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PROPRIOCEPTIVE TRAINING IN WOMEN'S ARTISTIC GYMNASTICS

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Abstract. *Women's artistic gymnastics is a sports discipline that places special emphasis on precision, strength and flexibility. One of the essential skills developed in this branch is balance, which is influenced by inputs from visual, vestibular and proprioceptive systems. Proprioception is the ability to perceive and control one's own body position in space, independently of sight. This sense is crucial in artistic gymnastics, as female athletes perform complex movements such as jumps, pirouettes and acrobatics, where coordination and body awareness are indispensable to maintain correct posture and prevent injury. Proprioceptive training helps develop joint and muscle sensitivity, allowing athletes to quickly adjust their movements and remain stable during the exercise. Balance is another vital component in women's artistic gymnastics. It involves the ability to maintain a stable and controlled position in various postures, for example, on the beam or during jumps. Balance development is important to meet the technical requirements of competitions because a small loss of stability can lead to significant penalties. The present study was conducted with a group of senior female gymnasts, and its purpose was to show that proprioceptive training on unstable surfaces could improve the dynamic balance of athletes. To demonstrate this, we used data collected by means of force plates that recorded the displacements of the center of pressure (COP) when the tested athletes performed different movements.*

Keywords: *artistic gymnastics, proprioception, balance, center of pressure.*

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Introduction

Gymnastics is a complex sport with high demands on strength and flexibility. Static balance and dynamic balance are essential in the training of elite female gymnasts, which is why both are developed from an early age and have a considerable impact on their performance (Lockard & Gable, 2023).

Dynamic balance is defined as the ability to maintain postural control or body balance while keeping the center of gravity within the base of support during activities that involve movements and changes in body position (Claxton et al., 2006; DiStefano et al., 2009; Kinzey & Armstrong, 1998). A critical aspect of dynamic balance is proprioception, namely the ability of the body to constantly perceive its position in space. Proprioception is achieved through a mechanism that integrates inputs from sensory receptors located in the muscles, skin and joints, but also central inputs from the nervous system (Taylor, 2009). These elements are particularly important for female gymnasts performing beam or floor exercises, as well as landings.

Balance training has recently been recognized as a valuable method in the preparation of young athletes, with significant benefits for both reducing the risk of injury and increasing athletic performance (Claxton et al., 2006). According to Filipa et al. (2010) and Holm et al. (2004), neuromuscular training that incorporates protocols aimed at stimulating strength, agility and balance can significantly contribute to improving proprioception and balance in elite athletes, including gymnasts.

Poor balance and ineffective postural control are directly related to the risk of injury and falls, and improving them is a fundamental component of basic motor skills. Balance, which is generally defined as the ability to keep the body’s center of gravity within the base of support, can be classified into two types: static balance and dynamic balance. Static balance involves maintaining the body in a fixed position on a stable support, while dynamic balance is more complex and involves maintaining stability during transitions from a dynamic to a static state. Both types of balance are dependent on the efficient integration of visual, vestibular and proprioceptive information, which allows for adequate postural control and correct motor responses (DiStefano et al., 2009).

Deficits in any component of the sensorimotor system can lead to loss of balance and therefore to injury. For example, poor balance may increase the risk of lateral ankle sprain, being a factor that differentiates individuals with and without functional ankle instability (DiStefano et al., 2009). Also, balance improvement is a key objective in rehabilitation and injury prevention programs, as it can contribute to reducing incidents and increasing athletic performance (McGuine & Keene, 2006; Olsen et al., 2005).

Studies on balance training have revealed that it can significantly reduce the rates of ankle sprains and other lower extremity injuries. For example, a balance-based training program can include a variety of exercises, such as those using ankle discs, exercises on unstable surfaces, or strengthening and plyometric exercises, which have been found to be effective in reducing injury risk and improving stability (McGuine & Keene, 2006; Wedderkopp et al., 2003). Although it has been suggested that balance training can reduce the risk of injury, there is still no clear evidence to establish a direct correlation between balance improvement and a lower number of injuries, especially in elite sports.

There are currently several studies that have assessed the impact of balance training on static and dynamic balance, but there is no generalized consensus on its effectiveness and ideal approaches. Existing studies have used various methods of measuring balance and different training durations, and this diversity of information can be confusing for coaches. It is therefore important to centralize these results in order to provide clear evidence-based recommendations for the design of a balance training program (Claxton et al., 2006).

Optimal postural control requires adequate integration of visual, vestibular and proprioceptive inputs; in addition, it is important for the sensory reweighting process to occur quickly and efficiently (Picot et al., 2022). Reweighting is the adjustment of sensory inputs to both environmental conditions and changes in body positions (Peterka, 2002). These changes may occur within a single sensory modality, for example, ankle proprioceptive inputs are predominant on firm surfaces (Ivanenko et al., 2000), while the reliance is shifted to lumbar inputs on unstable surfaces (Brumagne et al., 2008). Sensory reweighting plays a key role in maintaining optimal balance and reducing the risk of injury; however, suboptimal reweighting can decrease motor and postural performance and increase the risk of injury, especially during sports involving rapid movements or sudden changes in the environment (Paillard, 2019).

To ensure optimal performance in balance tasks, athletes need to effectively develop their ability to integrate multisensory information and adjust their motor mechanisms. For example, under conditions of increased difficulty of the balance task, such as maintaining balance on one leg, postural strategies can be modified to allow for greater stability (Guillou et al., 2007). In this situation, movement is controlled by a multisensory mechanism originating from the motor cortical system rather than the vestibular information (Dieterich et al., 2003). The above observations suggest that, during unipedal balance tasks, there is a functional postural dominance that can influence athletic performance (Guillou et al., 2007).

Sports training can significantly improve balance control and reduce body sway during static tasks and dynamic balance tests (Crémieux & Mesure, 1994; Golomer et al., 1997). Trained athletes tend to have greater stability than untrained individuals, regardless of the supporting leg, as reported for basketball players in static conditions (Hahn et al., 1999). Elite gymnasts are able to complete unipedal dynamic balance tasks with remarkable stability (Asseman et al., 2005) due to their intense physical training and specific balance development (Debu & Woollacott, 1988).

In conclusion, balance training is crucial in the preparation of athletes, having a significant impact on performance and injury prevention. However, there are still many aspects that require further research, and sports coaches and professionals need to rely on clear evidence to implement the most effective training protocols to enhance dynamic balance and proprioception in elite female gymnasts.

In women's artistic gymnastics, the ability to detect and quickly respond to changes in body position is crucial, and this is achieved through a combination of visual, vestibular and proprioceptive stimuli. According to Han et al. (2014), proprioception is closely related to the ability to perform precise and rapid movements that require perfect coordination between different body parts. Proprioception also has a strong influence on gymnasts' performance in terms of maintaining balance during rotations or landings from vaults, where stability and postural control are vital.

Moreover, a study by Filipa et al. (2010) suggests that the development of proprioception among gymnasts can be achieved through specific training that includes exercises on unstable surfaces and the use of equipment to stimulate balance. These types of training are meant to enhance motor responses and contribute to a better perception of the body position in space, thus reducing the risk of injury. In conclusion, proprioception is an essential ability in women's artistic gymnastics, which has a direct impact on performance and injury prevention. Training sessions designed to improve this ability are crucial for developing correct technique and optimizing stability when performing gymnastics elements. Existing studies suggest that the development of proprioception should be an integral part of gymnasts' training, as it contributes to achieving better performance and minimizing the risk of injury (Yılmaz et al., 2024).

Changes in the center of pressure (COP) are the result of a dynamic process called postural sway, which occurs when a person tries to maintain balance. This postural sway, either in the anteroposterior (forward and backward) or mediolateral (from side to side) plane, is the result of muscular activity that helps maintain an upright position. Sway can be a normal manifestation of postural control, and an increase in this phenomenon does not necessarily indicate a loss of balance but may suggest a decrease in neuromuscular control. According to Gribble and Hertel (2004), a greater variation in COP during static posture can be a sign of reduced neuromuscular control ability, which over time may lead to instability. Although postural sway can be a predictor of falling, it is not necessarily an immediate sign of instability but rather a natural component of the body's self-correcting mechanisms.

In conclusion, COP analysis plays a vital role in the assessment of postural balance and motor performance, and the use of force plates to measure and record these variations can provide valuable information, especially in the context of clinical studies, rehabilitation and research on human gait and posture.

Methodology

Purpose of the study

To describe how balance can be educated by using proprioception programs in the training of female artistic gymnasts.

Hypothesis

The use of proprioceptive training performed on unstable surfaces improves dynamic balance in female artistic gymnasts.

Participants

The research participants were 7 female athletes, members of the Romanian National Senior Team who followed a 16-week proprioceptive training program. During this period, four such programs were implemented, each lasting for weeks.

Research methods

This is an applied research where we used a combination of general, investigative and interpretive methods to gain a detailed understanding of the studied phenomenon. Among the general methods, we mention the literature review, which served to explore the topic addressed and provide the theoretical background of the research. The investigative methods consisted of observation and experiment, which were used to examine gymnasts' behaviors and performance before and after a training period. These approaches allowed us to collect relevant data and analyze the impact of different training techniques and strategies.

Regarding the analysis of variables, we considered the gymnasts' performance, namely their results following a training program, as the dependent variable, while the independent variable was represented by the types and means of training used during the research. This approach allowed us to assess the effectiveness and impact of different training methods on the gymnasts' performance, according to the specific parameters observed and measured.

Measures and Procedure

The initial testing was conducted on 10 January 2022 and was followed by a three-week period during which the obtained data were analyzed and the appropriate training programs were designed. Between 17 January and 8 May 2022, the proprioception programs were implemented, and the final testing took place on 9 May 2022. The programs were applied according to the following sequenced schedule (Table 1):

Table 1. *Sequenced schedule of proprioceptive training programs*

Program	Application period
Program no. 1	17.01. – 13.02.2022
Program no. 2	14.02. – 13.03.2022
Program no. 3	14.03. – 10.04.2022
Program no. 4	11.04. – 8.05.2022

Training was carried out 5 times a week on Mondays, Tuesdays, Wednesdays, Thursdays and Fridays. At every workout, each exercise of the program being completed in that period was performed. The working time per training session was approximately 20 minutes. The proprioception program was implemented in the workout after the general warm-up.

Testing was performed on the Force Decks equipment, and the collected data were analyzed and interpreted to formulate the research conclusions. Two tests were applied, namely marching in place with eyes open (Fukuda Test) and marching in place with eyes closed (Fukuda – Unterberger Test). If, in the first test, female athletes received information from the external environment, in the second test, they received only vestibular and proprioceptive information, eliminating visual information.

Preparation of the subject: the test is performed in a safe space, free from obstacles; the participant is asked to wear comfortable clothes and shoes; the instructions are clearly explained before the test begins.

Test execution:

- Initial position – The subject stands, with a straight back, hands relaxed at the sides and eyes open.
- Execution – The subject begins to walk in place, raising the knees to approximately 45 degrees, for 50 steps (or 30 seconds).
- Maintaining the initial position – The participant must try to stay in the same place without moving forward, backward or sideways.
- Observation and analysis – It can be observed whether the subject changes position or if he/she has a tendency to rotate in a certain direction.

Parameters: Anteroposterior Deviation (Forward/Backward)*;* Lateral Deviation (Left/Right)*;* Walking Surface. All data are automatically generated by the platform.

Proprioceptive training programs

Proprioceptive training program no. 1

Exercise 1

Standing on the balance disc. Perform toe raises with return by switching to heels. 12 repetitions.

Exercise 2

Standing with legs apart in the sagittal plane, left leg on the Bosu ball. Perform lunges with return. 12 repetitions on each leg.

Exercise 3

Standing on one leg on the Bosu ball. With the other leg, perform lifting and lowering movements forward, backward and sideways. 12 repetitions on each leg.

Exercise 4

Standing on the balance cushion. Perform leg bends into squats with return. 12 repetitions.

Exercise 5

Standing with legs apart on the elastic mini trampoline. Run in place with a stop on one leg while maintaining the balance position. Perform 6 stops on each leg.

Proprioceptive training program no. 2

Exercise 1

Standing on one leg on the balance cushion, the other leg bent backward, with a kettlebell fixed with an elastic band. Pass the weight from one hand to the other and maintain the position for 30 seconds. Perform 6 times for each leg.

Exercise 2

Standing on one leg on the Bosu ball, the other leg bent backward, facing a partner placed 1.5 m away in the same position, with a medicine ball held in both hands. Successive throwing of the medicine ball from one partner to the other while maintaining the position. Perform 6 times.

Exercise 3

Kneeling on the gym ball. Maintain the position for 30 seconds. Perform 2 sets.

Exercise 4

Standing on one leg on the balance disc, the other leg bent backward, arms down to the sides with a 5-kg weight in each hand. Shift your body weight in different directions with the balance disc movement and maintain the position. Perform 2 sets of 30 seconds.

Exercise 5

Standing in a lunge position with one leg on the Bosu ball and the other leg resting on the gym ball. Perform a slight bend and return with the lunged leg. 8 repetitions on each leg.

Proprioceptive training program no. 3

Exercise 1

Standing on one leg on the Bosu ball, with an elastic band attached to the ankles. Raise your leg and perform forward-backward and sideways movements while maintaining balance. 8 repetitions for each leg.

Exercise 2

Standing on one leg on the mini trampoline positioned 75 cm away from the wall, with the gym ball hold at the chest level with both hands:

- bend your supporting leg and throw the ball against the wall;
- return while catching the ball.

Perform 2 sets of 6 repetitions for each leg.

Exercise 3

Standing on one leg on the balance cushion positioned 75 cm away from the wall, with the gym ball hold at the chest level with both hands:

- throw the ball against the wall;
- catch the ball rebounding from the wall while maintaining balance on one leg.

Perform 2 sets of 6 repetitions for each leg.

Exercise 4

Lying prone with hands on the inverted Bosu ball and legs on the gym ball:

- bend your left leg with knee to chest;
- return.

Perform 2 sets of 10 consecutive repetitions for each leg.

Exercise 5

Standing on one leg on the Bosu ball, the other leg resting on a rubber ball. Drive the rubber ball left and right with your foot as far as the widest range of motion allows. Perform 10 repetitions for each leg.

Proprioceptive training program no. 4

Exercise 1

Standing on one leg on the Bosu ball, the other leg bent backward, arms to the sides with a 1-kg dumbbell in each hand; an elastic band attached to the waist is held tight by a partner standing behind. Maintain the position for 30 seconds while your partner tries to unbalance you using the elastic band. Perform 2 sets of 30 seconds for each leg.

Exercise 2

Standing on one leg on the balance cushion with the gym ball held in both hands 2 m away from the wall/partner. Throw the ball while maintaining the position and then catch it again. Perform 2 sets of 6 repetitions.

Exercise 3

Standing between two Bosu balls placed on the ground 50 cm apart, with 2-kg sandbags attached to both ankles:

- jump on your left leg on the Bosu ball and stabilize your position while catching a 1-kg medicine ball thrown by a partner placed 2 m away;
- maintain your position while throwing the ball back to your partner;
- jump on your right leg on the Bosu ball and stabilize your position while catching a 1-kg medicine ball thrown by a partner placed 2 m away;
- maintain your position while throwing the ball back to your partner.

Perform 2 sets of 4 repetitions.

Exercise 4

Standing on one leg on the trampoline, with your back to the fixed ladder, with an elastic band positioned in the middle and attached to the fixed ladder, with a 1-kg kettlebell or dumbbell attached to an elastic band and held with your left hand. Pass the weight from one hand to the other. Perform 2 sets of 30 seconds. Then resume by standing on the other leg.

Exercise 5

Sitting on the gym ball with your back against the wall, one leg on the balance cushion:

- lift on a single leg to a standing position on the balance cushion;
- return.

Perform 10 repetitions on each leg.

Results

Table 2. *Results obtained for the marching-in-place test with eyes open*

Item no.	Front-back deviation (cm)		Left-right deviation (cm)		Stepping area (cm^2)	
	IT	FT	IT	FT	IT	FT
1	12	4.2	14.6	0.9	20.7	18.1
2	19.2	7.4	13.3	7.1	25.2	19.9
3	11.9	3.2	3.4	0.2	37.6	25.4
4	16.6	4.5	1	0.4	25.6	17.2
5	5.5	0.9	3.1	2.1	49.6	32.7
6	18.3	7.6	4.7	2.4	29.2	21.9
7	16.1	4.4	2.2	0.6	25.6	18.2
Mean	14.22	4.6	6.04	1.95	30.5	21.91
S	4.77	2.33	5.53	2.41	9.90	5.52

Table 3. *Wilcoxon test results for marching in place with eyes open*

Statistical indicators	Wilcoxon test		
	Indicators		
	Front-back deviation	Left-right deviation	Stepping area
W	0	0	0
p	0.00	0.00	0.00
z	-2.366	-2.236	-2.236
r	0.89	0.89	0.89

To identify the occurrence of statistically significant differences between the initial and final testing in the experimental group, the non-parametric Wilcoxon test for marching in place with eyes open was applied, and the following results were obtained (Table 3):

- for the "front-back deviation" indicator, the statistical test result is W = 0 (Z = -2.366, p < 0.01), revealing a significant difference between the two testing sessions; the effect size is r = 0.89, which shows that there is a very strong effect on the results obtained by the research participants;
- for the other two indicators (left-right deviation and stepping area), the Wilcoxon test results are identical: W = 0 (Z = -2.366, p < 0.01); the effect size is r = 0.89, which highlights a very strong effect of the intervention on the participants' results.

Table 4. *Results obtained for the marching-in-place test with eyes closed*

Item no.	Front-back deviation (cm)		Left-right deviation (cm)		Stepping area (cm^2)	
	IT	FT	IT	FT	IT	FT
1	24.5	17.6	10.4	5.1	25.7	18.1
2	45.3	23.8	3.1	1.3	26.9	16.3
3	32.4	16.2	7.2	4.8	41.3	22.8
4	23	11.2	10.4	3.8	23.5	14.4
5	27.1	9.4	3.2	0.7	41.2	26.8
6	21.3	11.7	5.8	1.4	42.9	31.2
7	4.2	1.3	2.1	0.3	41.1	29.8
Mean	25.4	13.28	6.02	2.48	34.65	22.77
S	12.38	7.10	3.45	2.01	8.76	6.71

Table 5. *Wilcoxon test results for marching in place with eyes closed*

Statistical indicators	Wilcoxon test		
	Indicators		
	Front-back deviation	Left-right deviation	Stepping area
W	0	0	0
p	0.00	0.00	0.00
z	-2.366	-2.236	-2.236
r	0.89	0.89	0.89

To identify the occurrence of statistically significant differences between the initial and final testing in the experimental group, the non-parametric Wilcoxon test for marching in place with eyes closed was applied, and the following results were obtained (Table 5):

- for the "front-back deviation" indicator, the statistical test result is W = 0 (Z = -2.366, p < 0.01), revealing a significant difference between the two testing sessions; the effect size is r = 0.89, which shows that there is a very strong effect on the results obtained by the research participants;
- for the other two indicators (left-right deviation and stepping area), the Wilcoxon test results are identical: W = 0 (Z = -2.366, p < 0.01); the effect size is r = 0.89, which highlights a very strong effect of the intervention on the participants' results.

Discussion

Proprioception plays a fundamental role in gymnasts' performance and is an essential factor for the precise and safe execution of complex movements in artistic gymnastics. In this sports discipline, gymnasts must maintain fine control of their bodies in space, especially when performing elements on apparatus such as the beam, floor or vaulting table. Proprioception, which refers to the perception of one's own body in relation to the environment, facilitates coordination and balance by integrating sensory information from muscles, joints and ligaments. This ability is critical to maintaining stability and preventing injury, especially in the demanding conditions of women's artistic gymnastics, which requires strength, flexibility and very precise movements.

Studies have highlighted the importance of proprioception for gymnastics performance, as it influences not only static balance but also dynamic balance, which is essential in these exercises. For example, a study by Yılmaz et al. (2024) has revealed that gymnasts with developed proprioception are able to maintain better control over their bodies in motion, thus improving their performance on beam elements and landings from vaults. In addition, Aman et al. (2015) have shown that specific proprioceptive training can significantly reduce the risk of injury by improving motor responses and joint stability, particularly at the ankle and knee.

Proprioception is a fundamental sense of the human body. It allows individuals to move their bodies in space and move their body parts one in relation to the other. Proprioceptive inputs play a crucial role in postural control (Shokri et al., 2025). The purpose of this study was to assess the effect of interference with these inputs on postural stability, as measured by force plates that provided data on the displacement of the center of pressure.

Postural control requires the appropriate integration of information from sensory stimuli and neuromuscular responses to maintain the body in a standing position. The relative contribution of visual, proprioceptive and vestibular sensory information is dynamically adjusted as a consequence of changes in the environment, body or task conditions. Furthermore, it is important not only to maintain balance while these conditions are constant but also to regain postural control following a change occurring in the movement process (Busquets et al., 2018).

Comparing the results of the two tests (walking in place with eyes open and walking in place with eyes closed) we notice that for all three indicators taken into account, the values for walking with eyes closed are higher than for walking with eyes open in both tests. This shows that, when an athlete is deprived of the inputs received from a system (in our case, the visual one), the COP displacement is greater than when the athlete receives inputs from the three systems (visual, vestibular and proprioceptive).

In both cases, a decrease in all three indicators taken into account is observed, which demonstrates that proprioceptive training performed on unstable surfaces leads to an improvement in dynamic balance, and this is certified by the decrease in COP displacement.

Despite advances in this field, research on balance and proprioception, especially in girls under the age of 18 years, is still limited, and evidence-based approaches to enhance and measure dynamic balance and proprioception in female gymnasts are relatively few. Thus, further research is needed to identify various effective training methods that contribute to the development of these abilities (Claxton et al., 2006).

Conclusion

As a conclusion of the present study, we can say that proprioceptive training performed on unstable surfaces improves balance. In gymnastics, balance training is imperative, and proprioceptive training can improve sports results.

Regarding the results of the tests used to evaluate proprioception, improvements can be observed through the variations in the values obtained. Smaller deviations from the initial position indicate better proprioceptive stability and symmetry. Also, our study emphasizes that through specific exercises, proprioceptive education can increase receptor sensitivity, accelerate neural processing of sensory information, and improve neuromuscular control.

Proprioceptive exercises help stabilize and adjust body positions in different situations, for example, on unstable surfaces. Increasing proprioceptive sensitivity reduces the risk of falls in the case of the athletes.

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Informed Consent Statement: Written informed consent was obtained from all participants involved in this study.

Data Availability Statement: Data can be made available upon request to the contact author.

Conflicts of Interest: The authors declare no conflict of interest.

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