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Research article

Impact of Biodex systems equipment in prevention of ankle joint instability in junior footballers

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Abstract: (1) Background: The aim of this study was to identify differences in impact in the prevention of second-degree ankle sprain recurrence, more precisely agonist-antagonist muscle rebalance, recovery of proprioception junior footballers will have a different impact on patients undergoing rehabilitation program with the help of Biodex 4 Pro and Biodex balance compared to those who perform physical therapy using classical exercise programs. (2) Methods: the study included 30 subjects divided into two equal groups according to the agreement to practice modern exercise programs and soccer-specific exercises: the experimental group which performed exercises through Biodex 4 pro and biodex balance and the control group which performed classical exercises. Part evaluations included: Biodex balance for a range of stability assessments and the PodoSmart device for running assessment. (3) Results: Analyzing the data of the present scientific research, it can be concluded that the athletes belonging to experimental group 1, for which the intervention was carried out using modern means, did not register any recurrence at the level of the ankle, compared to the athletes included in the experimental group 2 for which the intervention was carried out with the help of classic means of recovery and which recorded an average of 1.46 recurrences (sprains) at the level of the ankle.(4) Conclusion: The study has shown that the Biodex System 4 Pro and Biodex Balance (together with the other modern therapies mentioned in the current paper) are very helpful in the recovery process.

Keywords: ankle sprain, prevention, recovery, Biodex dynamometer, Biodex Balance.

1. Introduction

Ankle sprains are a common musculoskeletal injury among athletes, particularly in sports that require jumping, pivoting, and sudden changes of direction, such as football [1].

Ankle sprains occur when the ligaments surrounding the ankle joint are overstretched or torn, leading to pain, swelling, and instability. While ankle sprains are typically not life-threatening, they can significantly impair an athlete's performance and ability to participate in sports.

In the United States, in 2010 the incidence was 2.15 per 1,000 people per year. Age 10-19 years is associated with higher rates of ankle sprain. Men between 15 and 24 have a higher incidence than women, while women over 30 have a higher incidence than men. Most ankle sprains occur during sports activities. This article will explore the causes, risk factors, classification, and management of ankle sprains, with a focus on ankle sprains in football [2].

The game of football is a team sport with a high risk of injury. Injuries in football are found in professionals, but also in amateurs because it is a dynamic and contact game. The causes of injuries are multiple, but the most common are muscle imbalances due to the low level of physical training [3]. Other research highlights significant differences in physical wear in athletes who have practiced a sport for less than 5 years and those who have been engaged in competitions for more than 5 years [4]. Physical training is part of sports training meant to ensure the energy background of performance [5].

Among all the systems and devices of the human body, the locomotor system is the most prone to accidents and trauma. In addition to the injuries that occur directly, the locomotor system also suffers due to certain immobilizations imposed after certain traumatic events, mainly determined by overuse.

Ankle sprains are of particular interest to active people, especially adults, and teenagers, after accidents at work, in traffic, or sports [6].

Inversion puts tension on the three bundles of the external collateral ligament of the ankle, and eversion puts tension on the internal collateral (deltoid ligament), which has two bundles: one superficial and one deep [7].

A pathological aspect that is frequently encountered in athletes, as a result of overstrain during repeated motor actions (running, jumping, sudden braking, changing direction, throwing, hitting, etc.), is determined by a series of post-traumatic conditions specific to the sport practiced.

Starting from this point of traumatic risk, the physiotherapist, being a component of the interdisciplinary team, is responsible for the training of the athletes and has the ability to intervene in order to prevent the installation of major injuries, through the possibility of eliminating some methodological training mistakes, to eliminate some wrong biomechanical skills, as well as by creating a training plan and a recovery protocol aimed at toning the intensely stressed muscles.

Feeley et al. (2008) reported that the injury rate is 4 times higher in official sports competitions than in practice, while athletes on the bench have a 13 times higher rate of injury during play than in practice [8].

Fong et al. (2009) claim that training protocols consisting of proprioceptive exercises and postural control exercises are the most widely used means to recover from and prevent ankle sprain recurrence [9].

Doherty et al. (2015) demonstrated that between 6-12 months after acute ankle sprain, there is a risk of chronic sprain. Comprehensive clinical evaluation before and after sprain rehabilitation has been found to be important. However, given the increased incidence of chronic sprain, researchers have recognized the need for a program to prevent joint instability [10].

A literature review of ankle sprain recovery using the Biodex Dynamometer and Biodex 4 pro system to assess was made (table 1).

Table 1. A literature review of ankle sprain recovery

Study	Participants	Treatment method	Outpot measures	Results
Riccio et al. (2019)[11]	19 subjects	Biodex Dynamometer	Side-to-side knee extension strength deficits	Although there were no statistically significant variations in knee range of motion between the two sides, the injured extremity exhibited a slightly smaller thigh circumference. The median difference measured 1.7 cm at 15 cm above the patella and 4.0 cm at the midpoint of the thigh's length. Furthermore, out of the total 19 subjects, 5 individuals (26%) displayed a notable quadriceps extension strength deficit in the affected leg when compared to the opposite side.
Ilie et al. (2019) [12]	Male subject 36 years	Isokinetic dynamometer machine Biodex system 4 pro	Assess joint function, gain ROM, strengthening knee stabilisers	Patients with a meniscus tear can experience a decrease in their recovery time by a minimum of 20%.
Power et al. (2013) [12]	24 subjects	Biodex Dynamometer	Dynamic contractions on a Biodex dynamometer using the "isotonic mode"	At baseline, the intraclass correlation coefficients (ICC) confidence intervals for velocity ranged from 0.85 to 0.97, while those for power ranged from 0.95 to 0.99. After the lengthening contractions, the ICC confidence intervals for velocity ranged from 0.82 to 0.90, and for power, they ranged from 0.93 to 0.96.
Xhardo et al. (2022)[14]	1 subject	Biodex 4 pro system	Isokinetic mode at 60,90, 120 for ankle flexion/ extension	The research findings indicate that the Biodex System 4 Pro, along with other contemporary therapies, plays a valuable role in the rehabilitation process. This is due to its capability to operate in the isokinetic mode, which effectively shortens the functional recovery duration and guarantees a swift return to sports activities.

The Biodex 4 PRO system is an isokinetic system that allows accurate, both qualitative and quantitative evaluation of the force produced at different speeds, but also of the range of motion. It can be used on the knee, elbow, fist, ankle, and shoulder joints [11].

The computerized evaluation provides us with data on movement parameters among which we find the following [15]:

- The ratio between agonist and antagonist muscles;
- Force torque;
- The elapsed time until the maximum torque is reached;

- The angle at which the maximum torque is reached;
- Functional deficit (proportionality index between joints);
- Mechanical work performed in the first third and last third of the program;
- Total mechanical work (sum of all repetitions);
- Range of motion (ROM);
- Developed power.

The isokinetic regime allows the speed of movement and the degree of resistance to be set, and the most important aspect is that the movement occurs in a self-adaptive and pain-free manner.

The ability to generate variable resistance is important because it allows the generation of maximum muscle force throughout the range of motion.

The Biodex balance system in recent years has been used to assess postural balance. Biodex balance is a multiaxial device that objectively assesses and records a subject's ability to stabilize the involved joint under dynamic stress. Using a circular platform that is free to move in the anterior-posterior and medial-lateral axes simultaneously can also be used for the purpose of dynamic or static balance training [16].

2. Results

For experimental group (1) the statistical analysis of the data (Table 2) comparing the results obtained in the case of the initial testing with those of the final testing, both for the healthy and for the affected ankle - regarding muscle strength, revealed.

Table 2. Results for experimental group 1 - initial test values vs. final test values – in the case of muscle strength evaluation, for the flexion test and the extension test

	Strength – Flexion (J)		**Strength – Extension (J)**	
Wilcoxon Test	**Healthy ankle**	**Affected ankle**	**Healthy ankle**	**Affected ankle**
Wilcoxon	0	0	0	0
Z	-3.407	-3.407	-3.407	-3.407
P	0.00	0.00	0.00	0.00
R	0.87	0.87	0.87	0.87

In the case of flexion, statistically significant differences are found ($p < 0.00$), between the results obtained at the initial assessment (median = 249.1) and those obtained at the final assessment (median = 280.1) in terms of muscle strength - for the healthy ankle; also, there are statistically significant differences ($p < 0.00$) between the results obtained at the initial assessment (median = 251) and those obtained at the final assessment (median = 283) and in the case of the previously affected ankle, in terms of muscle strength.

The size of the effect is $r = 0.87$, in all the situations investigated regarding flexion, which means that the effect of the experimental intervention, through modern methods (the Biodex system), is a very strong one, in terms of muscle strength, both in the case of the healthy ankle and in the case of the previously affected ankle. In the case of extension, statistically significant differences are found ($p < 0.00$), between the results obtained at the initial assessment (median = 61.3) and those obtained at the final assessment (median = 71.4) in terms of muscle strength - for the healthy ankle; also, statistically significant differences ($p < 0.00$) are found between the results obtained at the initial evaluation (median = 61.1) and those obtained at the final evaluation (median = 71.2) and in the case of the previously affected ankle, in terms of muscle strength. The effect size is $r = 0.87$, which means that the effect of the experimental intervention, by modern methods (Biodex system) is very strong, also in terms of muscle strength, for the extension test, both in the case of the healthy ankle and in the case of the ankle affected in the past.

The statistical analysis for the experimental group (1) of the data (Table 3) compares the results obtained in the case of the initial testing with those of the final testing, both in the conditions where the surface is stable and for the unstable surface - regarding the sensory integration of balance, highlighted.Table 3. Results for experimental group 1 - initial test values vs. final test values – in the case of assessment of sensory integration of balance (Biodex - Balance)

Wilcoxon Test	Stable surface balance (°)		Unstable surface balance (°)	
	Eyes open	Eyes closed	Eyes open	Eyes closed
Wilcoxon	0	0	0	0
Z	-3.407	-3.407	-3.407	-3.407
P	0.00	0.00	0.00	0.00
R	0.87	0.87	0.87	0.87

If the surface is stable, there are statistically significant differences ($p < 0.000$) between the results from the initial testing (median = 1.03) and those from the final testing (median = 0.46), regarding the balance index both in the case eyes are open and if eyes are closed, initial test (median = 1.07), final test (median = 0.82). If the surface is unstable, there are significant differences, under statistical ratio ($p < 0.00$) between the results obtained at the initial test (median = 1.12) and those recorded at the final test (median = 0.81) regarding the balance index, both in both with eyes open and eyes closed, initial test (median = 3.01), final test (median = 2.43). In all investigated situations, the effect size is $r = 0.87$, which reveals a very strong effect of the experimental intervention, through modern methods (Biodex system) in terms of the sensory integration of balance, both when there is a stable surface and and if the surface is unstable (both in the situation where the eyes are open and n the situation where they are closed). The statistical analysis of the data showed that the results improved statistically significantly ($p <0.00$), following the experimental intervention using modern methods (Biodex Balance), as the research participants recorded a significantly lower balance index throughout the period of the 30 seconds of the test, at the final test, in all test situations.

For the control group (2) the statistical analysis of the data (Table 4) comparing the results obtained in the case of the initial testing with those of the final testing, both for the healthy and for the affected ankle regarding muscle strength, revealed.

Table 4. Results for control group 2 - initial test values vs. final test values – in the case of muscle strength evaluation, for the flexion test and the extension test

Wilcoxon Test	Strength – Flexion (J)		Strength – Extension (J)	
	Healthy ankle	Affected ankle	Healthy ankle	Affected ankle
Wilcoxon	0	0	0	0
Z	-3.407	-3.407	-3.407	-3.407
P	0.00	0.00	0.00	0.00
R	0.87	0.87	0.87	0.87

In the case of flexion, there are statistically significant differences (p < 0.00) between the results obtained at the initial assessment (median = 247.1) and those obtained at the final assessment (median = 258.1) in terms of muscle strength - for the healthy ankle; also, there are statistically significant differences (p<0.00) between the results obtained at the initial assessment (median = 215.3) and those obtained at the final assessment (median = 232.4) and in the case of the previously affected ankle, in terms of muscle strength; The size of the effect is r = 0.87, in all the investigated situations regarding flexion, which means that the effect of the experimental intervention, by classical methods, is a very strong one, in terms of muscle strength, both in the case of the healthy ankle and in the case of the affected ankle in antecedents. In the case of extension, statistically significant differences are found (p < 0.00), between the results obtained at the initial evaluation (median = 61) and those obtained at the final evaluation (median = 64.4) in terms of muscle strength - for the healthy ankle; also, statistically significant differences (p <0.00) are found between the results obtained at the initial assessment (median = 50.1) and those obtained at the final assessment (median = 56.1) and in the case of the previously affected ankle, in terms of muscle strength. The size of the effect is r = 0.87, which means that the effect of the experimental intervention, by classical methods, is very strong, also in terms of muscle strength, for the extension test, both in the case of the healthy ankle and in the case of the previously affected ankle.

The statistical analysis of the results (Table 5) compares the scores obtained in the case of the initial testing with those of the final testing, both in the conditions where the surface is stable and for the unstable surface - regarding the sensory integration of balance, revealed the following aspects.

Table 5. Results for control group 2 - initial test values vs. final test values – in the case of assessment of sensory integration of balance (Biodex - Balance)

Wilcoxon Test	Stable surface balance (°)		Unstable surface balance (°)	
	Eyes open	**Eyes closed**	**Eyes open**	**Eyes closed**
Wilcoxon	0	0	0	0
Z	-3.407	-3.407	-3.407	-3.407
P	0.00	0.00	0.00	0.00
R	0.87	0.87	0.87	0.87

If the surface is stable, there are statistically significant differences (p<0.00) between the results from the initial testing (median = 1.15) and those from the final testing (median = 0.63), regarding the balance index both if eyes are open and if eyes are closed, initial test (median = 1.19), final test (median = 1.02). If the surface is unstable, there are significant differences, under statistical ratio (p < 0.00) between the results obtained at the initial test (median = 1.38) and those recorded at the final test (median = 1.01) regarding the balance index, both in both eyes open and eyes closed, initial test (median = 4.1), final test (median = 3.02). In all investigated situations, the size of the effect is r = 0.87, which reveals a very strong effect of the experimental intervention, through classical methods, regarding the sensory integration of balance, both when there is a stable surface and when the surface is unstable (both in the situation where the eyes are open and in the situation where they are closed). The statistical analysis of the data showed that the results improved statistically significantly (p <0.00), following the experimental intervention through classical methods, as the research participants recorded a significantly lower balance index throughout the 30 seconds of the test, at final testing, in all test situations.

The statistical analysis of the results (Table 6) comparing the values obtained by the participants of the experimental group 1 with those of the control group 2, in the case of the final testing, both for the healthy and for the affected ankle - regarding muscle strength, revealed.

Table 6. Results for the final testing – values experimental group 1 vs. control group 2 values – in the case of muscle strength evaluation (flexion test and extension test)

Mann-Whitney Test	Group 1 vs. Group 2 - *Final testing*			
	Strength – Flexion (J)		Strength – Extension (J)	
	Healthy ankle	Affected ankle	Healthy ankle	Affected ankle
Mann-Whitney U	3	0	0	0
Z	4.521	4.645	4.645	4.645
P	0.00	0.00	0.00	0.00
R	1.16	1.19	1.19	1.19

In the case of flexion, there are statistically significant differences ($p < 0.00$) between the results obtained by experimental group 1 (median = 280.1) and those obtained by experimental group 2 (median = 258.1) at the final test, in terms of strength muscular – for a healthy ankle; statistically significant differences ($p < 0.00$) are also found for the previously affected ankle, between experimental group 1 (median = 280.3) and experimental group 2 (median = 232.4) (Figure 1).

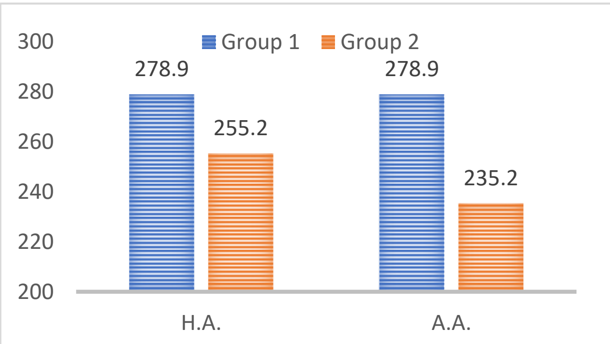

Figure 1. Muscle strength, Flexion, group 1 and group 2, Final testing (Healthy ankle – HA; Affected ankle – (AA)

Therefore, the participants belonging to experimental group 1 (intervention by modern methods) at the final testing recorded significantly better results, compared to the participants of control group 2 (intervention by classical methods), in the case of flexion.

At the final evaluation, the effect size is r = 1.16 (healthy ankle), respectively r =1.19 (ankle affected in the antecedents), which indicates a very strong effect of the group variable on the participants' results regarding muscle strength, in the case of flexion, at the level of both legs (Figure 2).

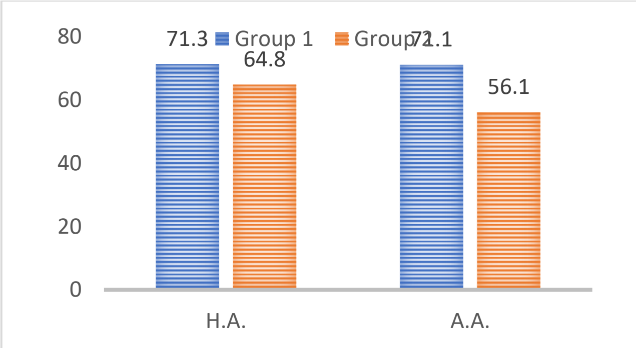

Figure 2. Muscle strength, Extension, group 1 and group 2, Final testing (Healthy ankle – HA; Affected ankle – (AA)

In table 7 the statistical analysis of the research data, comparing the values obtained by the experimental group 1 with those recorded by the control group 2, in the final evaluation, regarding the balance, highlighted.

Table 7. Results for the final testing – experimental group 1 vs. control group 2 - in the case of balance assessment (sensory integration of balance)

Mann-Whitney Test	Group 1 vs. Group 2 - *Final testing* Balance (°)			
	Stable surface		Unstable surface	
	Eyes open	Eyes closed	Eyes open	Eyes closed
Mann-Whitney U	0	15	0	0
Z	4.645	-4.130	-4.645	-4.645
p	0.00	0.00	0.00	0.00
r	1.19	1.06	1.19	1.19

If the surface is stable (eyes are open) significant differences (p <0.00) are found between the results obtained by experimental group 1 (median = 0.46) and those of experimental group 2 (median = 0.63), in what it's about balance. At the final testing, the results of participants in experimental group 1 are closer to normal values (0.44) which indicates good joint stability, compared to the results of participants in experimental group 2, when the surface is stable (eyes are open) (Figure 3).

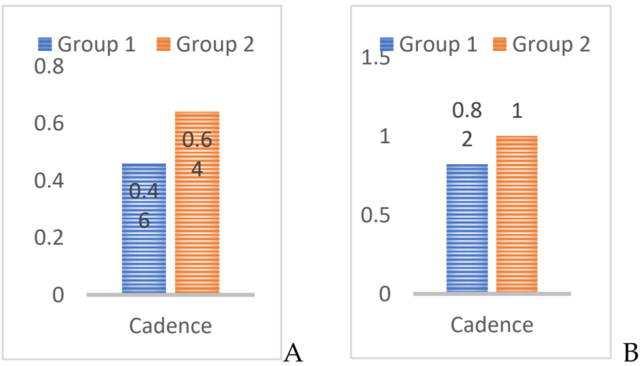

Figure 3. Balance, Stable surface, Final testing (Eyes open - A; Eyes closed - B)

The effect size indicator is r = 1.19, which demonstrates a very strong effect of the group variable on the participants' results regarding balance, in a situation where the surface is stable and the eyes are open. If the surface is stable (eyes are closed) there are statistically significant differences ($p < 0.00$) between the results obtained by the participants in experimental group 1 (median = 0.82) and those of the participants in experimental group 2 (median = 1.02), in terms of balance. In the final evaluation, the results of participants in experimental group 1 are closer to normal values (0.80) which indicates good joint stability, compared to the results of participants in experimental group 2, when the surface is stable (eyes are closed).

The effect size is r = 1.06, which demonstrates a very strong effect of the group variable on the participants' balance results when the surface is stable and the eyes are closed. If the surface is unstable (eyes open), significant differences ($p < 0.00$) are found between the values of experimental group 1 (median = 0.81) and those of experimental group 2 (median = 1.01), in terms of balance, at the final test.

And in this case, the effect size is r = 1.19, which translates to a very strong effect of the group variable on the participants' balance scores, in the situation where the surface is unstable and the eyes are closed, at the final assessment (Figure 4).

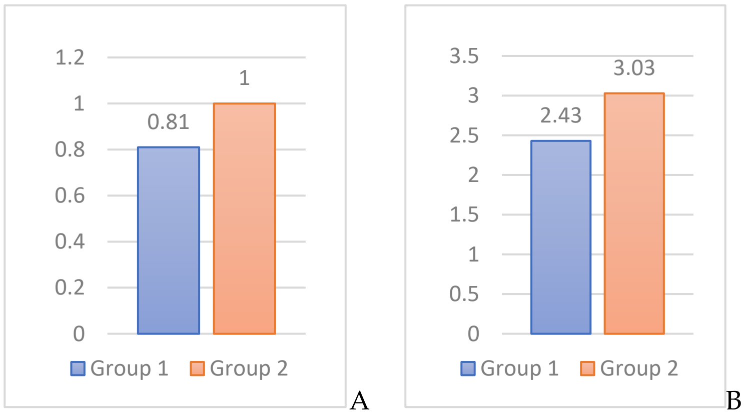

Figure 4. Balance, Unstable surface, Final testing (Eyes open - A; Eyes closed - B)

At the end of the research, the results of the participants in experimental group 1 (on average) are closer to normal values (0.79), which highlights good joint stability, compared to the results of participants in experimental group 2, in case the surface is unstable (and the eyes are open).

The effect size indicator is r = 1.19, which indicates a very strong effect of the group variable on the participants' results regarding balance, in a situation where the surface is unstable and the eyes are open. If the surface is unstable (eyes closed), significant differences ($p <0.00$) are found between the values of experimental group 1 (median = 2.43) and those of experimental group 2 (median = 3.02), regarding balance.

In the final testing, after the experimental intervention, the participants in experimental group 1 recorded, on average, values closer to normal values (2.41), which underlines good joint stability, compared to the values obtained by participants in control group 2, in the situation where the surface was unstable and the eyes were closed.

Looking at the incidence of injuries, using the non-parametric Kruskal-Wallis test for more than two independent samples, we investigated the existence of significant differences under a statistical ratio, between the results obtained (recurrences) by the participants of control group 2 (after the intervention by classical means), divided into the 3 groups, depending on the relapses (sprains) identified at the ankle level of the dominant leg: the group of athletes with the right dominant leg (n = 7), the group with the dominant left leg (n = 5) and the group of athletes with shows ambidexterity (foot) (n= 3).

Table 8. Results for control group 2 – group values with right dominant leg vs. group values with left dominant leg vs. ambidexterity group values – in the case of recurrences

Kruskal-Wallis Test	Right dominant leg group vs. left dominant leg group vs. ambidexterity group		
	$\chi 2$	df	p
Recurrences	3,50	2	0,174

Statistical analysis of the data (Table 8) comparing the results obtained in the case of the incidence of injuries (recurrences) at the level of the affected ankle, in the case of the three groups compared simultaneously – the group of athletes with the dominant right leg, the group of athletes with the dominant left leg and the group athletes presenting ambidexterity (foot), highlighted the following aspects: There are no significant differences, below the statistical ratio (p>0.05) between the results of the three groups of athletes (groups established according to the dominant leg), in terms of the number of recurrences (sprains) in the affected leg.

The next step in the statistical analysis was the comparison of the results of the groups two by two, regarding the recurrences identified at the level of the ankle of the dominant leg. So, in order to identify possible significant differences between the three groups established according to the dominant leg (the group of athletes with the right dominant leg, the group of athletes with the left dominant leg, and those who show ambidexterity at the level of the legs, in terms of the incidence of injuries (sprains) the Dwass-Steel-Critchlow-Fligner (DSCF) test was used. The non-parametric Dwass-Steel-Critchlow-Fligner (DSCF) test is a test for multiple comparisons analysis of the differences between the median values of the three groups regarding the number of relapses that occurred in the case of athletes participating in the research.

Statistical analysis of the results in Table 9, comparing the results recorded by the three groups (two by two) – group of athletes with the dominant right leg (group 1), group of athletes with the dominant left leg (group 2) and group of athletes who presents ambidexterity (group 3) emphasized the fact that there are no significant differences, below the statistical ratio (p > 0.05) between the groups, in terms of the incidence of injuries (recurrences) at the level of the affected ankle.

Table 9. Pairwise comparison – number of recurrences.

Groups	Dwass-Steel-Critchlow-Fligner Test	W	p
1	2	2,346	0,221
1	3	2,222	0,258
2	3	-0,231	0,985

W (Wilcoxon test value; p (significance threshold).

Statistical analysis of the results in Table 9, comparing the results recorded by the three groups (two by two) – group of athletes with the dominant right leg (group 1), group of athletes with the dominant left leg (group 2) and group of athletes who presents ambidexterity (group 3) emphasized the fact that there are no significant differences, below the statistical ratio ($p > 0.05$) between the groups, in terms of the incidence of injuries (recurrences) at the level of the affected ankle.

However, comparing the arithmetic averages obtained by the three groups subjected to research, we can see that there are differences between the three groups depending on the dominant leg, in terms of the incidence of injuries (ankle sprains), even if they are not statistically significant. Athletes with the dominant left leg recorded on average a higher number of relapses (m = 1.80), compared to those in the group with ambidexterity (m = 1.66) and those with a dominant right leg (m = 1.14).

Table 10 the statistical analysis of the results, comparing the values obtained by the group of athletes who had a history of right ankle damage with the group of athletes who had a history of left ankle damage, in terms of the number of relapses, revealed that: There are no significant differences, from a statistical point of view ($p > 0.05$), between the two groups established according to the ankle affected in the antecedents, in terms of the number of recurrences (sprains) that occurred.

Table 10. Results - group of athletes with a history of right ankle damage vs. group of athletes with a history of affected left ankle - regarding the number of recurrences.

Mann-Whitney Test	**Right ankle group vs. Left ankle group (affected in the antecedents) Recurrences**
Mann-Whitney U	21
Z	- 0,648
p	0,51
r	-

Comparing the arithmetic averages obtained by the two groups formed according to the ankle affected in the antecedents, we can see that there are differences in the incidence of injuries (ankle sprains) between athletes, even if they are not statistically significant. Athletes who had a history of left ankle damage recorded on average a higher number of relapses (m = 1.66) compared to athletes who had a history of right ankle damage (m = 1.33).

Table 11. Results - experimental group 1 vs. experimental group 2 – regarding the number of recurrences

Mann-Whitney Test	**Experimental group 1 vs. Control group 2 (modern means vs. classical means) Recurrences**
Mann-Whitney U	0
Z	- 4,645
p	0,00
r	1,19

Table 11 the statistical analysis of the results, comparing the values obtained by the participants of experimental group 1 (intervention by modern means - Biodex) and the participants belonging to experimental group 2 (intervention by classical means), in terms of the number of relapses (sprains), indicated the following relevant aspects: There are statistically significant differences ($p < 0.01$) between the values obtained by the participants of experimental group 1 ($n = 15$) and the results of the participants belonging to experimental group 2 ($n = 15$), in what concerns the number of relapses (sprains) that were recorded.

Therefore, it is found that, at the end of the research, the participants belonging to experimental group 1 (intervention by modern methods - Biodex) recorded significantly better results (median = 0), compared to the participants of experimental group 2 - intervention by classical methods (median =1), in the case of relapses found at the level of the ankle.

The size of the effect is $r = 1.19$, which indicates a very strong effect of the group variable on the results of the participants, regarding the number of recurrences (sprains) that occurred at the level of the ankle.

Analyzing the data of the present scientific research, it can be concluded that the athletes belonging to experimental group 1, for which the intervention was carried out using modern means (Biodex systems), did not register any recurrence at the level of the ankle, compared to the athletes included in the experimental group 2 for which the intervention was carried out with the help of classic means of recovery and which recorded an average of 1.46 recurrences (sprains) at the level of the ankle. We emphasize what we showed previously, namely the fact that, in the case of experimental group 2, there were significantly more recurrences (ankle sprains) than in the case of athletes from experimental group 1. And more than that, we can state that the athletes who had a history of left ankle damage recorded on average a higher number of relapses ($m = 1.66$), compared to athletes who had a history of right ankle damage ($m = 1.33$), even if the difference is not one statistically significant.

3. Discussion

Patients can trust that through every part of the rehabilitation structure, the plan is secure and documented. One of the crucial goals of the Biodex system is to provide patients with documented data and thus help them accurately communicate their needs, progress, and results.

Postle et al., (2012) proved that neuromuscular and proprioceptive exercises play an important role in restoring balance and postural control [18]. Periodic application of neuromuscular training during the first week of injury leads to higher levels of activity without consequences such as pain or inflammation. Therefore, early neuromuscular training is certainly effective and is recommended as an important part of the rehabilitation program for athletes with ankle sprains. In the early stages, neuromuscular exercises can be initiated with intrinsic foot movements (toe extension with ankle plantar flexion/toe flexion with ankle dorsiflexion) and exercises performed on an unstable foam surface, Bosu or DynaDisc in a seated position.

According to Marcu & Dan (2006), the main segment prone to injury or trauma in the game of football is the lower limb. Depending on the level and severity of the trauma, the most common are sprains, dislocations, muscle strains, or even ligament or muscle tears [19].

According to Oatis (2017), the tibialis posterior muscle (posterior compartment) is an important stabilizer of the foot, and low muscle strength affects the ability to rise on the toes, even when the plantar flexor muscles have normal muscle strength, the foot is unstable. Also, the low muscle strength of the tibialis posterior produces an imbalance with the levator muscles, a situation in which the foot tends to pronate [20]. In case of fracture, the reconstruction of the joint surface will be difficult simultaneously with the damage to the adjacent soft tissues, requiring the anatomical alignment of the fractured bone being an important objective in the recovery process. [21,22].

Fauris et al. (2021) argue that the hamstrings and gastrocnemius muscles have a fundamental role in sports performance [23]. Their constant role also includes a negative component, injuries at this level being frequent and associated with a high level of recurrence. As a result, the etiology of a hamstring injury has been extensively researched and several risk factors have been proposed. Previous investigations have shown that a lower range of motion (ROM = "range of motion") or flexibility and increased muscle stiffness are risk factors for sports injuries. Research has shown that increased muscle stiffness associated with antagonistic muscle contractions can inhibit joint movement and result in higher energy/metabolic costs. Therefore, improving ROM and decreasing muscle stiffness could be essential in sports and rehabilitation settings. With the goals of improving ROM and flexibility and reducing stiffness and pain in the field of rehabilitation and sports, myofascial therapy is found in physical therapy practice.
Jazayeri et al. (2007) conducted a study on the tibial and peroneal nerve pathway in ankle sprain, which concluded that lower limb injuries, especially ankle sprains, occur frequently among soccer players due to the high incidence of physical contact and lower limb nerve damage [24]. Football can increase nerve latencies and therefore decrease conduction in the lower limbs. That's why we consider physical exercise to be an important element in the whole process [25]. Therefore, in the muscle electrophysiological tests of football players (lower limb nerves, especially those with injuries) it should be taken into account that the decrease in clinical neuroconductivity may be pre-existing.

Previous studies highlight the importance of prevention protocols, and in our study, it was proven that the prevention protocol is very important in the prevention of accidents in junior soccer players.

Balduini et al., divide the healing process after ankle trauma into three phases, including the inflammatory, proliferative, and remodeling phases. The first phase of the healing process is the inflammatory phase in which proinflammatory interleukins intervene to modulate the response to trauma [26]. Classically, the interleukin cascade begins with a triggering stimulus which is trauma, and then releases molecular patterns associated with injury or molecular patterns associated with pathogens [27].
The implementation of preventive exercises through the Biodex systems assisted and improved the static and dynamic balance of the subjects.

Using biodex equipment as an active means of ankle sprain prevention has a multitude of advantages.

Control over biomechanically correct movement, and producing a feedback by visualizing and monitoring the most relevant parameters are some of the biodex equipment software on the effectiveness of the prevention plan.

4. Materials and Methods

The patient is in an upright position, with the lower limbs positioned on the platform in the areas of D6 (left foot), D16 (right foot), and the angle formed between the calcaneus and hallux 10°.

Depending on the height of the patient, the support base can be changed.
Test Steps:
1. The patient must have a sway index as low as possible throughout the 30 seconds keeping the eyes open and the platform is static with no unstable surface
2. The patient must have a swing index as low as possible throughout the 30 seconds keeping the eyes closed and the platform is static with no unstable surface.
3. The patient must have a balance index as low as possible throughout the 30 seconds keeping the eyes open and the platform is static, we use an unstable surface.
4. The patient must have a balance index as low as possible throughout the 30 seconds keeping the eyes closed and the platform is static, we use an unstable surface.

Study Design

The aim of the study is to verify the effectiveness of a protocol for the prevention of recurrence of ankle sprain in football players, consisting of physical exercise programs, aimed at rebalancing the muscle strength between agonist-antagonist to ensure optimal joint stability, carried out with the help of the Biodex system 4 Pro and Biodex balance.

Participants

Thirtieth subjects divided into two equal groups participated in the study, according to the agreement to follow a prophylaxis protocol regarding the recurrence of ankle sprains, based on an established rehabilitation protocol that includes physical exercises, or a protocol consisting of programs of individualized physical exercises, carried out with the help of Biodex 4 Pro and Biodex balance. Thus, the control group followed a protocol based on a program with general objectives and established physical exercises, while the experimental group followed a protocol containing physical exercise programs selected based on the results of the examination with Biodex 4 pro correlated with the results at Biodex balance.

The criteria for the inclusion of the subjects in the study were: confirmed clinical and functional diagnosis of recurrent ankle sprain, football players aged between 17 and 20 years.

Exclusion criteria were as follows: age below 17 years and above 20 years, grade 1, 2 or 3 ankle sprain without recurrence.

The study was carried out within the Football Academy belonging to FC Rapid from Bucharest and respected the principles and therapeutic deontology, as well as the ethics specific to the research activity. The study was structured in three stages: the first stage consisted of carrying out an initial test (It) for the two groups, between April 2022 and November 2022, in the next stage we implemented the programs for each group, a program with general objectives and means established in ankle sprains and another program based on the results of the examination with Biodex 4 correlated with the results of the pro and Biodex balance results, in the period April 2022 - December 2022, the final stage consisted in carrying out final tests (Ft) of participants from the two groups in the period May 2022 - January 2023.

The study was carried out over a period of 10 months (April 2022 - January 2023), the protocol established for each group (control and experiment) aimed to ensure the stability of the ankle joint to prevent ankle sprain recurrence, and the protocols were applied over a period of 2 months for each participant, with a frequency of 4 sessions per week.

The subjects in the control group (n=15) followed a protocol with a physical exercise program without the use of the Biodex dynamometer as an active part of the exercises, but only as an evaluation method and followed the achievement of the general objectives known in the rehabilitation of ankle sprain, respectively phase 3 of rehabilitation and phase 4 of reintegration into sports activity: maintaining/increasing the amplitude of joint movement, ensuring joint stability. The therapeutic physical exercises used were represented by: stretching for gastrocnemius and soleus; eccentric, concentric, and isotonic muscle contractions of the ankle and leg muscle groups; and balance exercises to re-educate proprioception. Soccer-specific exercises were also used with the aim of re-educating motor skills, such as specific exercises to increase explosive force and reaction speed during the game.

The protocol for the experimental group of subjects (n=15) consisted of therapeutic physical exercises performed with the Biodex 4 Pro System dynamometer as the main therapeutic method using the isokinetic system, plyometric exercises using the Dsmotec device, Biodex balance using the sensorial integration software. The exercises were determined based on the analysis of the results obtained in the initial muscle strength testing correlated with the results of the static balance examination. Based on the comparison of the two examinations, individualized therapeutic physical exercise programs for muscle strengthening and control were made. Thus, they tested the muscle groups of the ankle and foot in the anterior, posterior, and lateral compartments, they were correlated with the results of the balance test (with eyes closed and open), thus establishing the plane in which stability is compromised.

Biodex technology enabled early initiation of the treatment plan for subjects in the Pilot Group. Initially, the movement was performed actively to check muscle imbalances and deficits in joint degrees (ROM), and the active protocol started with 90g/s without exceeding 120g/s. After developing the ability to perform ankle movements without discomfort in all planes (flexion/extension and inversion/eversion), active resistance movements were implemented. If the subjects were able to perform without discomfort the active movements with resistance until the end of the movement performed the movement in an isokinetic regime with 120g/s.

The Biodex was used in an isokinetic regime with an execution speed with the aim of restoring joint balance and muscle strength, the session lasted 20 minutes.

Biodex Balance was used for stability testing and training through the special software, the sensory reintegration test was used for 30 seconds, 10 repetitions were performed for 3 sets and with a 2-minute break between sets.

The study was conducted in accordance with the principles set out in the Declaration of Helsinki. Written informed consent was obtained from all participants. The study was approved by the Ethics Commission of the National University of Physical Education and Sport in Bucharest, with no. 33/27.09.2021. All authors contributed equally to this article; all authors have an equal contribution to the first author.

5. Conclusions

The assessment made by the equipment provides information on joint mobility (ROM) and balance; therefore, the programs used in the recovery process can be performed without putting pressure on the joint and within the range and speed parameters set by the physiotherapist.

The study has shown that the Biodex System 4 Pro and Biodex Balance (together with the other modern therapies mentioned in the current paper) are very helpful in the recovery process because they offer the possibility to work in the isokinetic mode, which reduces the functional recovery period and ensures the return to sport in a minimum time and also help to reduce relapse.

The mentioned aspects demonstrate that the intervention programs, applied to the two research groups, were effective, with significant differences between the results at the end of the research, compared to the initial moment, in terms of the investigated dimensions: balance, and muscle strength.

However, comparing the final results of the two groups, it was found that the intervention that involved modern methods proved to be more effective, producing significantly better results (of experimental group 1) than if the intervention was carried out using classical methods (in the situation experimental group 2), a fact also emphasized by the size of the effect.

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