with the back and then the arms, which record the highest value, and this is correct from a methodological perspective because the athlete cannot mount the balance beam without lifting the arms as much as possible. The shoulder increases the speed of rotation. Compared to the TI, the shoulder has high values, followed by the values of the arms. The shoulder and arms play the execution role, which decreased, regulating the torso through motion. In the *MP*, we are interested in the legs. The front leg is bent, and the opening does not involve the split. However, in the case of S1, the front leg has the highest speed. Legs are the most important because they help with rotation. Concerning the PF, the legs are bent and slightly hesitant.

Figure 5.4. illustrates *the values of the strength resultant* (N) in the execution of the technical element ***RÎP (FF)*** in the *TI and TF*. Regarding *PP*, the following values were found: 2590 N in the *TI* and 3630 N in the *TF*. *MP:* 3250 N in the *TI* and 3260 N in the *TF*. *PP2:* 861,194 N in the *TI* and 1210 N in the *TF*. *PF1*: 1410 N in the *TI* and 703,762 N in

the *TF*. *PF2:* 3420 N in the *TI* and 1210 N in the *TF* and *PF*: 2790 N in the *TI* and 324,885 N in the *TF* (Appendix 2, Table 2.4.).

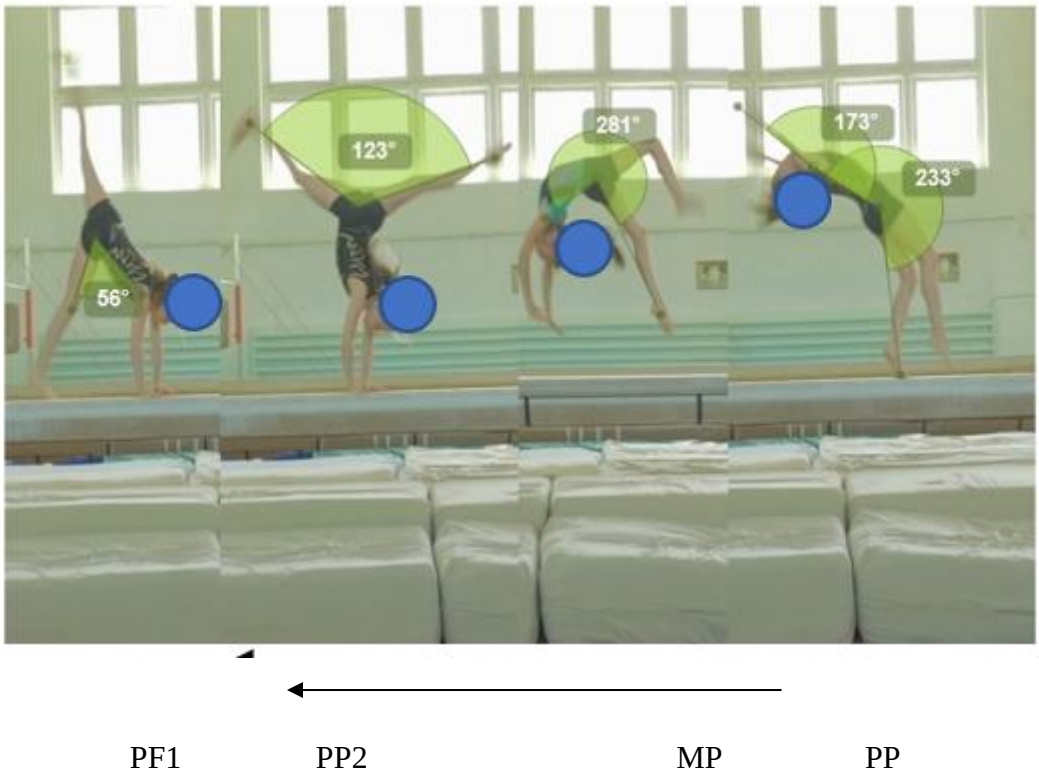


Figure 3.1. RÎP (FF) - Kinovea (Sagittal plane - side view) (S1_L1_TI)

Figure 3.2. RÎP (FF) - Kinovea (Front plane – anterior and posterior view) (S1)

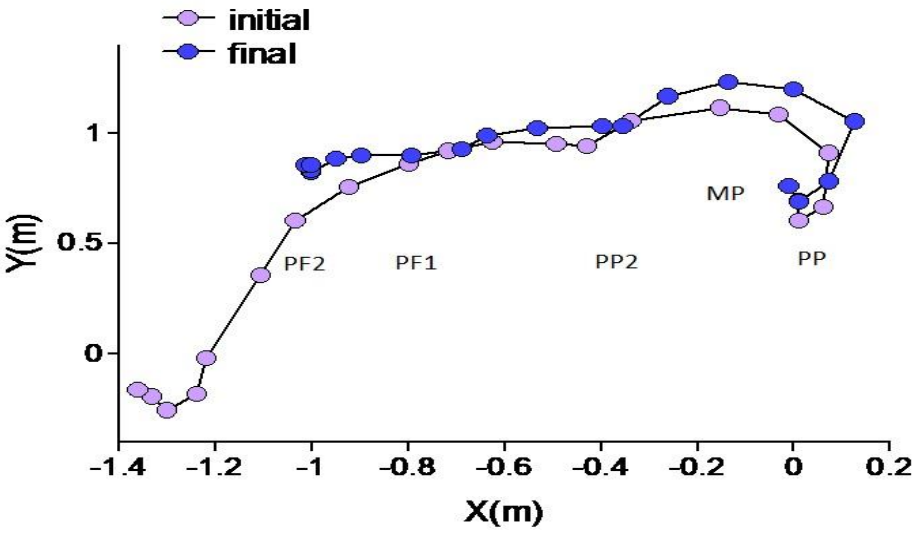


Figure 3.3. Trajectory of CGC - RÎP (FF) (TI and TF) (S1_L1)
Note: Trajectory of CGG - TI in PF2 features an execution outside the apparatus - fall

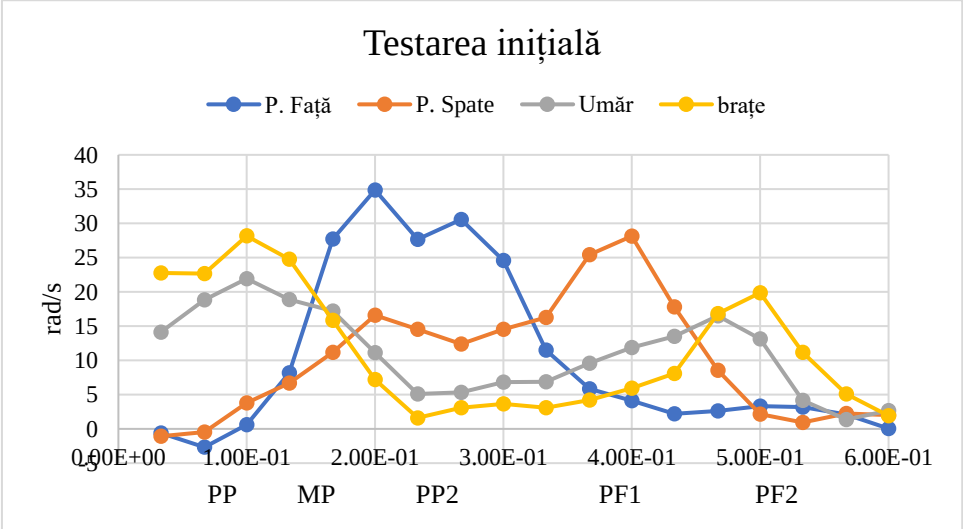


Figure 3.4. Graph on the angular speed of the body segments - RÎP (FF) (S1_L1 – TI)

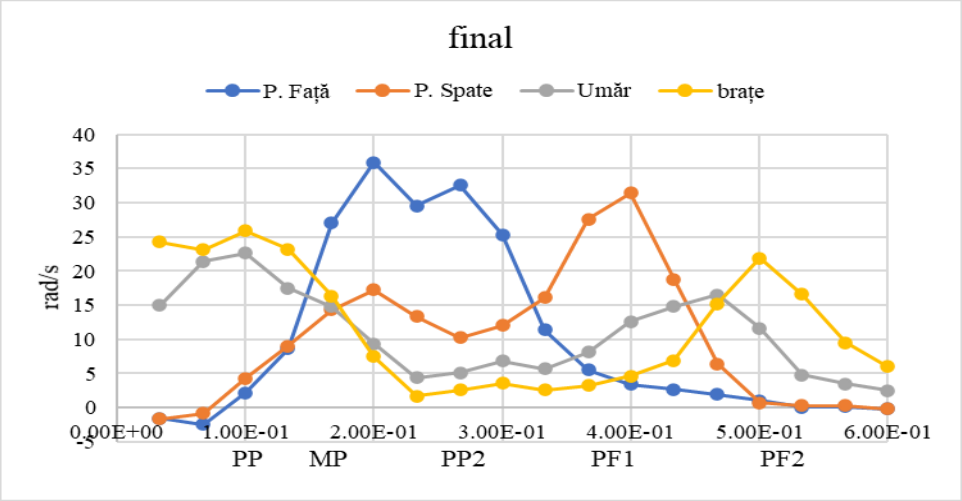


Figure 3.5. Graph on the angular speed of the body segments - RÎP (FF) (S1_L1 - TF)

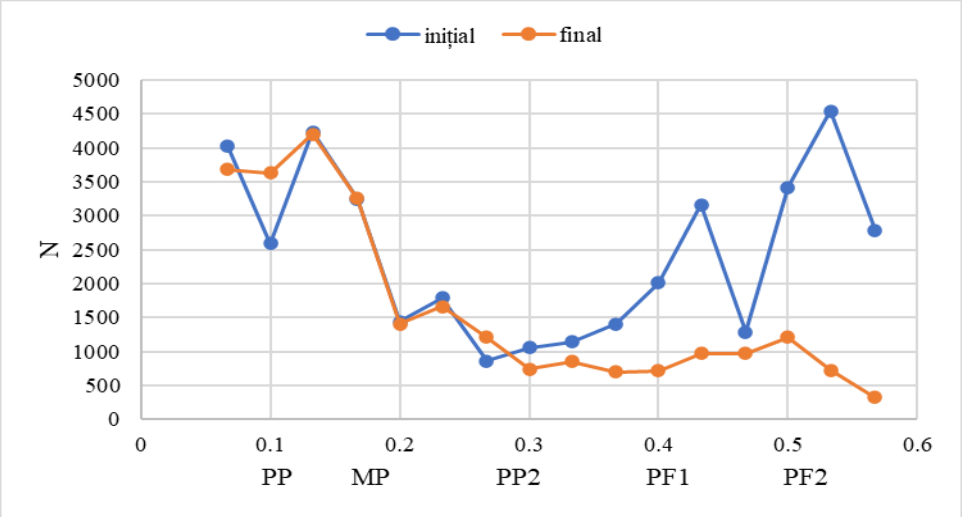


Figure 3.6. Graph of the strength resultant CGC - RÎP (FF) - TI and TF (S1_L1)

Preliminary research conclusions

Partial conclusions of the preliminary study

The improvement of the techniques and procedures involved within the training of juniors in AG relied on the intention of optimising technical training to obtain coveted sports performances as soon as possible.

Considering the aspects featured above, I believe that I attained the objectives proposed in the research, given the TI of junior gymnasts (aged 10 -12 years old) highlighted their level at the moment of testing, before implementing the strategies involved in the training routine. TF obtained after the implementation of the training routine facilitated the assessment of the dynamic of the technical elements included in tests, reason for which the analysis of the data obtained validated that individualised practice, based on specific programs and strategies, contributes decisively to improved technical execution of the elements considered.

Following the results obtained, several conclusions may be drawn:

- the kinematic and dynamic values of the key-elements of sports technique are identified and highlighted through the research
- through specific strategies and methods, the training process recorded an evolution of the gymnasts within the study
- through the implementation of a special training routine designed to optimise the execution of the balance beam technical elements, the parameters considered improved
- compared to the classic methods, the current training method is much more efficient in what concerns acquiring and developing physical abilities
- the analysis of the parameters contributed decisively to the identification of execution errors and the significant reduction of their number. The analysis of the four variables (trajectory, angles, angular speed, and strength resultant) has shown that the female gymnasts improved their flight phase, increasing the length of dismounting and elevating the position of the barycentre, thus reducing the speed of leg rotation
- the biomechanical analysis helped me identify the technical execution errors of the gymnasts (with the goal of correcting them).

It has been very useful that gymnasts maintained a positive attitude throughout the research.

Consequently, I am persuaded that the studies conducted represent a substantial scientific basis for the experimental research phase of the thesis, where my goal is to highlight the impact of training routines on the balance beam technical elements (RÎP (FF) and CSG) and increase the performances conducted by junior gymnasts.

General conclusions of the preliminary study

The scientific literature has mentioned several types of errors, with the goal of influencing the execution technique. The degree of execution accuracy depends on the motor and psychomotor skills practised in the execution of the technical elements, adapted to the age particularities. Hence, the research highlighted the existence of potential gaps, explaining at the same time in a well-argued manner the existence of stagnations, determining new training strategies meant to cope with and overcome the impasse.

Chapter 4 - Experimental study regarding the contribution of biomechanical analysis on the balance beam technical elements, the category of juniors - Handspring bwd (Flic - Flac) (RÎP (FF), Dismount by salto bwd tucked din Slow back walkover (RLÎ_CSG) and Slow back walkover - Handspring bwd (Flic - Flac) (RLÎ_RÎP (FF))

4.1 Research premises

The premises on which the experimental research relied are as follows:

- the results and conclusions of the preliminary research
- the need to use modern software programs and technological devices to optimise the training process
- the need to use the most efficient intervention methods in the optimisation of the technical elements in the "balance beam" event (RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF)
- the need for an organised methodical intervention concerning the training of female athletes to optimise balance beam technical elements (RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF).

4.2 Research purpose, objectives, tasks, and hypotheses

4.2.1 Research goal

The experimental research aims to improve the training process through the optimisation of technical and physical training in balance beam and to underline the modifications arising from the technical and physical perspective upon applying the special training routines proposed.

The experimental research observes the ethical norms because:

- the subjects, coaches and parents / tutors gave their informed consent by signing a statement, stating their voluntary participation in the research, to attain its purpose and objectives
- the subjects, coaches and parents were informed from the beginning regarding the primary objectives of the research involving them and the main practical conditions, as well as individualised working programs
- we ensured optimal conditions for the research

- the subjects involved in the research were not affected in any way, shape, or form (moral, physical, psychological damage)
- we did not reveal the identity of the subjects.

4.2.2 Research objectives

The *general objective of the study is* the optimisation of technical and physical training in balance beam, among subjects aged between 10 -12, practitioners of performance Artistic Gymnastics.

The specific objectives of the thesis are as follows:

1. stating the concrete research perspective
2. studying the indispensable parameters concerning the objective analysis of the research results
3. determining the biomechanical analysis of technical elements in the "balance beam" event (RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF)
4. designing and applying the training routine with the purpose of qualitative transformations in what concerns the execution of technical elements in the "balance beam" event
5. designing the programs of specific technical and physical training and applying them to the training process
6. exploiting the experimental research results and setting future research directions.

4.2.3 Research tasks

In the experimental research, I focused on performing the following tasks:

- elaborating the working hypotheses
- selecting the research and actuation means
- constituting the group of investigated subjects
- recording accurately the balance beam technical elements RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF)
- digitising in a just manner the elements proposed for investigation and processing the data using the software programs Kinovea and Physic ToolKit
- applying the technical training, physical training and psychological training trials to the group of investigated subjects as initial testing

- processing, interpreting the data recorded by the group of investigated subjects after TI
- designing and implementing the practical intervention program (training means, planning sessions per days/weeks/months; assessing the quality and efficiency of the programs applied by recording and processing the data, their analysis and interpretation)
- implementing and directing the training routine in the "balance beam" event
- applying the technical training, physical training and psychological training trials to the group of investigated subjects as TF
- processing, interpreting the data by the group of investigated subjects after final testing
- elaborating a training model specific to the balance beam event for junior gymnasts
- elaborating the general and applicative conclusions specific to experimental research.

4.2.4 Research hypotheses

I have started from the following hypotheses to attain my research goals:

General hypothesis 1:

Individualised practice determines an improved execution of technical elements (*RÎP (FF)*; *RLÎ_CSG and RLÎ_RÎP*) in the "balance beam" event among junior gymnasts.

Specific hypothesis 1.1:

Technical training, through an individualised training routine in the balance beam, will influence significantly certain biomechanical parameters specific to the characteristics of movements and certain spatial characteristics of the body segments within the execution biomechanics of the technical elements studied here.

Specific hypothesis 1.2:

The application of an individualised routine in the training of gymnasts will influence the psychomotor conducts specific to the elements in the balance beam analysed.

General hypothesis 2:

I predict that the physical training routine improves certain strength indicators of the main muscle groups.

General hypothesis 3

I assume that certain strength and mobility indicators can influence the execution technique of elements in balance beam among junior gymnasts.

General hypothesis 4:

The training routine, individualised (technical and physical), influences the psychological characteristics of gymnasts.

4.3 Research methods and techniques

4.3.1 Statistical methods used

In this research, I used the following statistical methods:

Descriptive statistics: Arithmetic mean (Ma); Standard deviation (S); Median (M); Interval of confidence (IC) and Variation coefficient (CV).

Statistical indicators used: the "T" STUDENT test; the Wilcoxon test; Spearman's correlation.

Statistical data processing: For the centralisation and graphical representation of data, considering the biomechanical analysis, I used Microsoft Office Excel. All the data were processed automatically by Physics ToolKit and downloaded and saved in Excel. The software program Kinovea helped me analyse the spatial characteristics of the body segments in the two planes of motion (anterior view (front) and posterior view (back), doubled by magnifying view (zoom 1.75).

To calculate the main statistical indicators and interpret the results of the search, I used the Software KyPlot.

For the statistical analysis of the data, I used the version SPSS 23.

4.4 Events, tests, and measurements applied in the research

The subjects comprised in the research were subjected to assessments aiming at the following:

4.4.1 Technical evaluation of the subjects:

Technical element 1: RÎP (FF); Technical element 2: RLÎ_CSG; Technical element 3: RLÎ_RÎP (FF).

4.4.2 Physical evaluation of the subjects:

The body composition (body mass, BMI, body fat, muscle mass, BMR and visceral fat); Abdominal muscle strength; Low back muscle strength; Palmar flexor strength; 5. Squat jump; Counter movement jump; Free jump; 60-second plyometric jumps;
Spine mobility; Hip mobility; Ankle mobility; Shoulder mobility; The Matorin test; The Flamingo test; Maintaining position on the balance plate; The Bass test; The "Y" test.

4.4.3 Psychological evaluation of the subjects:

In this respect, I used the questionnaires "Emotion Measurement Scale"; "Behavioural Scale", and The Toulouse Pieron test - to determine the attention span.

4.5 Research organisation and unfolding

4.5.1 Period, place, and material conditions for research unfolding

The research proposed to underline the way and manner in which specific individualised routines with new means, designed pursuant to the conclusions drawn using the biomechanical analysis software programs, optimise the execution technique of the elements in balance beam among junior gymnasts.

I determined the following phases:

- identifying and reviewing the information within the scientific literature, subsuming them, and determining the study directions
- designing the research plan and establishing its objectives and phases
- determining the assessment devices, the group of investigated subjects, and the practical conditions for the research per se
- carrying out the TI by applying the physical, technical, psychomotor trials, and the psychological tests to the group of subjects within the research
- performing the video analysis of the balance beam technical elements

- creating personalised physical and technical training intervention routines and enforcing them within the training process
- carrying out the final testing for the group of subjects comprised in the research
- centralising the results
- interpreting the results statistically
- formulating final conclusions, recommendations, and setting future research directions.

The practical phase of the research was carried out in the period October 2020 – to October 2021, at the Municipal Sports Club in Onești, Bacău, at the School Sports Club of Focșani - Vrancea, and the School Sports Club of Bârlad - Vaslui.

4.5.2 Research phases

I planned the tasks, given their essential role in determining the order of the experimental research phases:

- reviewing the scientific literature
- determining the group of investigated subjects
- TI of the group of investigated subjects comprised in the research (video analysis)
- formulating and applying personalised intervention programs
- TF of the group of investigated subjects comprised in the research
- statistical-mathematical data interpretation
- formulating conclusions, recommendations, and future research directions.

4.5.3 The group of investigated subjects

The group of investigated subjects involved in the research is female-only; it comprises 19 female gymnasts, aged between 10 and 12. It was determined on the basis of the following inclusion criteria:

- female gymnasts aged between 10 and 12
- female athletes practicing performance AG
- clinically healthy / medically fit, as per the medical file of each female gymnasts
- executing the technical elements studied here: *RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF)*

- written consent obtained from the parents / tutors, of coaches and club management to include the minors in the experimenat research study.

4.6 Research variables

Dependent variables:

- body composition
- anthropometrical and biomechanical parameters specific to the characteristics of movements of the technical elements
- spatial characteristics of the body segments in the execution of the technical elements (PP - the position before the dismount - the angle between the horizontal of the balance beam and the shoulder, the angle between the thigh and the torso, and the angle between the torso and the arms ; MP - the multiplication of the position (the maximum flight height CGG) - the angle between the thigh and the torso, the angle between the thigh and the calf, and the angle between the arms and the torso; PF - the final position (dismount)
- psychomotor qualities (general coordination, temporal and spatial orientation, static and dynamic balance)
- motor skills (strength, mobility)
- psychological factors (positive, negative emotions, behaviour, and attention).

Independent variables:

- operational models for optimising the technical element RÎP (FF)
- operational models for optimising the technical elements *RLÎ_CSG*
- operational models for optimising the technical elements RLÎ_RÎP (FF)
- routines for the development of abdominal muscle strength
- routines for the development of back muscles
- routines for the development of lower limb muscles
- routines for the development of mobility
- means to educate the coordination capacity and psychomotor aptitude.

4.7 Training routines

4.7.1 Objectives of training routines

The means used in the training routine of gymnasts to optimise technical and physical training in balance beam aimed at attaining the objectives proposed, namely:

- developing the motor and psychomotor aptitudes, coordinating capacities, and developing the joint mobility of the various segments involved in executing the balance beam technical elements
- developing the primary muscle groups
- developing suppleness
- correcting the executions errors of the technical elements targeted in the balance beam
- improved execution of the balance beam technical elements.

4.7.2 Content of training routines

The training routine proposed was elaborated in conformity with the age particularities of the female athletes within the research and adapted to their training level. I used teaching strategies to ensure the applicative character of learning and the acquisition of specific skills. To optimise the teaching activities, I used the materials within the sports clubs effectively. The content of the training routines proposed was elaborated in agreement with the aforementioned objectives, and it included specific means to AG, individualised for the group of investigated subjects. They involved the following: means to improve the execution technique in balance beam (the method of individualised training of each element analysed), operational means used in the physical training of gymnasts (the method of analytical training of muscle groups: arms, abdomen, back, and legs), and means for the development of mobility (method of mobility development at the level of the spine, hip, ankle, and shoulder). Throughout the research, the entire group of investigated subjects was properly monitored, and the training routines proposed were analysed regularly. To maintain the interest of the gymnasts, open educational resources were used and plays within the didactic planning activity.

4.7.3 Training process planning

The content of the programs and subprograms of training, specially designed and planned for the sample of subjects analysed here, includes Appendix 26 of the doctoral thesis, Tables 26.1. - 26.19.

4.8 Results and discussions

4.8.1 Results regarding the group of investigated subjects

The group of investigated subjects is homogeneous from the perspective of two characteristics (age and experience).

Table 4.1. Characteristics of the group of investigated subjects (*mean and standard deviation*)

Characteristic	Mean	Standard deviation
Age (years)	10,47	0,69
Experience (years)	4,57	0,83
Height (cm)_TI	139,86	10,14
Height (cm)_TF	140.52	10,03
Body mass (kg)_TI	32,13	6,76
Body mass_TF	32,36	6,57
Number of subjects	**19**	

Source: Personal processing in SPSS

4.8.2 Processing and interpretation of the measurements applied

4.8.2.1 Anthropometrical parameters

From the perspective of body composition, we recorded significant differences between the values of *three* characteristics out of the five (body mass, BMI, and basal metabolic rate). It is worth stating that, at the end of the training routine, the values obtained by the athletes are generally normal, which shows the efficiency of the training process.

Table 4.2. Results of applying the Student test on paired samples to highlight the differences between the characteristics within *The body composition* of gymnasts (the values at the beginning and the end of the training routine)

	Paired differences				t	df	Sig.
	Mean	Standard deviation	Confidence interval for the difference (95%)				
			Lower limit	Upper limit			
Pair 1 Body mass_TI - Body mass_TF	-0,2263	0,0733	-0,2617	-0,1910	-13,449	18	0,000
Pair 2 BMI_TI - BMI_TF	0,05053	0,09519	0,00465	0,9641	2,314	18	0,033

Pair 3 Body fat_TI - Body fat_TF	-1,8737	4,0992	-3,8494	0,1021	-1,992	18	0,062
Pair 4 Muscle mass_TI - Muscle mass_TF	-0,0053	1,5266	-0,7411	0,7305	-0,015	18	0,988
Pair 5 Basal metabolic rate_TI - Basal metabolic rate_TF	-47,474	36,048	-64,848	-30,099	-50740	18	0,000

Source: Personal processing in SPSS

4.8.3 Psychomotor tests

Testing the specific hypothesis 1.2:

The application of an individualised routine in the training of gymnasts will influence the psychomotor conducts specific to the elements in balance beam analysed.

In what concerns the results obtained in the *psychomotor tests*, progress was recorded between the two tests, the differences being significant for all the *13* pairs of indicators. It may be posited that, upon implementing the training routine, the results of the female athletes show better general coordination, temporal-spatial orientation, and evolution of the static and dynamic balance, showing the effectiveness of the training process. Through the results obtained, we test the specific hypothesis 1.2.

Table 4.3. Results of applying the Student test on paired samples to highlight the differences between the characteristics within *Psychomotor tests* of gymnasts (the values recorded initially and after the training routine)

	Paired differences						
	Mean	**Standard deviation**	**Confidence interval for the difference (95%)**		**t**	**df**	**Sig.**
			Lower limit	**Upper limit**			
The Matorin test (^{0})							
Pair 1 Dominant side_TI - Dominant side_TF	-76,053	20.587	-85,975	-66,130	-16,103	18	0,000
Pair 2 Nondominant side_TI - Nondominant side_TF	-56,579	17,955	-65,233	-47,925	-13,736	18	0,000
The Flamingo test (s)							
Pair 3 Right leg_TI - Right leg_TF	-12,66105	8,39669	-16,70813	-8,61398	-6,573	18	0,000
Pair 4 Left leg_TI - Left leg _TF	-13,53824	7,50793	-17,15713	-9,91917	-7,860	18	0,000
Maintaining position on the balance plate (s)							

Pair 5 With eyes open_TI - With eyes open_TF	-34,70053	9,84223	-39,44433	-29,95672	-15,368	18	0,000
Pair 6 With eyes closed_TI - With eyes closed_TF	17,45421	8,98980	-21,78716	-13,12126	-8,463	18	0,000
Pair 7 The Bass test (s)_TI - The Bass test (s)_TF	-5,211	3,441	-6,869	-3,552	-6,600	18	0,000
The "Y" test							
Right leg_TI							
Pair 8 A_TI - A_TF	-7,8474	1,0627	-8,3596	-7,3352	-32,188	18	0,000
Pair 9 PM_TI - PM_TF	-10,9895	4,2603	-13,0429	-8,9361	-11,244	18	0,000
Pair 10 PL_TI – PL_TF	-8,878	2,912	-10,2828	-7,4751	-13,287	18	0,000
Left leg_TF							
Pair 11 A_TI - A_TF	-5,8000	1,5815	-6,5623	-5,0377	-15,986	18	0,000
Pair 12 PM_TI - PM_TF	-8,3474	4,1812	-10,3627	-6,3321	-8,702	18	0,000
Pair 13 PL_TI - PL_TF	-7,0947	3,0637	-8,5714	-5,6181	-10,094	18	0,000

Source: Personal processing in SPSS

4.8.4 Physical trials

Testing the general hypothesis 2:

I predict that the physical training routine improves certain strength indicators of the main muscle groups.

Results *of the physical trials* include significant differences between the mean values of the *eight* indicators in the case of the two tests (TI and TF). The values obtained by the female athletes show increased indicators of the explosive power in the lower limbs and strength in the upper limbs, abdomen, and torso, and they can influence the efficiency of the training process. Through the results obtained, we test general hypothesis 2.

Table 4.4. Results of applying the Student test on paired samples to highlight the differences between the characteristics *of the physical trials* of gymnasts (the values at the beginning and at the end of the training routine)

	Paired differences				**t**	**df**	**Sig.**
	Mean	**Standard deviation**	**Confidence interval for the difference (95%)**				
			Lower limit	**Upper limit**			
Pair 1 Squat jump (cm)_TI - Squat jump (cm)_TF	-3,40211	1,21814	-3,98923	-2,81498	-12,174	18	0,000

Pair 2 Counter movement jump (cm)_TI - Counter movement jump (cm)_TF	-4,3211	0,9443	-4,7762	-3,8659	-19,945	18	0,000
Pair 3 Free jump (cm)_TI - Free jump (cm)_TF	-2,9421	0,9766	-3.4128	-2,4714	-13,132	18	0,000
Pair 4 60 sec free jump (cm)_TI - 60 sec free jump (cm)_TF	-1,736	0,6710	-2,0603	-1,4134	-11,283	18	0,000
Pair 5 Back muscle strength (rep)_TI - Back muscle strength (rep)_TF	-2,316	1,336	-2,959	-1,672	-7,558	18	0,000
Pair 6 Abdominal muscle strength (rep)_TI - Abdominal muscle strength (rep)_TF	-2,684	0,820	-3,079	-2,289	-14,267	18	0,000
Pair 7 Right palmar flexor_strength_TI - Right palmar flexor_strength_TF	-2,3105	0,8717	-2,7307	-1,8904	-11,554	18	0,000
Pair 8 Left palmar flexor_strength _TI - Left palmar flexor_strength _TF	-2,1579	1,0606	-2,6691	-1,6467	-8,869	18	0,000

Source: Personal processing in SPSS

4.8.5 Joint mobility

In the case of joint mobility, significant differences were found between their mean values at the two tests in the case of the 15 pairs of indicators, while following the training proposed here, gymnasts displayed improved indicators of joint mobility at the level of the spine, hip, ankle, and shoulder, and they can determine the efficiency of the training process.

Table 4.5. Results of applying the Student test on paired samples to highlight the differences between the characteristics of *Joint mobility* of gymnasts (the values at the beginning and at the end of the training routine)

	Paired differences				**t**	**df**	**Sig.**
	Mean	**Standard deviation**	**Confidence interval for the difference (95%)**				
			Lower limit	**Upper limit**			
Spine mobility (^{0})							

Pair 1 Flexion (gym bench (cm)_TI - Flexion (gym bench (cm)_TF	-3,105	0,994	-3,584	-2,626	-13,615	18	0,000
Pair 2 Flexion (flexiometer (º)_TI - Flexion (flexiometer (º)_TF	-4,5211	1,3394	0,3073	-3,8755	-14,713	18	0,000
Pair 3 Extension (º)_TI - Extension (º)_TF	-5,947	3,488	-7,628	-4,266	-7,433	18	0,000
Right hip mobility (^{0})							
Pair 4 Flexion (^{0})_TI - Flexion (^{0})_TF	-9,895	4,421	-12,026	-7,764	-9,756	18	0,000
Pair 5 Extension (^{0})_TI - Extension (^{0})_TF	-6,263	1,284	-6,882	-5,644	-21,259	18	0,000
Left hip mobility (^{0})							
Pair 6 Flexion (^{0})_TI - Flexion (^{0})_TF	-11,105	6,208	-14,098	-8,113	-7,797	18	0,000
Pair 7 Extension (^{0})_TI - Extension (^{0})_TF	-5,579	2,293	-6,684	-4,474	-10,606	18	0,000
Right ankle mobility (^{0})							
Pair 8 Dorsal flexion (^{0})_TI - Dorsal flexion (^{0})_TF	-11,737	39,071	-30.568	7,095	-1,309	18	0,207
Pair 9 Plantar flexion (^{0})_TI - Plantar flexion (^{0})_TF	-4,579	2,116	-5,599	-3,559	-9,430	18	0,000
Left ankle mobility (^{0})							
Pair 10 Dorsal flexion (^{0})_TI - Dorsal flexion (^{0})_TF	-3,211	1,584	-3,974	-2,447	-8,835	18	0,000
Pair 11 Plantar flexion (^{0})_TI - Plantar flexion (^{0})_TF	-3,789	1,932	-4,720	-2,858	-8,552	18	0,000
Right shoulder mobility (^{0})							
Pair 12 Flexion (^{0})_TI - Flexion (^{0})_TF	-16,474	6,577	-19,644	-13,303	-10,917	18	0,000
Pair 13 Extension (^{0})_TI - Extension (^{0})_TF	-7,211	2,149	-8,246	-6,175	-14,623	18	0,000
Left shoulder mobility (^{0})							
Pair 14 Flexion (^{0})_TI - Flexion (^{0})_TF	-14,684	5,618	-17,392	-11,976	-11,393	18	0,000
Pair 15 Extension (^{0})_TI - Extension (^{0})_TF	-5,789	1,843	-6,678	-4,901	-13,691	18	0,000

Source: Personal processing in SPSS

4.8.6 Psychological testing

Testing the general hypothesis 4:

The training routine, individualised (technical and physical), influences the psychological characteristics ale of gymnasts.

The results *of the psychological testing* features improvements in the means for all the coefficients tested. The values of the Wilcoxon test in the case of the mean score of positive emotions improves and decreases in the case of negative emotions between the two tests, the level of the mean score in the case of the Behavioural scale increases, while the mean score concerning the 460 signs increases in the case of signs correctly barred and decreases in the case of signs omitted or additional bars. The aspects mentioned above show that the training routine had a positive effect on positive emotions, behaviour, and attention span, and they can determine the efficiency of the training process. Through the results obtained, we test the general hypothesis 4.

Table 4.6. Positive ranks and negative ranks used in the Wilcoxon test for "*The measurement scale of positive emotions"*

	N	Mean Rank	Sum of Ranks
Positive emotions_TF - Negative Ranks	0[a]	.00	.00
Positive emotions_TI - Positive Ranks	18[b]	9.50	171.00
Ties	1[c]		
Total	19		

Source: Personal processing in SPSS

a. positive emotions TF < positive emotions TI
b. positive emotions TF > positive emotions TI
c. positive emotions TF = positive emotions TI

Table 4.1. The Wilcoxon test – *"The measurement scale of positive emotions"*

	Positive emotions_TF Positive emotions_TI
Z	-3,728[b]
Asymp. Sig. (2 - tailed)	.000

Source: Personal processing in SPSS

a. Wilcoxon Signed Ranks Test

b. Based on negative ranks.

Table 4.8. Positive ranks and negative ranks used in the Wilcoxon test for **"***The measurement scale of negative emotions"*

	N	Mean Rank	Sum of Ranks
Negative emotions TF - Negative Ranks	17[a]	9.00	153.00
Negative emotions TI - Positive Ranks	0[b]	.00	.00
Ties	2[c]		
Total	19		

Source: Personal processing in SPSS

a. negative emotions TF < negative emotions TI
b. negative emotions TF > negative emotions TI
c. negative emotions TF = negative emotions TI

Table 4.2. The Wilcoxon test – *"The measurement scale of negative emotions"*

	Negative emotions_TF Negative emotions_TI
Z	-3,623[b]
Asymp. Sig. (2 - tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

4.8.7 Results of biomechanical analysis of the technical elements analysed (RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF))

Testing the general hypothesis 1:

Individualised practice determines an improved execution of the technical elements - *RÎP (FF)*; *RLÎ_CSG and RLÎ_RÎP* in balance beam among gymnasts.

Testing the specific hypothesis 1.1:

Technical training, through the individualised training routine in balance beam, will influence significantly certain biomechanical parameters specific to the characteristics of movements and certain spatial characteristics of the body segments within the biomechanics of the execution of the technical elements studied.

Testing the general hypothesis 2:

I predict that the physical training routine improves certain strength indicators of the main muscle groups.

4.8.7.1 Results of the technical element RÎP (FF)

In the case of the element RÎP(FF), significant differences were found between the mean values in four characteristics (Weight; Height; Rotation inertia, Segmental movement radius - hand). Upon covering the training routine, the results of the female athletes tend to record a normal weight, an optimal technical execution at the level of the lower limbs, and an improvement of the rotation inertia, due to the training focusing on it, relying on the conclusions in the in the TI.

In the case of the results obtained in what concerns spatial characteristics of the body segments, significant differences were found of a pairs of indicators (PF2 - b, the angle between the horizontal of the balance beam and the shoulder and the angle between

the thigh and the torso). It may be posited that thanks to having covered the training routine focusing on these parameters, the results obtained confirm the improvement in the technical execution of this element. Through the results obtained, we test the general hypothesis 1, specific hypothesis 1.1. and general hypothesis 2.

Table 4.10. Results of applying the Student test on paired samples to highlight the differences between the characteristics within the descriptive statistics indicators for *Anthropometrical and biomechanical parameters specific to the movement characteristics* of the technical element RÎP (FF) of gymnasts (the values at the beginning and at the end of the training routine) - Physics ToolKit

	Paired differences				**t**	**df**	**Sig.**
	Mean	**Standard deviation**	**Confidence interval for the difference (95%)**				
			Lower limit	**Upper limit**			
Pair 1 Weight (kg)_TI - Weight (kg)_TF	-0,2263	0,0733	-0,2617	-0,1910	-13,449	18	0,000
Pair 2 Height (cm)_TI - Weight (kg)_TF	-0,737	0,452	-0,955	-0.519	-7,099	18	0,000
Pair 3 Rotation inertia (½(kg·m^2)_TI - Rotation inertia (½(kg·m^2)_TF	-0,140842	0,061717	-0,170589	-0,111095	-9,947	18	0,000
Segmental movement radius (m)							
Pair 4 ***Front_leg_TI - Front_leg_TF***	-0,005789	0,020887	-0,015857	0,004278	-1,208	18	0,243
Pair 5 ***Rear_leg_TI - Rear_leg_TF***	-0,002895	0,038295	-0,021353	0,155563	-0,329	18	0,746
Pair 6 Shoulder_TI - Shoulder_Tf	-0,006684	0,015945	-0,014369	0,001001	-1,827	18	0,084
Pair 7 Hand_TI - Hand_Tf	-0,055158	0,077395	-0,092461	-0,017855	-3,107	18	0,006

Source: Personal processing in SPSS

Table 4.11. Results of applying the Student test on paired samples to highlight the differences between the characteristics within the descriptive statistics indicators for *Spatial characteristics specific to the movement characteristics of the technical element* RÎP (FF) of gymnasts (the values at the beginning and at the end of the training routine) – Kinovea

	Paired differences				t	df	Sig.
	Mean	Standard deviation	Confidence interval for the difference (95%)				
			Lower limit	Upper limit			
PP (grade)							
Pair 1 a_TI - a_TF	-2,053	6,459	-5,166	1,061	-1,385	18	0,183
Pair 2 b_TI - b_TF	-1,316	6,541	-4,468	1,837	-8,77	18	0,392
MP, ÎMZ (grade)							
Pair 3 a_TI - a_TF	2,105	8,504	-1,994	6,204	1,079	18	0,295
Pair 4 b_TI - b_TF	0,474	6,826	-2,816	3,764	0,302	18	0,766
Pair 5 c_TI - c_TF	0,368	6,344	-2,689	3,426	0,253	18	0,803
PP2							
Pair 6 a_TI - a_TF	2,737	13,349	-3,697	9,171	0,894	18	0,383
PF1(grade)							
Pair7 a_TI - a_TF	-0,737	5,455	-3,366	1,893	-0.589	18	0.563
Pair 8 b_TI - b_TF	0,105	9,339	-4,396	4,606	0,049	18	0,961
Pair 9 c_TI - c_TF	0,684	6,700	-2,545	3,914	0,445	18	0,662
PF2 (grade)							
Pair 10 a_TI - a_TF	-5,944	12,581	-12,201	0,312	-2,005	17	0,061
Pair 11 b_TI - b_TF	-5,889	9,461	-10.594	-1,184	-2,641	17	0,017
Pair 12 c_TI - c_TF	-4,889	25,699	-17,669	7,891	-0,807	17	0,431

Source: Personal processing in SPSS

Figure 4.1. RÎP_RLÎ (FF)) (S1_L3) (Kinovea (Sagittal plane - side view)

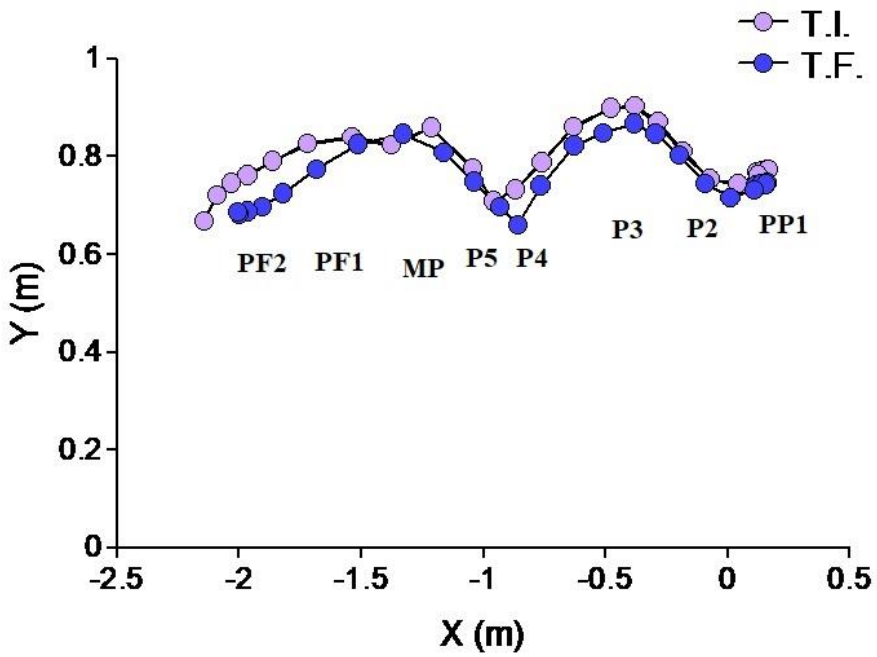


Figure 4.2. Trajectory of CGC - RÎP_RLÎ (FF) - (TI and TF)

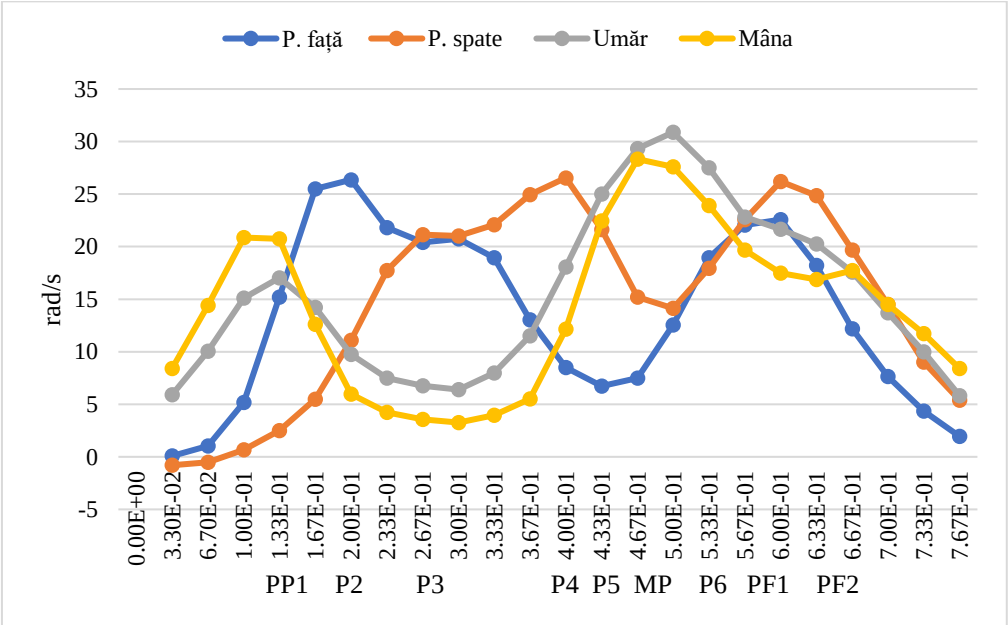


Figure 4.3. Graph on the angular speed of the body segments - RÎP_RLÎ (FF) - TI

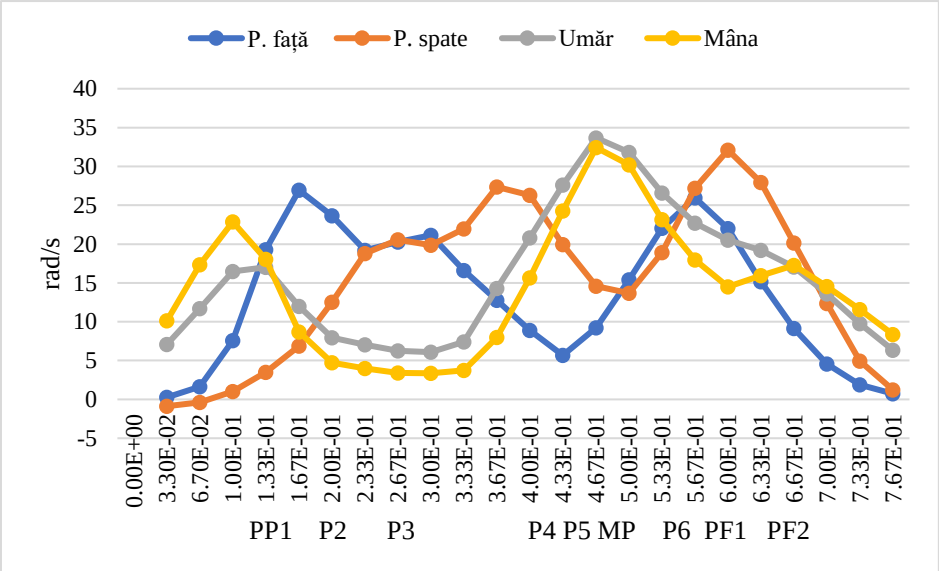


Figure 4.4. Graph on the angular speed of the body segments - RÎP_RLÎ (FF) - TF

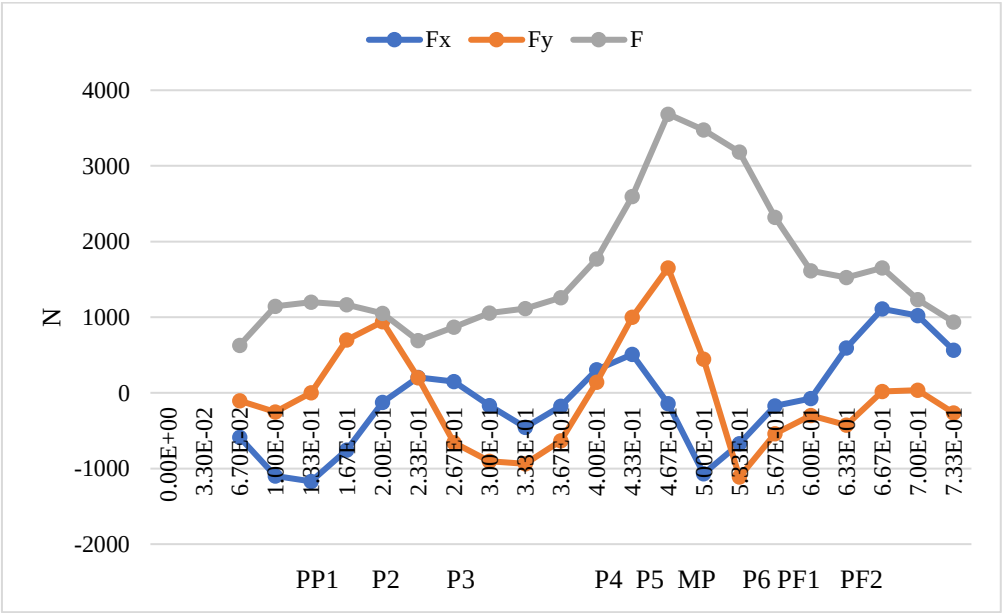


Figure 4.5. Graph of the strength resultant CGC - RÎP_RLÎ (FF) – TI

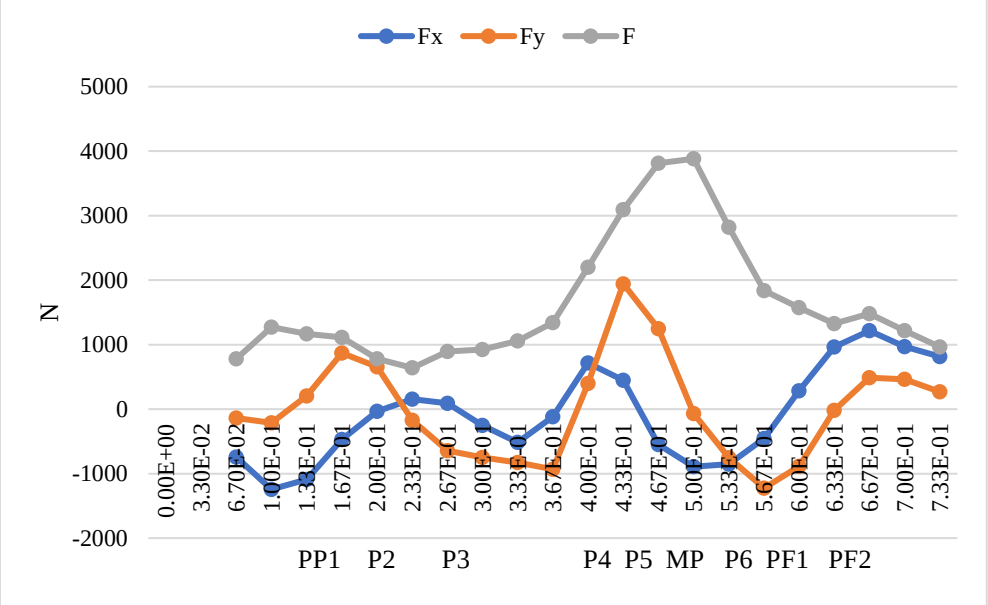


Figure 4.6. Graph of the strength resultant CGC - RÎP_RLÎ (FF) - TF

4.8.7.2 Results of the technical element RLÎ_CSG

In what concerns of the technical element *RLÎ_CSG* significant differences were found between the mean values in *three* characteristics (Weight (kg); Rotation inertia, Segmental movement radius - rear leg). After covering the training routine, the results of the female athletes tend to show a normal weight, an optimal technical execution at the level of the lower limbs and an improvement in the rotation inertia, based on the training focused on this aspect, relying on the conclusions in the TI.

Concerning the results obtained in the spatial characteristics of the body segments, significant differences were found between the mean values in three characteristics MPZ/ÎMZ b and PF a – b (namely, the angle between the thigh and the torso, and the angle between the thigh and the calf). It may be stated that by covering the training routine, focusing on these parameters, the female athletes tended to improve the execution technique of this element. Through the results obtained, we test the general hypothesis 1, specific hypothesis 1.1. and general hypothesis 2.

Table 4.12. The indicators of descriptive statistics for the *Anthropometrical and biomechanical parameters specific to the movement characteristics* of the technical element *RLÎ_CSG* - Physics ToolKit

Characteristic	Mean	Median	Standard deviation	Variation coefficient (%)	Lower limit of the confidence interval	Upper limit of the confidence interval
Weight (kg)_TI	32,13	32,9	6,76	21,05	28,87	35,39
Weight (kg)_TF	32,36	33,1	6,75	20,88	29,10	35,61
Height (cm)_TI	139,78	141	10,21	7,31	134,86	144,71
Height (cm)_TF	140.52	142	10,03	7,14	135,68	145,36
Rotation inertia (½(kg·m^2)_TI	8,262	8,38	2,85	34,52	6,88	9,63
Rotation inertia (½(kg·m^2)_TF	1595,67	8,55	6918,13	433,56	-1738,76	4930,10
Segmental movement radius (m)						
Front_leg_TI	0,605	0,628	0,098	16,28	0.557	0,652
Front_leg_TF	0,625	0,635	0,082	13,18	0.585	0,664
Rear_leg_TI	0.587	0,616	0,091	15,63	0.542	0,631
Rear_leg_TF	0,608	0,625	0,0751	12,36	0.571	0,644
Shoulder_TI	0,378	0,387	0,050	13,39	0,354	0,432
Shoulder_TF	0,380	0,379	0.535	14,07	0.547	0,4063
Hand_TI	0.561	0.582	0,129	23,05	0,499	0,624
Hand_TF	0.551	0.523	0,140	25,45	0,483	0,618

Source: Personal processing in SPSS

Table 4.3. Results of applying the Student test on paired samples to highlight the differences between the characteristics *within the descriptive statistics indicators for Spatial characteristics specific to the movement characteristics* of the technical element *RLÎ_CSG* of gymnasts (the values at the beginning and at the end of the training routine)

	Paired differences				t	df	Sig.
	Mean	Standard deviation	Confidence interval for the difference (95%)				
			Lower limit	Upper limit			
PP (grade)							
Pair 1 a_TI - a_TF	0,211	3,537	-1,494	1,915	0,259	18	0,798
Pair 2 b_TI - b_TF	-1,789	13,066	-8,087	4,508	-0.597	18	0.558
Pair 3 c_TI - c_TF	2,579	6,686	-0,644	5,801	1,681	18	0,110
MP, ÎMZ (grade)							
Pair 4 a_TI - a_TF	8,579	21,536	-1,801	18,959	1,736	18	0,100
Pair 5 b_TI - b_TF	7,947	13,990	1,204	14,690	2,476	18	0,023
Pair 6 c_TI - c_TF	6,789	38,908	-11,964	25,543	0,761	18	0,457
PF (grade)							
Pair 7 a_TI - a_TF	-16,737	18,080	-25,451	-8,023	-4,035	18	0,001
Pair 8 b_TI - b_TF	-13,895	17,842	-22,494	-5,295	-3,395	18	0,003
c_TI - a_TF	10.579	34,629	-6,112	27,269	1,332	18	0,200

Source: Personal processing in SPSS

Figure 4.7. *RLÎ_CSG* (S1_L2) (Kinovea (Sagittal plane - side view)

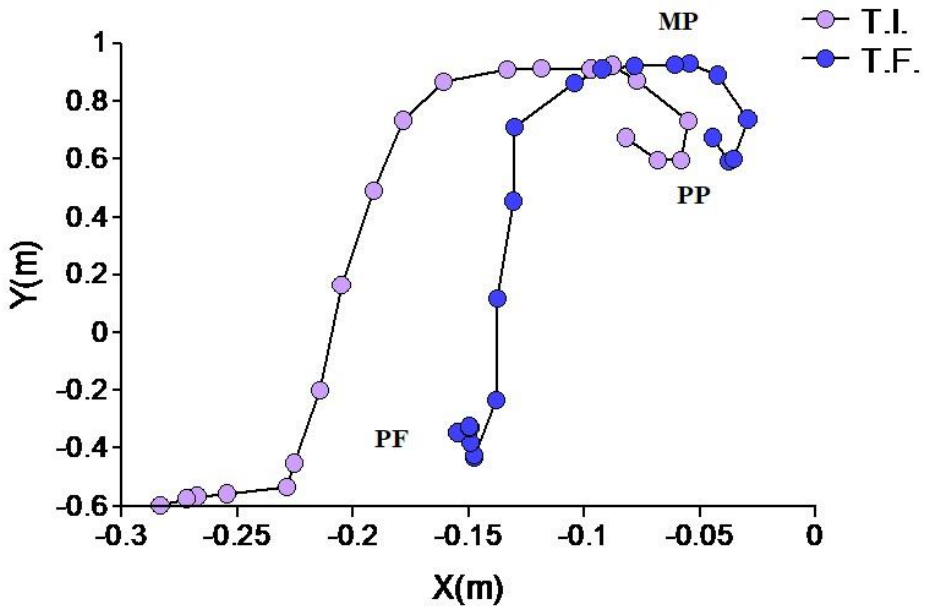


Figure 4.8. Trajectory of CGC *RLÎ_CSG* - (TI and TF)

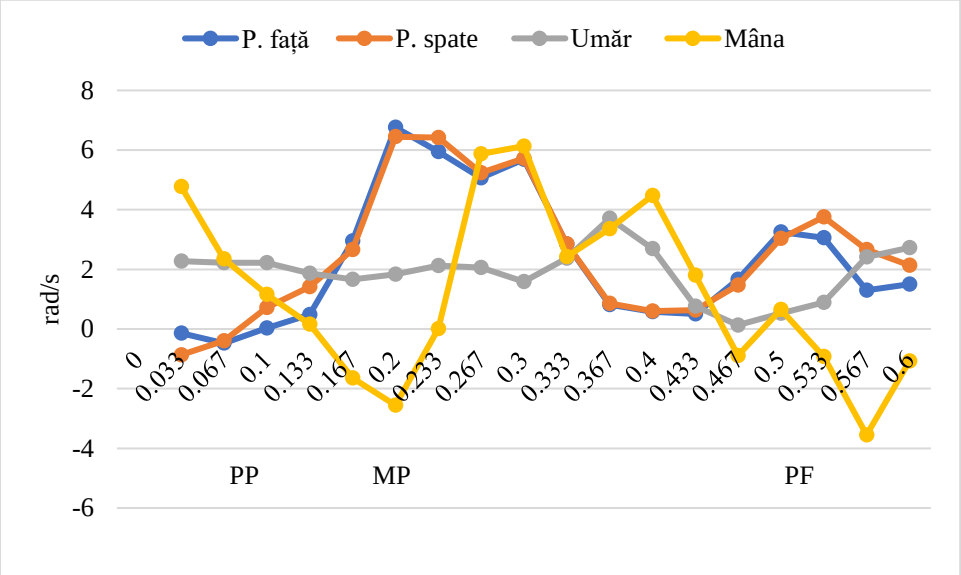


Figure 4.9. Graph on the angular speed of the body segments *RLÎ_CSG* - TI

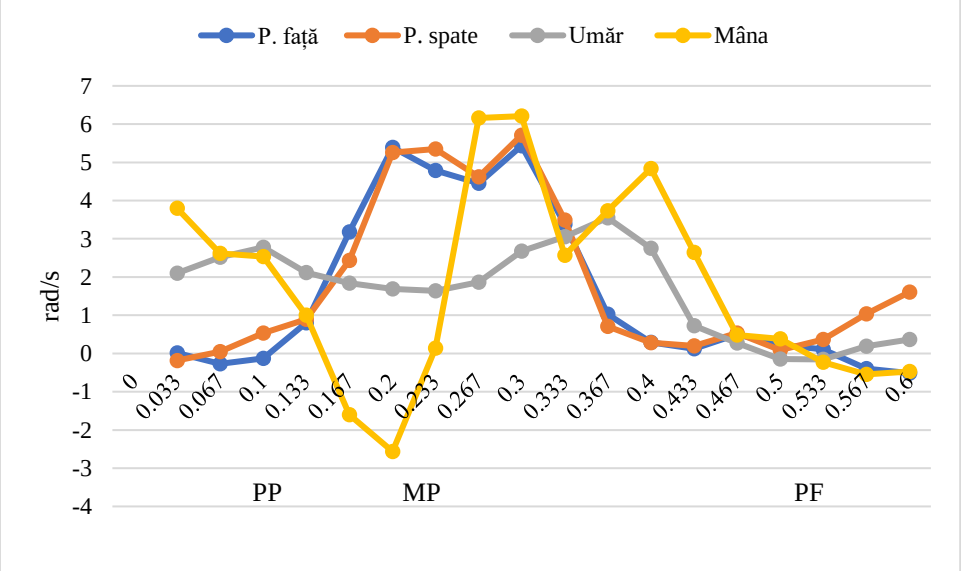


Figure 4.10. Graph on the angular speed of the body segments *RLÎ_CSG* - TF

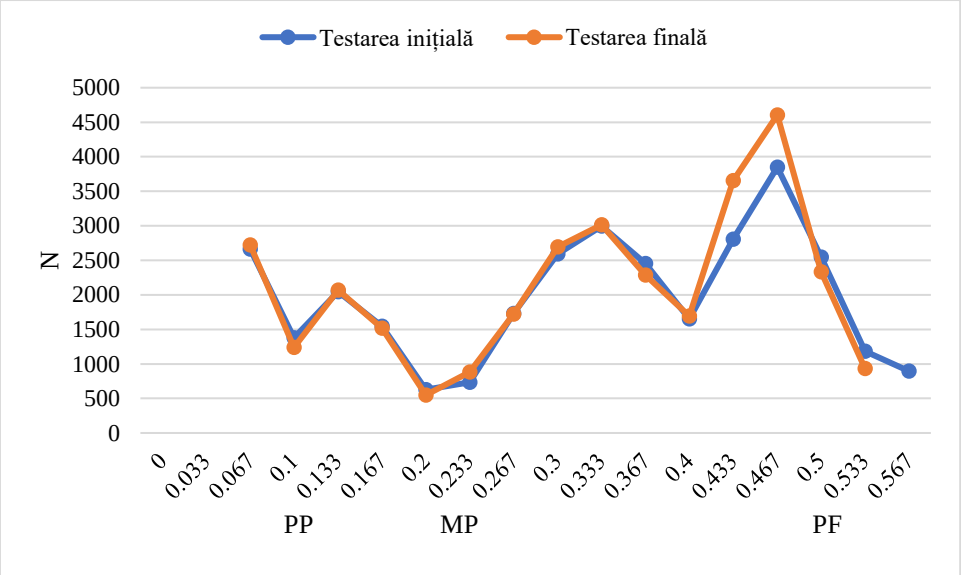


Figure 4.11. Graph of the strength resultant CGC - *RLÎ_CSG* - (TI and TF)

4.8.7.3 Results of biomechanical analysis of the technical elements - RLÎ_RÎP (FF)

Concerning the technical element RLÎ_RÎP (FF), significant differences were found between the mean values in two characteristics (Weight (kg) and Height (cm). After covering the training routine, the results of the female athletes tend to show a normal weight, which represents a relevant criterion in obtaining great performance. The low percentage of body fat plays an essential role in the success within AG. In what concerns results obtained in the spatial characteristics of the body segments, significant differences were found in two characteristics (PF2 a and b, *namely, the angle between the thigh and the torso, and the angle between the thigh and the calf).* It may be posited that, after covering the training routine, centred on these parameters, the female athletes tended to improve the execution technique of these elements. Through the results obtained, we test the general hypothesis 1, specific hypothesis 1.1. and general hypothesis 2.

Table 4.14. Results of applying the Student test on paired samples to highlight the differences between the characteristics within the descriptive statistics indicators for *Anthropometrical and biomechanical parameters specific to the movement characteristics* of the technical elements RLÎ_RÎP (FF) of gymnasts (the values at the beginning and at the end of the training routine) - Physics ToolKit

	Paired differences				t	df	Sig.
	Mean	Standard deviation	Confidence interval for the difference (95%)				
			Lower limit	Upper limit			
Pair 1 Weight (kg)_TI - Weight (kg)_TF	-0,2294	0,0166	-2647	-1941	-13,789	16	0,000
Pair 2 Height (cm)_TI - Height (cm)_TF	-0,00706	0,00114	-00947	-00464	-6197	16	0,000
Pair 3 Rotation inertia (½(kg·m^2)_TI - Rotation inertia (½(kg·m^2)_TF	-0,312118	0,176054	0,685336	0,061101	-1,773	16	0,095
Segmental movement radius (m)							
Pair 4 ***Front_leg_TI - Front_leg_TF***	0,024529	0,017054	-011624	0,060683	1,438	16	0,170
Pair 5 ***Rear_leg_TI - Rear_leg_TF***	0,027941	0,018266	-010780	0,066663	1,530	16	0,146
Pair 6 Shoulder_TI - Shoulder_Tf	0,004941	0,008105	-012241	0,022123	0,610	16	0.551
Pair 7 Hand_TI - Hand_Tf	0,006176	0,022613	-041762	0,054115	0,273	16	0,788

Source: Personal processing in SPSS

Table 4.15. Results of applying the Student test on paired samples to highlight the differences between the characteristics *within the descriptive statistics indicators for Spatial characteristics specific to the movement characteristics* of the technical elements RLÎ_RÎP (FF) of gymnasts (the values at the beginning and at the end of the training routine) - Kinovea

	Paired differences				t	df	Sig.
	Mean	Standard deviation	Confidence interval for the difference (95%)				
			Lower limit	Upper limit			
PP1 (grade)							
Pair 1 a_TI - a_TF	0.529	0,728	-1,014	2,073	0,727	16	0,478
Pair 2 b_TI - b_TF	4,647	2,737	-1,156	10,450	1,698	16	0,109
Pair 3 c_TI - b_TF	0,235	1,365	-3,130	2,659	-0,172	16	0,865
P2 (grade)							
Pair 4 a_TI - a_TF	-2,353	1,859	-6,294	1,588	-1,266	16	0,224
Pair 5 b_TI - b_TF	-0,353	0,804	-2,058	1,352	-0,439	16	0,667

Pair 6 c_TI - c_TF	0,235	0,877	-1,623	2,094	0,268	16	0,792
P3 (grade)							
Pair 7 a_TI - a_TF	0,294	1,025	-1,878	2,466	0,287	16	0,778
PF-P4 (grade)							
Pair 8 a_TI - a_TF	-8,647	8,322	-26,288	8,994	-1,039	16	0,314
Pair 9 b_TI - b_TF	-0,471	1,312	-2,311	3,252	0,359	16	0,725
Pair 10 c_TI - c_TF	-2,235	2,146	-6,778	2,308	-1,043	16	0,312
P5 (grade)							
Pair 11 a_TI - a_TF	6,882	4,099	-1,807	15,572	1,679	16	0,113
Pair 12 b_TI - b_TF	1,471	2,024	-2,820	5,761	0,727	16	0,478
MP (grade)							
Pair 13 a_TI - a_TF	-0,882	1,768	-4,629	2,865	-0,499	16	0,624
Pair 14 b_TI - b_TF	-0.588	1,170	-3,068	1,891	-0.503	16	0,622
Pair 15 c_TI - a_TF	0,118	1,385	-2,818	3,054	0,085	16	0,933
P6 (grade)							
Pair 16 a_TI - a_TF	-1,412	2,554	-6,826	4,002	-0.553	16	0.588
PF1 (grade)							
Pair 17 a_TI - a_TF	1,941	2,441	-7,116	3,234	-0,795	16	0,438
Pair 18 b_TI - a_TF	0,176	1,058	-2,066	2,419	0,167	16	0,870
Pair 19 c_TI - a_TF	1,706	3,201	-5,081	8,492	0.533	16	0,601
PF2 (grade)							
Pair 20 a_TI - a_TF	-4,692	1,696	-8,388	-,0997	-2,767	12	0,017
Pair 21 b_TI - a_TF	-7,846	3,343	-15,131	-0.562	-2,347	12	0,037
Pair 22 c_TI - a_TF	-12,462	5,967	-25,463	540	2,088	12	0,059

Source: Personal processing in SPSS

Figure 4.22. RÎP_RLÎ (FF)) (S1_L3) (Kinovea (Sagittal plane - side view)

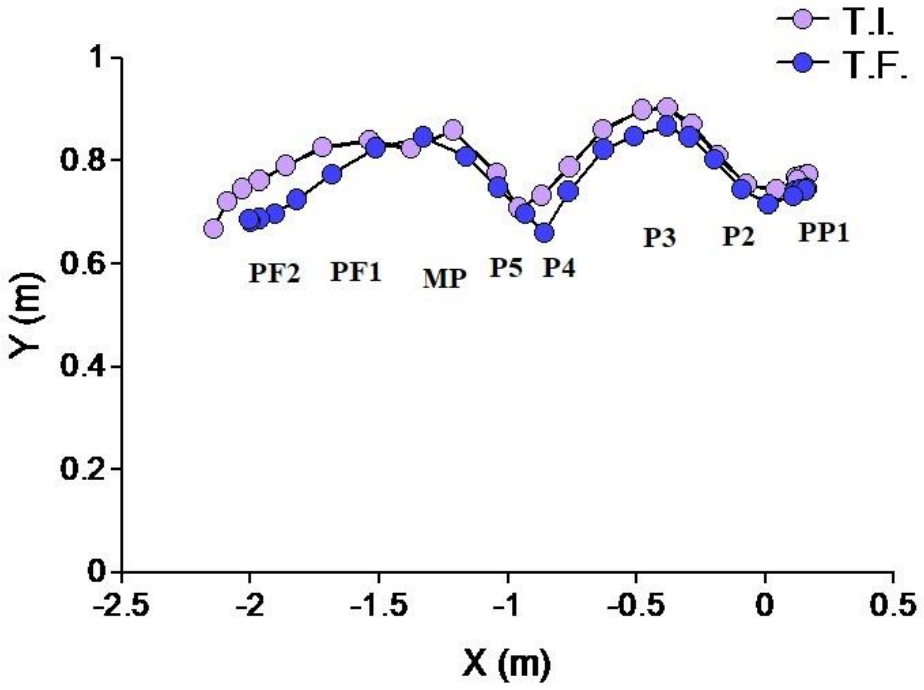


Figure 4.13. Trajectory of CGC - RÎP_RLÎ (FF) - (TI and TF)

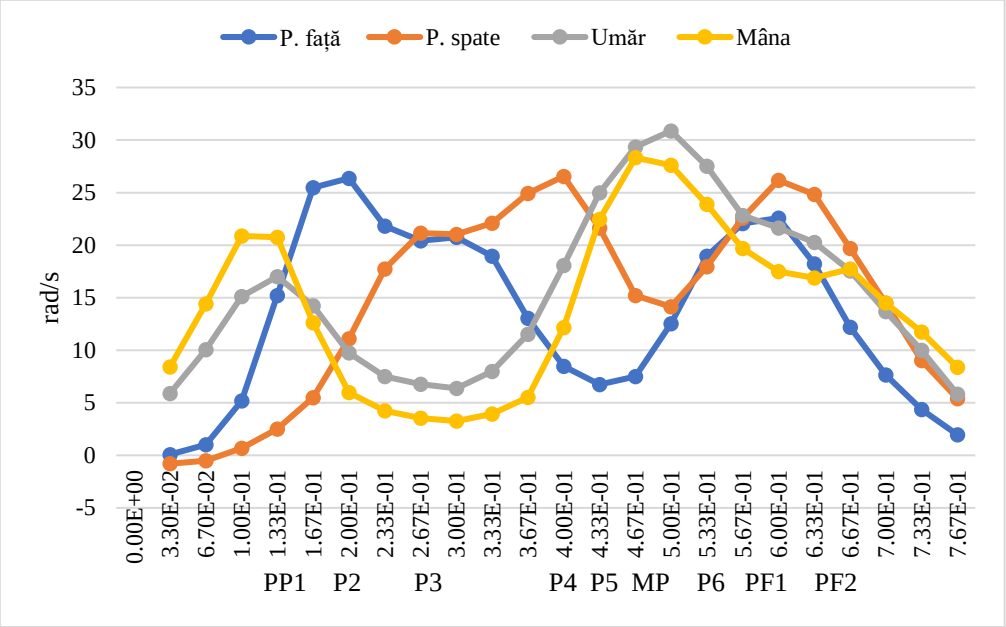


Figure 4.14. Graph on the angular speed of the body segments - RÎP_RLÎ (FF) - TI

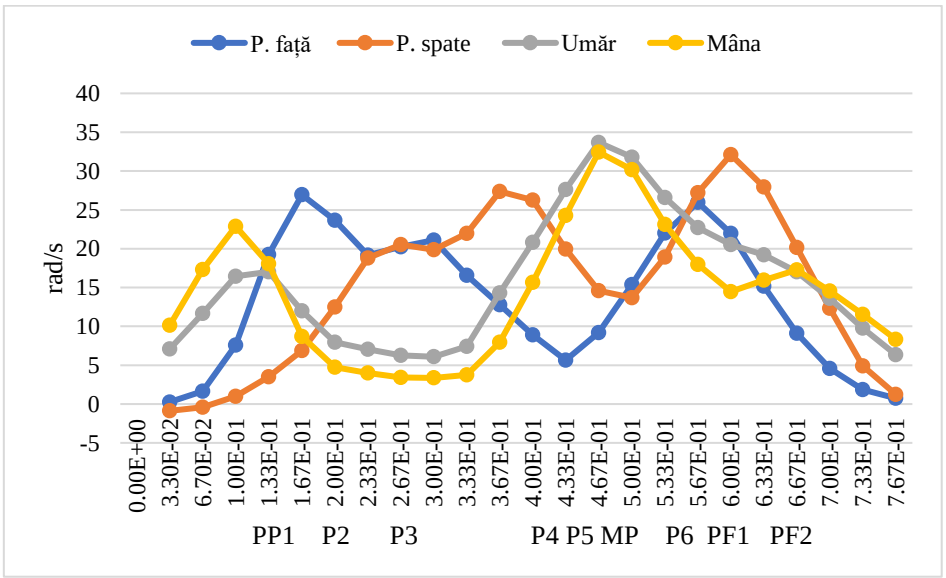


Figure 4.15. Graph on the angular speed of the body segments - RÎP_RLÎ (FF) - TF

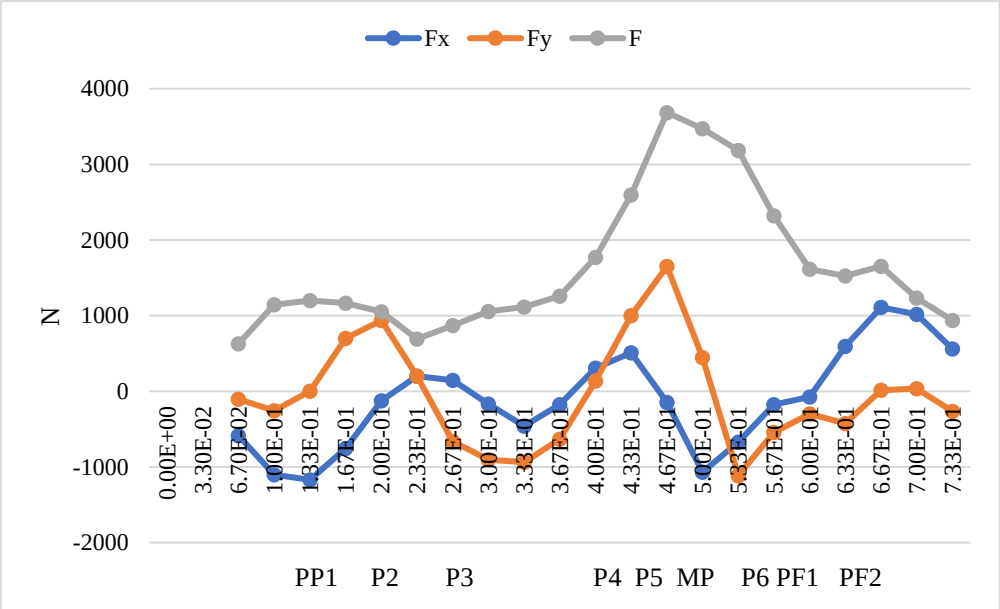


Figure 4.16. Graph of the strength resultant CGC - RÎP_RLÎ (FF) - TI

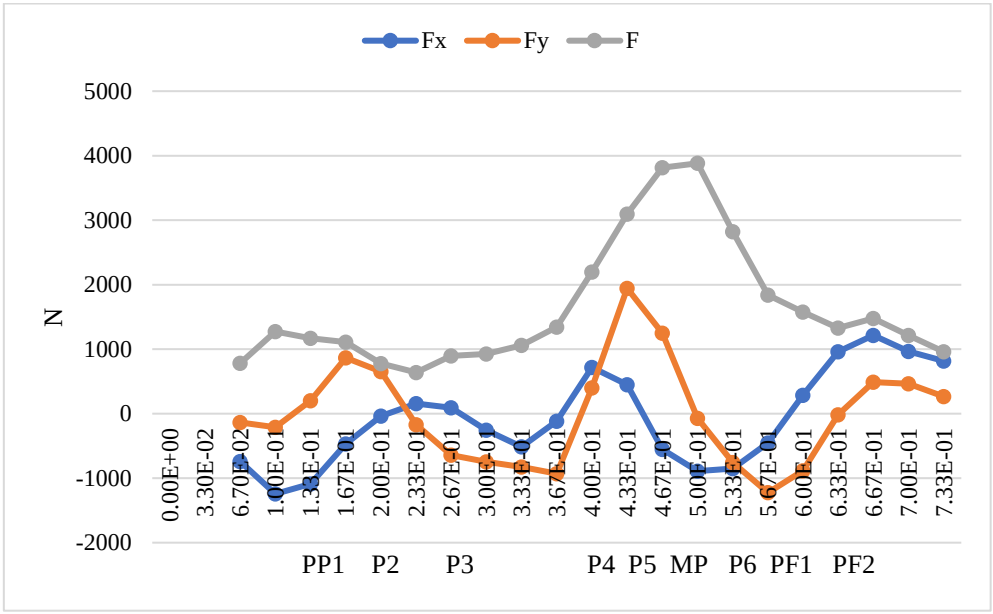


Figure 4.17. Graph of the strength resultant CGC - RÎP_RLÎ (FF) - TF

4.8.8 Influence of technical and physical training on the technical elements analysed - a correlative analysis

Testing the general hypothesis 3:

I assume that certain strength and mobility indicators can influence the execution technique of elements in balance beam among junior gymnasts.

Following *the correlative analysis* of the results obtained in the *physical trials* and the tests applied and the results of the female athletes obtained for the *three* technical elements analysed, correlations were found between the technical elements analysed (RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF), with the strength of the lower limbs and mobility. Starting from the correlations obtained, it is worth highlighting the relevance of physical training and mobility in the training of performance gymnasts. From the perspective of the correlation between the technical elements analysed (RÎP (FF), RLÎ_CSG and RLÎ_RÎP (FF)) and of the physical trials (SJ, CMJ And FJ), it may be stated that they require an adequate development of the strength of leg muscles. Furthermore, data analysis shows that, for the adequate execution of the technical elements, gymnasts also need good joint mobility at the level of the ankles, shoulders, and legs.

Another correlation was obtained between the technical characteristics of the three elements, regarding rotation inertia and the angular speed (front leg; rear leg; shoulder and hand), relevant factors in the improvement of the execution technique. Moreover, significant differences were found between the mean values of these two characteristics. Due to the implementation of the training routine, the values obtained by the female athletes recorded an improvement in the rotation inertia and the angular speed (namely, they influence each other). Through the results obtained, we test the general hypothesis 3.

Table 4.16. Statistically significant Spearman's correlation coefficients

Dimension analysed	Correlated variables	Correlation coefficient	Sig.
Rotation inertia and The angular speed (RÎP (FF))	Rotation inertia - The angular speed hand	-0,630	0,007
Rotation inertia and The angular speed (RLÎ_CSG)	No significant correlation		
Rotation inertia and The angular speed (RLÎ_RÎP (FF))	Rotation inertia - The angular speed hand	0.500	0,041

Strength resultant and Physical trials (SJ, CMJ, FJ) (RÎP (FF))	SJ – Strength resultant	0.507	0,027
Strength resultant and Physical trials (SJ, CMJ, FJ) (RLÎ_CSG)	FJ – Resultant_of strength	0,465	0,045
Strength resultant and Physical trials (SJ, CMJ, FJ) (RLÎ_RÎP (FF))	SJ – Resultant_of strength	0,663	0,025
	60 sec - Resultant_of strength	0.541	0,025
Motion radius_RÎP (FF) and Mobility	Motion radius front leg - Left leg ankle flexion	-0.476	0.040
	Motion radius front leg - Right shoulder extension	0.557	0.013
	Motion radius shoulder - Right leg hip flexion	-0.484	0.036
	Motion radius hand - Left leg ankle flexion	-0,651	0.003
Motion radius_(RLÎ_CSG) and Mobility	Motion radius front leg - Right leg hip extension	0.500	0.029
	Motion radius front leg - Left leg ankle flexion	-0.597	0.007
	Motion radius front leg - Left leg ankle plantar flexion	0.512	0.025
	Motion radius front leg - Right shoulder extension	0,657	0.002
	Motion radius rear leg - Right leg hip extension	0.567	0.011
	Motion radius rear leg - Left leg ankle flexion	-0.538	0.018
	Motion radius rear leg - Right shoulder extension	0,639	0.003
	Motion radius shoulder - Right leg hip flexion	-0,467	0.044
	Motion radius shoulder - Right leg hip extension	0,670	0.002
	Motion radius shoulder - Left leg ankle flexion	-0,605	0.006
	Motion radius shoulder - Left leg ankle plantar flexion	0,495	0.031
	Motion radius shoulder - Right shoulder extension	0,632	0.004
	Motion radius hand - Right leg hip extension	0,608	0.006
	Motion radius hand - Left leg ankle flexion	-0.565	0.012
	Motion radius hand - Right shoulder extension	0.54	0.017
Motion radius_RLÎ_RÎP (FF)) and Mobility	Motion radius front leg - Right leg ankle plantar flexion	-0.584	0,014
	Motion radius rear leg - Right leg hip extension	-0.512	0,035
	Motion radius rear leg - Right leg ankle plantar flexion	-0.557	0,020
	Motion radius shoulder - Right leg ankle plantar flexion	-0.506	0,038
	Motion radius hand - Right leg ankle plantar flexion	-0.681	0,003
	Motion radius hand - Left leg ankle plantar flexion	-0.489	0,046
Motion radius and The angular speed (RÎP (FF))	The angular speed hand - Motion radius front leg	-0,607	0,010
	The angular speed hand - Motion radius rear leg	-0,613	0,009
	The angular speed hand - Motion radius shoulder	-0.581	0,014
Motion radius and The angular speed (RLÎ_CSG)	No significant correlation		
Motion radius and The angular speed (RLÎ_RÎP (FF)	No significant correlation		

Source: Personal processing in SPSS

Experimental research conclusions

Partial conclusions of the experimental study

From the perspective of body composition, out of the five characteristics (the body composition; body mass (kg); BMI (kg / m^2); body fat (%); muscle mass (kg); basal metabolic rate (kcal)), we recorded significant differences between the values of *three* characteristics out of the five (body mass, BMI, and basal metabolic rate). It is worth stating that, at the end of the training routine, the values obtained by the athletes are generally normal, which shows the efficiency of the training process.

In what concerns results obtained in the *psychomotor tests*, progress was recorded between the two tests, the differences being significant for all the *13* pairs of indicators (The Matorin test - dominant side and non-dominant side; The Flamingo test – right leg and left leg; Maintaining position on the balance plate - with eyes closed and with eyes open and the "Y" test - A, PM, and PL). Considering the results recorded and featured in the aforementioned chapter, it may be posited that, upon implementing the training routine, the results of the female athletes show better general coordination, temporal-spatial orientation, and an evolution of the static and dynamic balance, showing the effectiveness of the training process.

The results *of the physical trials* (Strength of leg muscles - Squat Jump, Free Jump, Counter Movement Jump, Free Jump - 60 seconds; Abdominal muscle strength - Raising the outstretched legs from the wall bar; Back muscle strength - Gym bench extensions and Palmar flexor strength – the right arm and the left arm) include significant differences between the mean values of the *eight* indicators in the case of the two tests (TI and TF). Taking into account the results of these tests, it may be stated that, following the training proposed, the values obtained by the female athletes show increased indicators of the explosive power in the lower limbs and of strength in the upper limbs, abdomen, and torso, and they can influence the efficiency of the training process.

The values estimated for the probability of the null hypothesis, in the case of the 15 mobility tests (Spine - Flexion (cm), Flexion (^{0}), Extension; Right and left hip mobility - Flexion and Extension; Mobility of the left and right ankle - dorsal flexion and plantar flexion; Mobility of the right and left shoulder - Flexion and Extension) it may be stated, taking into account a risk of 5%, that the null hypothesis is rejected in the case of the 15 pairs of indicators. Consequently, significant differences were found between their mean values at

the two tests (TI and TF), while following the training proposed here, gymnasts displayed improved indicators of joint mobility at the level of the spine, hip, ankle, and shoulder, and they can determine the efficiency of the training process.

The results *of the psychological testing* (The assessment of emotions - positive and negative; The assessment of behaviour and the assessment of the attention span) features improvements of the means for all the coefficients tested. The values of the Wilcoxon test in the case of the mean score of positive emotions improves and decreases in the case of negative emotions between the two tests, the level of the mean score in the case of Behavioural scale increases, while the mean score of 460 signs increases in the case of signs correctly barred and decreases in the case of signs omitted or additional bars. The aspects mentioned above show that the training routine had a positive effect on positive emotions, behaviour and the attention span, and they can determine the efficiency of the training process.

In what concerns the results of the technical trials, it is worth noting that improvements were recorded. In the case of the element RÎP(FF) in the seven tests of *the anthropometrical and biomechanical parameters* (Weight; Height; Rotation inertia and Motion radius (front leg; rear leg; shoulder and hand), the null hypothesis is rejected in the case of *three* pairs of indicators (Weight; Rotation inertia, Segmental movement radius - hand). Consequently, significant differences were found between the mean values of the *three* characteristics for the two moments (TI and TF). After covering the training routine, the results of the female athletes tend to record a normal weight, an optimal technical execution at the level of the lower limbs and an improvement of the rotation inertia, due to the training focusing on it, relying on the conclusions in the in the TI.

In the case of the results obtained in what concerns the spatial characteristics of the body segments (PP, MPZ/ÎMZ, PP2, PF1, PF2), starting from the values estimated for the probability of the null hypothesis, in the case of the *12* tests, it may be stated, taking into account a risk of 5%, that we reject the null hypothesis in the case of *a* pairs of indicators, namely PF2 - b. Hence, there are significant differences between the mean values of a characteristics for the two moments (TI and TF). It may be posited that, thanks to having covered the training routine focusing of these parameters, the results obtained confirm the improvement in the technical execution of this element.

In what concerns of the technical element *RLÎ_CSG*,, for the *seven* tests of the anthropometrical and biomechanical parameters (Weight; Height; Rotation inertia and

Motion radius (front leg; rear leg; shoulder and hand), the null hypothesis is rejected in the case of *three* pairs of indicators (Weight (kg); Rotation inertia, Segmental movement radius - rear leg). Consequently, significant differences were found between the mean values of the four characteristics for the two moments (TI and TF). After covering the training routine, the results of the female athletes tend to show a normal weight, an optimal technical execution at the level of the lower limbs and an improvement in the rotation inertia, based on the training focused on this aspect, relying on the conclusions in the TI.

Concerning the results obtained in the spatial characteristics of the body segments (PP, MPZ/ÎMZ, PF), starting from the values estimate for the probability of the null hypothesis, in the case of the eight tests, it may be stated, taking into account a risk of 5%, that we reject the null hypothesis in the case of three pairs of indicators, namely MPZ/ÎMZ b and PF a - b. Consequently, significant differences were found between the mean values of the three characteristics for the two moments (TI and TF). It may be stated that by covering the training routine, focusing on these parameters, the female athletes tended to improve the execution technique of this element.

Concerning the technical element RLÎ_RÎP (FF), in the case of the *seven* tests of the anthropometrical and biomechanical parameters (Weight; Height; Rotation inertia and Motion radius (front leg; rear leg; shoulder and hand), the null hypothesis is rejected in the case of two pairs of indicators (Weight (kg) and Height (cm). Consequently, significant differences were found between the mean values of these two characteristics for the two moments (TI and TF). After covering the training routine, the results of the female athletes tend to show a normal weight, which represents a relevant criterion in obtaining great performance. The low percentage of body fat plays an essential role in the success within AG. In what concerns results obtained in the spatial characteristics of the body segments (PP1, P2, P3, PF - P4, P5, MP, P6, PF1, PF2), starting from the values estimate for the probability of the null hypothesis, in the case of the 22 tests, it may be stated, considering a risk of 5%, that we reject the null hypothesis in the case of *two* pairs of indicators, namely PF2 a and b. Therefore, there are significant differences between the mean values of these 2 characteristics for the two moments (TI and TF). It may be posited that, after covering the training routine, centred on these parameters, the female athletes tended to improve the execution technique of these elements.

Following the *correlative analysis* of the results obtained in the *physical trials* and the tests applied and the results of the female athletes obtained for the *three* technical elements

analysed - RÎP (FF), *RLÎ_CSG* and RLÎ_RÎP (FF), correlations were found between the technical elements analysed (RÎP (FF), RLÎ_CSG și RLÎ_RÎP (FF) and strength of the lower limbs and mobility. Starting from the correlations obtained, it is worth highlighting the relevance of physical training and of mobility in the training of performance gymnasts. From the perspective of the correlation between the technical elements analysed (RÎP (FF), RLÎ_CSG și RLÎ_RÎP (FF)) and of the physical trials (SJ, CMJ And FJ), it may be stated that they require an adequate development of the strength of leg muscles. Furthermore, data analysis shows that, for the adequate execution of the technical elements, gymnasts also need good joint mobility at the level of the ankles, shoulders, and legs.

Another correlation was obtained between the technical characteristics of the three elements, regarding rotation inertia and the angular speed (front leg; rear leg; shoulder and hand), relevant factors in the improvement of the execution technique. Moreover, significant differences were found between the mean values of these two characteristics. Due to the implementation of the training routine, the values obtained by the female athletes recorded an improvement in the rotation inertia and the angular speed (namely, they influence each other).

General conclusions of the experimental research

Upon reviewing the scientific literature, it is worth highlighting the diversity of issues related to balance beam technical elements that one can analyse and that play and= essential role in the execution technique.

Following the interpretation of the statistical analysis, I assessed the statistical significance of the difference between means in the case of two sets of scores. Hence, it was demonstrated whether the mean value for a set of scores was different from the mean value for another set of scores. Thus, I was able to include the findings within the general means of a population.

The monitoring *of body composition* is relevant for both athletes in general and Artistic Gymnastics practitioners. Consequently, it is not surprising that numerous studies have suggested that the low percentage of body fat (GC %) and an adequate body image are crucial to being successful in Artistic Gymnastics.

The results *of the physical trials* highlight that the *strength* of the main muscle groups conditions performance in Artistic Gymnastics by significantly influencing the technical

elements, related to certain fundamental groups, and representing elements of difficulty for which gymnasts obtain bonus points.

The values obtained in the assessment *of mobility* show that it is a quality with an essential role in obtaining great results in Artistic Gymnastics, from both an artistic and a technical perspective. This skill should agree with the coordinative capacities, which are, in their turn, indispensable for acquiring the technique specific to each apparatus, especially the "balance beam" event.

The results in the *psychomotor tests* have helped obtain the overall picture from the perspective of motricity on gymnasts and it may be stated that the technical elements, through their structure, require an adequate level of balance because, in the composition of the exercise for competitions, there are manifestations of both static and dynamic balance.

Furthermore, it must be noted that the assessment of emotions, behaviour, and attention span influences performance at a functional level. Positive and negative emotions play a facilitating role, reflected in the availability of resources and their efficient identification and efficient application.

Another aspect to be extracted from the information analysed in this study concerns *the execution technique* of the *three* elements investigated. It is worth underlining that technical training plays a significant role in Artistic Gymnastics, and it is closely connected with the other components: insufficient physical training leads to faulty and inadequate technique, and to failure in competitions, ultimately. High-quality technical training without good physical training and an optimal development of joint mobility leads to modest results. I agree with this idea because, through the identification of the various relations or correlations between the various components of training in Artistic Gymnastics, as well as the correlation between their indicators, a contribution can be brought to the development of new research directions.

The hypotheses proposed in this study were confirmed; hence, I reiterate the relevance of the presence of physical, motor, psychomotor, psychological, and technical aspects in the evaluation process of junior gymnasts aged 10 and 12. In addition, it may be stated that a special training routine elaborated to improve the technical elements targeted by this study ensures an improvement in the execution and sports performances, implicitly.

CONCLUSIONS

After reviewing the scientific literature, it has been underlined that the efficient use of the learning transfer in the gymnastics routines on various apparatus, based on the biomechanical analysis of the primary elements of sports technique, can contribute to an increase in the difficulty of routines, to improved technical executions, and to better performance in competitions. Furthermore, the scientific literature highlights the diversity of the types of technical errors, thus playing a particular role in the execution technique. The motor and psychomotor skills involved in the execution of the technical elements involved depending on age particularities determine the level of execution accuracy. They also highlight the potential gaps, explain stagnations logically, and often provide new strategies to organise the training meant to cope with such stagnations.

The results were included in the general means of a population by interpreting the statistical analysis, to assess the statistical significance of the difference between means for two sets of scores. Thus, I have shown whether there was a difference between the mean value for a set of scores and the mean value for another set of scores.

Hence, I believe that the topic of my research project is part of the field of advanced theory and practice (pertaining to the "Sports and physical education science"). It involved the elaboration and confirmation of an instruction model by developing training routines meant to optimise the current version, thus highlighting the accomplishments of modern technique, and combining the classic and modern elements, thus aiming to enrich the theoretical and practical sports knowledge. I believe that that approach to the theme and the organisation of the scientific endeavour are original. Its originality resides, primarily, in the biomechanical analysis of technical elements in the "balance beam" event and the individualisation of the training routines. Optimising the training process of the juniors in Artistic Gymnastics was possible by improving technical training, to develop the performance capacity as quickly as possible and of obtaining notable sports results.

The results obtained in this research study, the individualised training routines applied to improve the execution technique of various technical elements in the "balance beam" event and those applied to improve the physical training of junior gymnasts will acquire a concrete form. Namely, a methodical and practical guide will be elaborated. It will be dedicated to the coaches in this sports branch who wish to apply in the training process the routine proposed here, for a more efficient training process of junior gymnasts in Artistic Gymnastics.

This research study can be extended by assessing a greater number of athletes, by including more clubs in the research, as well as by analysing more technical elements and introducing other types of apparatus in the research.

LIMITS AND FUTURE RESEARCH DIRECTIONS

Regarding the limits of the research, I highlight that it was impossible to assess a greater number of the AG practitioners, due to the current pandemic context. For this reason, I will not generalise the conclusions, but I only propose the application of the training model in agreement with the errors identified.

Furthermore, it was not possible to analyse several technical elements, due to the training level of the female athletes throughout the application of the research protocol. Due to this same pandemic context, their training level was less than optimal. The common elements executed by the female athletes pertaining to the three clubs were only the ones featured in this thesis.

Another aspect that limited the research study was the existence of restrictions concerning sports activities, caused by the SARS-Cov-2 virus: home isolation of the infected athletes; limitation or temporary suspension of the activity of sports clubs due to the teaching and auxiliary personnel having been infected; and social distancing. Hence, the long recovery process upon resuming sports activity and the potential injuries made some athletes give up sports activity altogether, therefore being removed from the research sample.

Concerning future research directions, I propose to underline several relevant and useful aspects for the experts in the field of artistic gymnastics:

- assessing a greater number of athletes
- introducing more clubs in the research
- analysing more technical elements
- introducing in the research study several competition trials
- collaborating with the coaches within sports clubs and the Romanian Gymnastics Federation, for better exploitation of the training routines proposed here.

DISSEMINATION OF RESULTS

The dissemination of the results regarding our scientific endeavour throughout the three years of doctoral studies was performed by conveying the findings to coaches within the clubs participating in the preliminary and experimental research phases. The findings were also disseminated during scientific events, conferences, and congresses, as well as through the publication of scientific papers in various journals:

1. **Tanasă, A.R.,** Moraru, C.E., Trofin, P.F., Iordache, A.M., Tomozei, A.R., Ștefan, G.N. (2021). Study On The Physical Training Of Female Gymnasts In Beam. *Science of Human Kinetics*, 14(63), 23 - 30. https://doi.org/10.31926/but.shk.2021.14.63.1.3
2. **Tanasă, A.R.,** Trofin, P.F., Puni, A.R. (2021). Monitoring Force In Midle School Students During The Covid 19 Pandemic. *Journal of Physical Education and Sports,* 21(1), 1 - 7. https://doi.org/10.36836/2021/2/23
3. **Tanasă, A.R.,** Moraru, C.E., Dumitru, I.M., Trofin, P.F., Tomozei, A,R,, Toader, N.G. (2021). Study On The Practice Of Combined Muscular Fitness Forms. Filodirito Editore Proceedings, pp. 63 - 69. **https://www.webofscience.com/wos/woscc/full-record/WOS:000682773700009**
4. **Tanasă, A.R.,** Dumitru, I.M., Budacă, M.V. (2020). The Effects of Gymnastics Training on Static Balance Among Children Aged 4 to 8. *Bulletin of the Transilvania University of Brasov,* 13(62), 111 - 118. 10.31926/but.shk.2020.13.62.1.14
5. **Tanasă, A.R.,** Tomozei, A.R., Ștefan, N.G., Gavriluț, G. (2020). Qualitative Changes In Rhythmic Gymnastics Hoop Throws from The Perspective of Biomechanical Analysis. *Interdisciplinary Journal of Physical Education and Sport,* 20(1), 1 - 8. 10.31926/but.shk.2020.13.62.1.14
6. **Tanasă, A.R.,** Moraru, C.E., Trofin, P.F., Tomozei, A.R., Ștefan, N.G. (2021). Study Concering The Improvement Of Coordinative Abilities In Junior Female Gymnasts Aged 10 - 12. *International Congress Of Education, Health And Human Movement*, 10 - 12 June, Bucharest - to be published.
7. **Tanasă, A.R.,** Moraru, C.E. (2021). Study On The Motor Capacity Of Female Gymnasts Aged 10 - 12 In The Pandemic Context. *International Conference of the Universitaria*

Consortium in Physical Education, Sports and Physiotherapy, 12 - 13 Noiembrie, Iași - to be published.

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